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Elements of Chemiſtry:

BEING THE

ANNUAL LECTURES

OF

Herman Boerhaave, M.D.

Formerly PROFESSOR of

CHEMISTRY and BOTANY,

And at preſent,

PROFESSOR of PHYSICK

IN THE

UNIVERSITY of *LEYDEN*.

Tranſlated from the ORIGINAL *LATIN*,

By *TIMOTHY DALLOWE*, M.D.

VOL. I.

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THE TRANSLATOR TO THE READER.

AS the Reader, in this Translation, may observe several Variations from the Original, it is necessary to inform him that the Alterations are made with the Author's Approbation. I am very sensible that, upon the whole, I shall be challenged for following the Original too minutely: but I was willing rather to err on this hand, than to leave out any thing, that might have a Meaning and Propriety that I was not aware of. It must be confessed however, that our Author is evidently, in many places, pretty prolix; nor in reality, considering these as Publick Lectures, could this possibly be avoided: For as we had nothing to depend upon but our Memories, and the short Hints we could take in Writing from the Professor's Mouth, it was necessary for him to dwell longer upon Things, and set them in various Lights, in order to make them appear with more Evidence, and fix them upon the Mind with greater Certainty. It were to be wished, indeed, that when he came to printing them, he had had Time sufficient for retrenching these Superfluities; but I have a great deal of Reason to think this was not the case; and yet he was under a kind of Necessity of putting them out as soon *as possible, to justify himself from the monstrous Absurdities published in a Course of Chemistry with his Name to it, which some of his Pupils ungenerously printed without his Knowledge, as you will find taken notice of in the Preface. Had this Work, at first, been designed purely for the Press, or had the Author had Leisure to have put a finishing Hand to it in the Form it stands at present, it would, without dispute, have appeared much more to Advantage, both in point of Elegance, and Correctness. As the Substance of the Performance, however, is still the same, and it contains abundance of curious and valuable Observations and Experiments, both in Chemistry, and Natural Philosophy, the Reader no doubt will readily overlook any Inaccuracies he may meet with, and think himself obliged to the worthy Author, who has so candidly communicated the Result of many Years indefatigable Application.*

T. Dallowe.

London
1 *March* 1734-5.

THE

THE
AUTHOR's DEDICATION

To his BROTHER

JAMES BOERHAAVE.

AS I could not avoid publiſhing the Work which I now addreſs to you, I have been obliged in my old Age to review the Labours of my Youth. And whilſt I have been thus engag'd, I could not help, I confeſs, being ſometimes ſurpriz'd, when I conſider'd both the number of them, and the remarkable Dangers that frequently attended them. The grateful Reflection, however, of your having been my conſtant faithful Companion and Partner in both, gave me at the ſame time a very ſenſible Satisfaction. You know very well, nor is the Remembrance, I flatter myſelf, diſagreeable, how many whole Days and Nights we have ſpent ſucceſſively together in the chemical Examination of Natural Bodies. At that time, indeed, your Thoughts were turned chiefly to Phyſick, mine to Divinity: But Providence ordered otherwiſe; ſo that altering our Deſigns, you devoted yourſelf intirely to Sacred Things, making it your whole Concern to promote the true Worſhip of God, by the Plainneſs of your Preaching, and the Integrity of your Life; whilſt I, conſcious of my weaker Abilities, and not daring to attempt any thing higher, was content to apply myſelf to the Study of the Healing Art.

Who,

Who, therefore, has an equal Right to this Work with yourſelf, to whom it in ſome meaſure owes its being what it is? Accept it, therefore, I entreat you, with the ſame kind Reſentments, with which I offer it; and let it ſtand as a publick Token of a grateful Acknowledgment, and a laſting Memorial of Fraternal Affection. I have always eſteem'd it my particular good Fortune to be favoured with ſuch a Brother, whoſe happy Genius, and vertuous manner of Life, render him not unworthy of that great Office he is entruſted with, the noble End of which is purely to recommend the Terms of Reconciliation, offered by God to Mankind, by Precept and Example, without a vain Affectation of any thing more. If in my Province, I have been ſo happy likewiſe to behave in ſuch a manner, as to meet with your Approbation, I ſhall have wherein to rejoice. Adieu; and whilſt you are now and then amuſing yourſelf with Things of this Nature, don't forget thoſe joint-labours we were formerly ſo agreeably engaged in.

Leyden, 1. *July* 1731.

THE

THE

AUTHOR's

PREFACE.

NOTHING was formerly farther from my Thoughts, than that I should ever trouble the World with any thing in Chemistry. There are so many Books already upon this Subject, and many of them wrote so well, that it is hardly possible for me, either to represent things in a better Light, or to offer any thing that has not been said before. My Academical Office however made it necessary, that I should annually give a Course of Lectures in this Art; but this was with no other View, than just to lay down the Rudiments of it, and give some Examples of the Operations, for the sake of those Gentlemen, who were pleased to put themselves under my Tuition. And so far it is possible, the Method I have made use of in digesting the Subject, and the great Simplicity I have constantly and carefully studied, may not have been without their use. And in these two Particulars, indeed, there seemed still some room left for farther Application; that at last Chemistry too might deserve to be introduced among the Academical Sciences. This, therefore, I endeavoured to the best of my Abilities; and having done this, I thought I had discharged my Duty, and that nothing farther could reasonably be expected from me. It has happened, however, very different from what I was aware of: For the Ingratitude of some of my Pupils, the promoting whose Interest was always my Study; and the insatiable Avarice of some Booksellers, who will not stick at the basest Actions, if they can make any Advantage of them, sufficiently sowered my Chemistry-Professorship. For these Persons, under a false pretence of doing Service to Learning, published, without my Knowledge, a Course of Chemical Institutions and Experiments, and prefixed my Name to *to it; and thus did an Injury both to the Publick and me, in a manner certainly very dishonourable, and that ought to be taken notice of by the Laws. The false Notions, Absurdities, and Barbarisms, that are imputed to me in every Page of that Work, are so abominable, that they will not bear mentioning. It happened, however, to the Misfortune of the present Age, of which by this means they have left an instance to the succeeding, that this sorry Book met with too many Buyers, very much to the Loss and Disgrace both of them, and the Persons who recommended it. By this means I had the daily Mortification of seeing my Pupils before me with this Book in their Hands, whilst I was giving my Lectures; and could plainly perceive, that every Word I said must be examined by the Text of that miserable Performance. Quite tired with this, I applied myself for Relief to some Persons in Authority, who had Power to restrain and punish such Enormities as these; and I had almost gained my point, had not some others designedly delay'd, put off, nay and opposed it too, though I had deserved much better things at their Hands, and had received from them so many fair Promises in my favour, as, I think, would have deceived the most cautious Man living. Thus then I was satisfied by an uncomfortable Experiment, that there are some Persons in the World, who take Pleasure in triumphing over Learning, by every method that lies in their Power. These, and other Considerations, determin'd me to give Lectures in Chemistry no longer; and therefore I immediately resigned my Professorship. But this was no sooner over, than I was again engaged in new Difficulties; for my Friends were all of opinion, that in my own Defence I ought to publish my Chemical Institutions and Experiments myself, that by this Means the World might have an Opportunity of judging in what manner I did in reality teach Chemistry, both in the publick and private Schools. It was to no Purpose for me to object, that these Institutions were designed only for my private Use, and calculated purely for Beginners, to lay before them the first Elements of the History and Method of Chemistry, and of consequence would be of no manner of Service to the Publick. Nay I insisted farther, that as these only laid down the Rudiments of the Chemical Art, and had nothing else to recommend them, they must necessarily be disagreeable to any Reader that was ever so little versed in it. They on the other hand urged, that the spurious Work met with general Approbation, was mightily wanted, grew dearer, and would be very soon reprinted, if I did not take care to prevent it. This I confess gave me some Uneasiness, and brought to my Mind the great* Petrarch, *who lamented the Misfortune of his Cotemporaries, when he saw them set such a value upon his Works, as to think him worthy to be rank'd amongst the famous* Poets. *How much more then, thought I, ought I to be ashamed, should I, who am conscious of my own poor Abilities, and am an Admirer of other Authors, dare to intrude myself*

among

among the Chemical Writers. Not able, however, to stand out any longer, I at last undertook the disagreeable Task; and I publickly declare, that the Book with which I now trouble the World, was forced from me much against my Inclination. As for the Work, I have wrote it in as concise a manner as the Subject would admit of; and have avoided as much as possible pure Terms of Art. That this might be done, I saw evidently in the Example of the incomparable George Agricola, *in that immortal Work,* De Fossilibus, Re Metallica, & Subterraneis. *I heartily wish, indeed, I had had so much Time at command whilst I was composing this Treatise, as was necessary for the sufficient Imitation of so great an Author. For want of this, and being hurried with a Variety of Business whilst this large Work was in Hand, I am sensible, many Expressions have escaped me, that are not so elegant. I am aware too, that some Persons will think I very often insist too particularly upon things that seem but of little Consequence: But this I have done with Design, on purpose to caution sufficiently against those Inconveniencies, that in these kind of Inquiries continually surround us. I have constantly had Beginners in my view; and therefore thought myself obliged to point out every thing doubtful, or dangerous. For the same reason you'll find I every where proceed chiefly upon particular Experiments, not laying down any general Rules, without a great deal of Caution. By this Example, young People may learn the Method that Beginners should pursue in their philosophical Inquiries; a laborious one, I confess, but certainly a just one, and that will lead us most securely to true Knowledge. In the first part of this Work I had those Lectures to insert, which I had given at particular times upon Chemical Subjects in the publick Schools: And as I thought it necessary to relate them again, and confirm them by new Observations, it has happened, that I have sometimes repeated things I had said before; which it was not possible to avoid. And thus the Size of the Book insensibly grew upon my Hands, though at the same Time I was too much engaged in Business of another Nature. How happy, under these Difficulties, did I count those Authors, who have Time enough to study, digest, and put a finishing Hand to the Works they are employed in. For my part, amidst a thousand Avocations, I have been obliged to dispatch these things in a rude manner, and very different from what I should have done, had I been Master of that Leisure and Retirement which I have long wished for: Especially, as I have a great Desire to confirm and improve some particular Parts by new Experiments. Those which are now contained in this Work, are what I made in publick many Years ago: And this I think proper to mention, lest any body should suspect I borrowed them elsewhere, without making mention of the Author's Name. But to detain my Reader no longer, please to accept this Performance, such as it is, in a favourable manner; excuse the*

Trouble I by this means give you; and impute the Liberty I take of appearing in Print upon this Subject, to the very good Reception the spurious Copy, which was worse, met with from the Publick. Upon this Occasion, too, give me leave to inform you, that I never published any thing besides what follows; which I confess I am ashamed to mention.

Oratio de commendando Studio Hyppocratico. *Spoken and printed at* Leyden 1701; *for* Abrah. Elsevier.

—— de Usu Ratiocinii Mechanici in Medicina, 1703, *for* John Verbessel.

—— quâ repurgatæ Medicinæ facilis asseritur Simplicitas, 1709, *for* John Vander Linden.

—— de comparando certo in Physicis, 1715, *for* Peter Vander Aa.

—— de Chemia suos errores expurgante, 1718, *for* Peter Vander Aa.

—— de Vita, & Obitu Clarissimi Bernardi Albini, 1721, *for* Peter Vander Aa.

—— de Honore Medici Servitute, 1731, *for* Isaac Severinus.

An Oration, *which I delivered when the Curators of the University honourably gave me leave to resign my Professorships of Botany and Chemistry,* 1729, *for* Isaac Severinus.

Institutiones Medicæ in Usus annuæ exercitationis domesticæ, 1708, *for* John Vander Linden, *Father and Son.*

Which was afterwards reprinted several times, with Additions in 8vo.

Aphorismi de Cognoscendis, & Curandis Morbis in usum Doctrinæ Domesticæ, 1709, *for* John Vander Linden.

Of which there were afterwards several Editions, with Additions, in 8vo.

Index Plantarum, quæ in Horto Academico Lugduno-Batavo reperiuntur, 1710, *for* Cornelius Boutestein, *in 8vo.*

Materia

6

Materia Medica, & Remediorum formulæ, 1719, *for* Isaac Severinus, *in* 8*vo.*

Afterwards reprinted in 8*vo.*

Index alter Plantarum, quæ in Horto Academico Lugduno-Batavo aluntur, 1720, *for* Peter Vander Aa, *in* 4*to.*

Atrocis nec descripti prius morbi Historia, secundum Medicæ artis leges conscripta, 1724, *for* Boutestein, *in* 8*vo.*

Atrocis rarissimique morbi Historia altera *for* Samuel Luchtmans, *and* Theodore Haak *in* 8*vo.*

A medicinal Treatise de Lue Venerea, *prefixed to the Collection of Authors upon the Venereal Disease,* 1728, *for* John Arn. Langera, *and* John *and* Herm. Verbeek, *in Folio.*

Epistola pro sententiâ Malpighianâ de Glandulis ad Clariss. Ryiscium, 4*to for* Peter Vander Aa.

Every thing else printed in my Name, except a few Prefaces, is spurious, and published without my Knowledge.

A VIEW

A VIEW *of the* CHAPTERS *into which this Volume is divided.*

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ERRATA.

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THE

DESIGN.

GENTLEMEN,

AS you have put your ſelves under my care, to inſtruct you in the knowledge of Chemiſtry, I ſhall think it my duty to endeavour as much as poſſible to anſwer your expectations. The Deſign.

And in this, as far as I can judge, I ſhall moſt effectually ſucceed, if I clearly and methodically explain to you every thing you will have occaſion for, either to underſtand the moſt valuable Authors, in this Art, from whom you may gain a knowledge of it purely as it ſtands founded upon Experiments; or, to enable you to perform the principal operations in Chemiſtry; that by this means you may be ready in the exerciſe of the Art, as well as thoroughly underſtand it.

This, however, is not ſo eaſy to accompliſh, in an Art cultivated by men taught rather by accidental diſcoveries, than acting according to rules of Art, and who for the moſt part wanted intirely the knowledge and aſſiſtance of the more liberal Sciences. Difficulty of the Deſign.

For hence it came to paſs, that they have given us only a confuſed collection of the things they obſerved, juſt in the order they happened, without any regard to a methodical diſpoſition of them.

And this difficulty was ſtill farther increaſed, by an almoſt conſtant neglect of thoſe things which came very frequently under their obſervation: for theſe they did not think worth taking notice of; and yet without them, to a reader not verſed in the Art, the cauſes of many things muſt be unintelligible.

But then this Science became moſt perplexed, when theſe Artiſts began to introduce their diſputations into it; came to coining their general principles; and went about to explain the cauſes of the different appearances they met with.

Theſe difficulties however may in ſome meaſure be removed, by collecting together the genuine Experiments, which have been performed in this Art; from thence deducing ſome general rules; and then diſpoſing thoſe rules the moſt to advantage.

Eſpecially, if the perſon who ſets about it, has the happineſs of having his mind formed to the work, by a long and careful exerciſe in the practical part of the Art; which I hope without vanity I may lay a ſmall claim to. Method propoſed.

With ſome hopes therefore of ſucceſs I undertake writing theſe Inſtitutions; which I ſhall divide into three parts. Diſtribution of the work.

The firſt of which will contain the riſe, progreſs, culture, and fate of Chemiſtry; will give an account of the principal Authors in this Art, according to the times in which they lived, briefly hinting at the things in which they agreed, Part the firſt.

and wherein they differed; and hence will make mention of the different ſects, and what they have contributed towards the advantage or prejudice of the Art: And here (which caution may be of ſervice for guiding your conduct in this Science) giving to every one the glory due to their merit, I ſhall candidly commend thoſe who on account of their ſervices to the Art diſtinguiſh themſelves above the reſt; and through the whole ſhall carefully proceed according to thoſe rules, and with that integrity, which Hiſtories ought religiouſly to obſerve.

Second part. The ſecond part will lay down certain, indiſputable, chemical Poſitions, collected from ſuch evident phyſical truths, as have been diſcovered by the Chemiſts; and theſe will be chiefly of a general nature, and ſo contrived, that by the help of them may be performed all the operations, that truly belong to the chemical Art.

Theory of Chemiſtry, what? Nor indeed in this Art do we allow of any other Theory, than what is built upon ſuch general Propoſitions, as have firſt been deduced from many common undoubted Chemical Experiments, from which, as they always ſucceed in the ſame manner, ſome general truth may be fairly inferred.

Limits of this Chemical Theory. We muſt take care, however, not to carry even this rule any farther, than ſimply to apply it to ſuch particular bodies, as we evidently diſcover to be perfectly of the ſame nature.

The reaſon of this cautious proceeding. For it is certain, that the powers of ſome particular bodies, frequently produce ſuch effects, as could not poſſibly have been foreſeen from any general Theorem, in as much as they depend purely upon the peculiar nature of thoſe bodies, which perhaps may be different from all others.

Phyſico-Mathematics, and Phyſics made uſe of in Chemiſtry. We ſhall farther, in forming this Theory, take the liberty to make uſe of ſuch truths, as are demonſtrated in Phyſics, Mechanics, Hydroſtatics, and Hydraulics; ſince the properties, which belong to all bodies in common, muſt hold good in chemical ones too: but then, we muſt in this affair proceed with a great deal of caution; as we find, that by the application of ſome particular bodies to one another, from the ſingular nature of thoſe bodies effects are often produced, that are quite contrary to the demonſtrations which are true of bodies in general. An inſtance will make this plain: *Galilæo* has ingeniouſly demonſtrated the law by which a body will deſcend from a fixt point above to a point on the earth perpendicularly under it, ſuppoſing it to move in a ſpiral, or elliptical line, and with a certain degree of acceleration. Let us now only imagine the falling body to be a loadſtone, and another to be ſo diſpoſed, that the former in its deſcent ſhall come within the ſphere of its activity; and then his Demonſtration will appear to be falſe. In like manner, the things which *Archimedes* has proved in his Hydroſtatics, though they are ſtrictly true when applied to bodies in general, yet do not always hold ſo, when applied to particular ones; as we ſee that gold, which ſinks in all other fluids, is diſſolved, and ſuſpended in ſo light a one as *Aqua regia*.

Under theſe limitations then, the truths diſcovered by the Philoſophers, and others abovementioned, will always be of ſervice to this Art; nor can ever poſſibly do it any prejudice.

The laſt part of the Deſign. In the third and laſt part of theſe Inſtitutions, I ſhall actually exhibit to your view the methods made uſe of in Chemiſtry, in order to change natural bodies in ſuch a manner as this Art directs, and to the end which it likewiſe had before determined.

And

And here I ſhall take care, that the moſt common things, if it is of any conſequence to know them, ſhall not be omitted; nothing ſhall be unneceſſarily repeated; and that, ſhall be always treated of firſt, of which there will be occaſion in the proceſs that follows.

The order in which the chemical Operations are digeſted.

In the proſecution of which, the Theorems explained in the ſecond part, will be made great uſe of; by the help of which all the operations in Chemiſtry will be eaſily underſtood, and both the head and the hand fitted for the exerciſe of the Art: At the ſame time alſo, every one of theſe Proceſſes will be a Demonſtration of the truth of the particulars, from which the general Theorem was at firſt conſtructed. By this method, Gentlemen, I propoſe to lead you into the moſt perfect knowledge of Chemiſtry; nor have I loaded with difficulties a Science, which in its own nature is ſufficiently troubleſome. Without this, all the labours of the Chemiſts, which they call Proceſſes, indeed are of no real ſervice, but waſte our time, and inſtead of being an advantage, are really a prejudice to thoſe that are fond of them.

The uſe of the chemical Theory in the Operations.

COURSE of CHEMISTRY.

PART I.

The History of the ART.

The name of the Art.

THE word, which in the Greek Language signifies *Chemistry*, is Χημία, or Χημεία: and this is of so very ancient a date, that it is supposed to have been in use before the flood.

This certainly was the opinion of *Zosimus* the *Panopolitan*, whose Greek manuscripts, which *George Agricola* had seen in the year 1550, and *Joseph Scaliger*, and *Olaus Borrichius* perused afterwards in the King of *France*'s Library, have a remarkable passage in confirmation of it.

For in the book intitled χρῆσις Ζωσίμȣ τȣ̃ πανοπολίτȣ φιλοσόφȣ ἐκ τȣ̃ πρὸς Θεοσέβειαν ἐν τῇ θ τῆς Ιμȣ̃θ βίβλῳ, he expresly says, that the Art which was revealed to the daughters of men by Dæmons, as an acknowledgment of their favours, (χημίαν καλεῖσθαι) was called *Chemistry*: For this is the sense of the text, as it was read by *Joseph Scaliger*, and inserted by him in his notes upon *Eusebius*, p. 243, 258. N. 38; And by *Borrichius* against *Conringius*, p. 49. *The sacred Writings tell us, that there is a sort of Dæmons that are familiar with women. And* Hermes *mentions the same thing in his Physics; and almost all our learning both open and occult, take notice of it likewise. This then the ancient and sacred Scriptures inform us, that the Angels were inamoured of women, and came and taught them all the Works of Nature. Now the first tradition they gave concerning these Arts was called* ΧΗΜᾶ; *and the book likewise that contained it, they called* ΧΗΜᾶ; *and hence also the Art obtained the name* ΧΗΜΊΑ. Now this very ancient fiction arose from the misunderstanding those words of *Moses*, *Gen.* vi. 2. for from this passage they concluded, that by the sons of God were meant Dæmons, consisting of a spiritual part, and a corporeal one, that was visible only, like the image or phantom reflected from a looking glass; that these beings were endued with a universal knowledge, were conversant with men, were very fond of women, were great with them, revealed secrets, and appeared to mankind. Compare with this, *Luke* xxiv. 37, 39. *Matt.* xiv. 26. And this fable probably gave rise to this story of Σίβυλλα, (Σιȣ̃, that is in the Æolic Dialect, Διȣ̃ βύλλα, or βȣλή,) on whom *Phœbus* in return for her favours conferred the gift of Divination, so that she could discover the will and counsels of the Gods. Thus is the mind of man, whilst in a state of uncertainty, apt to run into very strange conceits, which it afterwards idolizes and regards with veneration.

But farther, the land of *Egypt* was likewise very anciently called by the same name as *Plutarch* observes, (*Is. & Osir.* p. 364. C.) *Besides, the soil of Egypt being of an exceeding black colour, like the black of the eye, they call it* ΧΗΜΊΑ. And the same country went also by the name, ἑρμοχήμιος, as *Steph. Byzant.* takes notice

tice under the word ἄιγυπτος. But the word χημᾶ too, as *Bochart* informs us, among the *Arabians* signifies *to hide.*

If we now lay all these things carefully together, we may easily perceive that this name was made use of before the flood; that it continued in use in the succeeding ages; and that in those days it signified,

It is very ancient.

1. A knowledge of the works of nature, διδασκαλίαν πάντων τῶν τῆς φύσεως ἔργων.
2. A book containing the Tradition of such a Science.
3. That *Hermes* in his book of Physics had made mention of it.

The meaning of this very old name.

The word now, if it is wrote χημᾶ, according to *Bochart* signifies *to hide*, as we took notice just now: And hence if χημία, as *Plutarch* will have it, (*de Is. & Os.* p. 364. *C.*) expresses the black of the eye, or any thing exceeding black, there will be no great difference betwixt them, as used by the hieroglyphical writers; for among them the pupil of the eye denotes something hidden, and precious.

Especially, if we consider that the same *Egypt*, called in the sacred Writings the land of *Cham*, (*Psalm* cv.) stiled their God Αμοῦν; which according to *Manetho* the *Sebennite* signifies *somewhat concealed. Plut. de Is. & Os.* p. 354. *C.*

Nay, and that the same country even to this day is called in *Coptic* the land of *Cemi*; as we learn from the same *Samuel Bochart.*

This name therefore signifies something hidden, occult, mysterious, secret; and the Art which it expresses is called likewise, *Chemi*, *Chemia*, *Alchemia*, *Alkumia*, χημᾶ, χημία, Ἰμουθ, ποιητική, the Spagarite and Hyssopic Art separating the pure from the impure.

And by it, the Authors who first made use of the word meant, a universal knowledge of Nature.

The word therefore was used originally in a very pure sense, though it was afterwards perverted to a very different one; which misfortune likewise, by means of illiterate persons, befel the word *Magic.*

But as Metals now comprehend a large and very beautiful part of natural bodies; hence the same word came likewise to signify Metallurgy.

The word used to express Metallurgy.

And this Art also was cultivated to great perfection by the Antidiluvians: for *Tubal-cain*, the true *Vulcan* of the Ancients, son of *Lamech* and *Zillah*, and the eighth person from *Adam*, understood how to prepare copper, and iron in such a manner as to work it into utensils, *Gen.* iv. 22.

But fossil copper as it is dug in the ore requires both exquisite art and labour to make it fit for use; no less than twelve fusions being necessary to render it sufficiently malleable; as both *Agricola* and *Erker* inform us.

The difficulty of the metallurgic Art.

And iron in like manner must be managed with a vast deal of skill and pains, before it can be applied to the same purposes; as we learn from the same faithful Authors, who were the top masters in this Art.

Hence therefore we see that the original of Chemical Metallurgy is exceeding ancient, as well as that of the name itself.

The country which is first celebrated for the cultivation of this Art, is that which was inhabited by the first people, as the History of *Tubal-cain* evinces (*Gen.* iv. 22): Especially, if you compare this with the Fables and Histories of the *Vulcan* of the Ancients, who was the same with *Tubal-cain*, (*Voss. Id.* g. I. 65.) And indeed the very name of the Arts seems by it original to confirm the same thing, as you have seen already.

Chemical Metallurgy first cultivated in *Asia.*

From

Then in *Egypt.*

From hence as its ſource, this, like other Arts, began to ſpread, and was next carried into *Egypt*; and there it was practiſed with a vaſt deal of application. For *Moſes* who was ſkilled in all the learning of the *Egyptians* (*Acts* vii. 21.) knew how by the help of fire to reduce gold to a powder, ſo as to render it miſcible with water, and by this means potable, (*Exod.* xxxii. 20;) and this is what is certainly one of the top performances of the Art, and what even the greateſt Adepts of the preſent age are not maſters of. *Vulcan*, the ſon of *Jupiter* and *Juno*, was the firſt who reigned in *Egypt*, and was deified after his death for the invention of fire (*Diod. Sic.* l.) or rather for the firſt application of fire to making utenſils of metals, as the ſame Author ſays expreſly (*γ.*) *They tell us, that* Vulcan *was the Inventor of all works in iron, braſs, gold, ſilver, and other bodies that require the management of fire. He found out likewiſe all the uſes of fire, which he diſcovered both to the workmen and every body elſe.*

But *Egypt* itſelf in the ſacred language of the Prieſts is called χημία, (*Plut. Iſ. & Oſir.* 364. *C.*) and ἑρμοχήμιος, *Steph. Byz.* in the word ἄιγυπτος.

The ſame country likewiſe went by the name, Ἡφαιςία, or the land of *Vulcan*, (*id. ib.*) The great *Scaliger* indeed aſſerts, that the Art χημία, was by the *Egyptians* called Ἰμὺθ. And yet in the book entitled, *Minerva mundi*, taken out of *Stobæus*, it is ſaid, ποιητικῆς τ᾽ Ἀσκλήπιον τ᾽ Ἰμύθης, (*Conring. h. m. c.* III.) *i. e.* That *Æſculapius* the ſon *Imuth*, was the inventor of Chemiſtry; for ποιητικὴ is the ſame as *Chemia*, (*Reineſ. var. lect.* lib. II. c. v.)

Vulcan it is certain had Prieſts at *Memphis* (*Herod.* II. 3.) A very beautiful temple was erected to him there (*Herod.* II. 99.) with portico's (*id. ib.* 102.) and images (*id. ib.* 176. III. 37.) And his ſymbol there was a Vultur (*Voſ. id. g.* III. 573.) *viz.* a bird of prey. But *Zeno* tells us that *Jupiter* too was called Ἥφαιςος, *on account of the extenſion of his influence to artificial fire* (*Diog. Laert.* VII. 147.); which name plainly appears to be derived from τὸ ἧφθαι, to be ſet on fire, or to burn. Agreable to which opinion, *Horace*, who is remarkable for the elegance of his Epithets, expreſſes himſelf,

——*dum gravis Cyclopum*
Volcanus ardens urit officinas. Carm. I. 4. 7.

as *Plautus* indeed had done before him (*Amphitr.* 1. 1. 1885.)

Quo ambulas tu, qui vulcanum in cornu concluſum geris?

All theſe obſervations then ſeem to make it plain, that the part of Chemiſtry called Metallurgy, or the Art of Metals, was by the ancients cultivated chiefly in *Egypt*. Nor do I think there can be the leaſt doubt about the antiquity of this very old Art, in this ſenſe; or about the name itſelf.

The origin of the word as applied to the Art of making gold.

A conſiderable time after, the ſame word firſt came to be uſed to expreſs that Art, by which the pureſt gold might be procured from any ſort of metal; either by a true tranſmutation, maturation, or ſome peculiar kind of ſeparation, that was not commonly known.

Afterwards, the *Arabians*, who principally cultivated this Art, altering the ſound a little, called it *Alchemia* in the ſenſe juſt now mentioned; and with a little more variation, *Alchimia*, Alchemy.

Very uncertain.

Suidas, who lived in the tenth century, tells us (under the word χημεία) that *Diocleſian*, who reigned the twenty laſt years of the third century, gave orders that all the books of this Art ſhould be inquired after, and burnt, becauſe the *Egyptians* were plotting againſt the *Roman* Government. Χημεία, (*Chemiſtry*) on *or the Art of preparing gold or silver. The books concerning which,* Dioclesian *got together and burnt, because the* Egyptians *rebelled against him. He used them cruelly and without mercy, when he sought after their books that were written by their forefathers concerning the* χημεία *of gold and silver, and burnt them, lest by the help of this Art they should grow rich, and so be tempted again to oppose the* Roman *government.*

But under the word δέρας he carries the affair still a great deal higher, expresly and positively asserting, that *the Golden Fleece, which* Jason *and the* Argonauts *brought away when they sailed thro' the Pontic Sea to* Colchis, *was nothing but a book written upon parchment teaching the method of making gold* (διὰ χημείας) *by the Chemical Art.* This now, had he confirmed it by sufficient authority, would have advanced the antiquity of this Science to thirteen centuries before Christ, that is, before the time of the *Argonauts.* And yet upon this supposition we see the Art even at that time was known, practised, committed to writing, and was the motive to the *Argonauts* to undertake that fatiguing and dangerous expedition. If this was the case however, it must be confessed it is pretty extraordinary, that neither *Moses*, the *Sacred Writers*, *Sanchoniatho*, *Orpheus*, *Homer*, *Hesiod*, *Pindar*, *Herodotus*, *Thucydides*, *Hippocrates*, *Aristotle*, *Theophrastus*, *Dioscorides*, *Galen*, or *Pliny* should mention one word of it: Especially, as every body who is acquainted with their works must allow, that both the capacities of the Authors, and the design, subject, and times of their writing, must necessarily have led them to have taken notice of it.

Nor is this difficulty at all removed by that passage in *Pliny* (xxxiv. 25.) concerning flexible Glass; or by that of *Dion Cassius* (lvii. p. 617.) concerning the same project's being rejected by *Tiberius*; nor yet by the other of *Pliny* (xxxiii. 4.) where he tells us, that *Cajus*, by a very intense fire, procured from orpiment a small quantity of very choice gold: For supposing these things to be true, they in reality prove nothing more, than that they were at that time excellently skill'd, both in the docimastic Art, and that of Glass.

'Tis ancient however, chiefly amongst the *Greek* divines.

It must, however, be acknowledged, that *Julius Maternus Firmicus*, in the beginning of the fourth Century, writes of the Science of Alchemy, as a thing perfectly well known (3 *Mathes.* lv.) if this is the genuine text of the author.

And *Æneas Gazæus*, towards the close of the fifth Century, discoursing upon the same subject, as a common thing, tells us, in his *Theophrastus*, or treatise *De Immortalitate Animæ*, that those Persons who were thoroughly versed in this Art, take silver and tin, and perfectly destroying their original nature, transmute them into the most beautiful gold. *Biblioth. Patr. vol.* 2. *pag.* 373.

But *Anastasius* the *Sinaïte*, about fifty years after, as *Vossius* thinks (*Id. G. l.* 1. *pag.* 25.) or rather towards the latter part of the seventh Century, as upon weighing the matter carefully, *Fabricius* is of opinion, (*Biblioth. gr. v. pag.* 313.) writes still more expresly; ὁ γὰρ δὴ χρυσοχόους ἡμᾶς, καὶ λιθεργοὺς, καὶ χημευτὰς, χρυσοκολλήτων λίθων ἀπεργάζεσθαι, ἡ γραφὴ βουλομένη, καὶ παιδεύουσα ταῦτα φησίν.

And lastly, in the seventh Century, *Georgius Syncellus*, wrote professedly upon the same subject.

Christian *Greeks* the principal Alchemistical Writers.

Soon after him, there sprung up a whole tribe of Alchemistical Writers, whose manuscripts at *Rome*, *Venice*, and *Paris*, by their *Greek* Idiom, make it plain what age they liv'd in; and by their style make it very probable, that

Were they the first too? they were of religious orders. A Catalogue of these Works, which are not yet printed, we have in *Borrichius*, and others (*de Hermetis, Ægyptiorum, & Chemicorum Sapientia, pag.* 78. & *seq.*)

A Catalogue of these. Σωέσιος, whose treatise of the Philosophers Stone, is in the Library of the University of *Leyden*.

Συνέσιος φιλόσοφος εἰς βιβλίον Δημοκρίτου. The whole treatise is in *Fabric. Bibl. Gr.* L. v. *cap.* 22. *p.* 232. *Gr. & Lat.*

Σώσιμος ὁ μέγας, ὁ θεῖος, ὁ Πανοπολίτης, of πανάπολις a city of *Egypt*. xxiv. books Ἰμοὺθ to Θεοσέβεια. The title is Σωσίμου τοῦ παναπολίτου γνησία γραφὴ, περὶ τῆς ἱερᾶς, καὶ θείας τέχνης τοῦ χρύσου, καὶ ἀργυρίου ποιήσεως. and Ζώσιμος περὶ ὀργάνων, καὶ καμίνων.

Ὀλυμπιόδωρος ὁ Ἀλεξάνδρινος.

Ἡλιόδωρος περὶ χρυσοποιήσεως.

Ἰωάννης Ἀρχιερεὺς, τοῦ ἐν ἁγίᾳ πόλει περὶ τῆς ἁγίας τέχνης.

Στέφανος ὁ φιλόσοφος ἀλεξανδρεὺς οἰκονομικὸς περὶ τῆς ἱερᾶς, καὶ θείας τέχνης τοῦ χρυσοῦ ποιήσιος. The Manuscript of this also is in the University Library at *Leyden*.

Ὧρος. χημευτικά.

Σοφὰρ ἐν περσίδι.

Ἑρμης handed about in the sixth Century, and commended by *Zosimus*.

Διόσκουρος ὁ ἱερεὺς μεγάλου Σεράπιδος ἐν Ἀλεξανδρείᾳ.

Ὀσάνης ἀπ' Αἰγύπτου πρὸς Πετάσιον περὶ τῆς ἱερᾶς καὶ θείας τέχνης.

Μώσης προφήτης περὶ χημευτικῆς συντάξεως.

Μαρία Ἑβραῖα.

Πελάγιος φιλόσοφος περὶ τὴς θείας, καὶ ἱερᾶς τέχνης.

Πορφύριος.

Ἐπιβύχιος. or Ἐπιβήχιος.

Κομάριος φιλόσοφος, καὶ ἀρχιερεὺς, διδάσκων τὴν Κλεοπάτραν τὴν θεῖαν καὶ ἱερὰν τέχνην τοῦ λίθου τῆς φιλοσοφίας.

Κλεοπάτρα ἡ γυνὴ Πτολεμαίου τοῦ βασιλέως. The same περὶ σαθμῶν καὶ μέτρων.

Κοσμᾶ ἱερομονάχου ἑρμηνεία τῆς χρυσοποΐας.

Ἀγαθοδαίμων εἰς τὸν χρησιμὸν Ὀρφέως συναγωγὴ, καὶ ὑπόμνημα.

Πάππου φιλοσόφου ἔργον.

Ἡρακλείος ὁ βασιλεύς.

Σαλμανᾶ Ἄραβος μέθοδος.

Χερσίανος περὶ τοῦ θείου ὕδατος.

Θεόφραστος φιλόσοφος περὶ τῆς θείας τέχνης.

Ἀρχέλαος φιλόσοφος περὶ τῆς θείας τέχνης.

Κλαυδίανος.

Σέργιος.

Ἀνεπίγραφος φιλόσοφος περὶ χημείας.

Μιχαὴλ ψέλλος περὶ χρυσοποΐας. He lived in the time of *Constantine Ducas*, in the year of our Lord 1060. *Borrich.* 79.

Ἶσις προφῆτις τῷ ρῷ ὥρῳ.

Βλεμμίδας ἔργον χημευτικόν.

Νικέφορος.

Δημοκρίτου βίβλος προφωνηθεῖσα λευκίππῳ.

Δημόκριτος φυσικὰ καὶ μυστικά.

Ἱερόθεος

Ἱερόθεος φιλόσοφος περὶ λίθου τῶν φιλοσόφων.

Ἰσαακ Μόναχος, ὅπως δεῖ εὑρίσκειν μεθοδὸν ἀργύρου.

Concerning theſe *Greek* Alchemiſtical Writers, conſult in particular, *Andreas Libavius* throughout all his Works; but eſpecially againſt *Guibertus. Conring. de Med. Herm. pag.* 21, to 31. *Borrich. Ort. Ch.* 97. and againſt *Conring.* from pag. 66, to 95. *Joann. Albert. Fabric. Biblioth. gr.* in various places. And the Catalogue of the Univerſity Library at *Leyden.*

Is it not ſurpriſing now, that the incomparable *George Agricola*, ſhould have been acquainted with theſe Authors? For thoſe elaborate Books of his, *De Re Metallica*, which the great *Eraſmus* ſo highly extoll'd, he wrote, and perfectly finiſh'd, before the year 1550; and yet, in a very elegant Preface prefix'd to theſe Works, he recites in order, almoſt all the Writers we have juſt now mention'd. For your intire ſatisfaction on this head, I'll beg your patience, whilſt I give you the paſſage in the very words of this noble Author. *Of Chemiſtry* (Χυμευτικά) *wrote Oſthanes, Hermes, Chanes, Zoſimus of Alexandria to his Siſter Theoſebia, Olympiodorus of Alexandria likewiſe, Agathodæmon, Democritus, not of Abdera, but another, Oris Chryſorichites, Pebechius, Comerius, Joannes, Appuleius, Petaſius, Pelagius, Africanus, Theophilus, Syneſius, Stephanus to Heraclius Cæſar, Heliodorus to Theodoſius, Geber, Calides, Rachaidibus, Veradianus, Rhodianus, Canides, Merlinus, Raymond Lully, Arnaud de Ville Nieuve, Auguſtinus Pantheus a Venetian; three of the female ſex, Cleopatra, the Taphnutian maid, Maria the Jeweſs; theſe all wrote in proſe; one only, Joannes Aurelius Augurellus of Merrechia, in verſe.*

The meaning of Alchemy.

All theſe Authors, however, made uſe of the Word Chemiſtry hitherto, to expreſs the Art of converting the baſer Metals into pure Gold; and don't ſeem ſo much as ever to have thought of any univerſal Medicine for all the diſeaſes of the human body. See *Conring. de Med. Herm.* 15, 16.

The origin of medicinal Chemiſtry, from the miſunderſtanding the Expreſſions of the Chemiſts.

But after the *Arabians* began to cultivate Chemiſtry in the ſenſe hitherto deſcribed, *viz.* as it relates to Metallurgy, and the Art of making Gold, they ſeem by their metaphorical and hieroglyphical ſtyle, to have given occaſion to the Materials made uſe of to perfect their Metals, going by the name of Medicines; the impure Metals being called ſick Men; and Gold, a Man in perfect health and ſtrength. Hence, in time it came to paſs, that perſons, who were unacquainted with this way of writing, imagin'd theſe expreſſions were to be underſtood in the literal ſenſe; eſpecially, when they ſaw the impurity of the baſer Metal called a Leproſy, which of all diſtempers is particularly incurable.

And this is ſuppoſed to have given riſe to that report, which afterwards ſpread ſo far, and grew ſo common, that the impure Metals might be tranſmuted into pure Gold, by the very ſame chemical inſtrument, by which the bodies of ſick perſons might be reſtored to health.

And this inſtrument they call'd the *Philoſophers Stone*, and the *Gift of Azoth*; and to the perſons that were poſſeſs'd of it, they gave the name of *Adepts.*

And this prejudice a few ſimple Experiments afterwards rooted ſtill deeper; for by theſe, they ſaw the healing vertues of Medicines might be extracted from them by the Chemical Art. Of this *Rhazes* had given ſome inſtances. *Avicenna* too, in the eleventh Century, had in his book, *De Viribus Cordis*, exhibited the same thing in the Julab of the *Arabians*, or the distill'd Water of Roses; and it was afterwards confirm'd likewise by *Mesue*.

The Authors in Alchemy after the *Greeks*.

Among these, the Authors of the greatest character are *Geber*, called the *Arab*; tho' *Leo Africanus* will have him to be a *Greek*: He was at first a Christian, but afterwards renounc'd his Religion. He wrote in *Arabic*, and liv'd in the seventh Century. The Library of *Golius* furnish'd us with his Works, which have been translated into *Latin* by various hands. See *Leo Afric.* L. III. p. 136. *Conr. h. m.* 369. 372, 373. He wrote chiefly

De Alchimia, vel Chimia; aut de investigatione perfectionis Metallorum.

De Summâ Perfectionis Metallorum.

De Claritate Alchimiæ.

De Lapide Philosophico.

De Testamento.

De Epitaphio.

De inveniendâ arte Auri & Argenti.

Morienus Romanus, a Hermit of *Jerusalem*: He wrote concerning this *Arcanum*, in a very elegant manner, and is reckoned among the purest Authors. His Works were translated out of *Arabic* into *Latin* the 11th of *February* 1182.

Albertus Magnus, a *German*, Bishop of *Ratisbon*, born at *Laving* in *Schwaben*, about the year 1200. He wrote

A Treatise *De Mineralibus*.

Lilium floris de spinis evulsum.

Speculum Alchemiæ de compositione Lapidis, &c. See *Borellus*.

Roger Bacon, a *Briton*, who was a Monk of *Westminster*, and resided at *Oxford*. He was famous for his knowledge in Alchemy, Chemistry, natural Magic, Mechanics, Metaphysics, Physics, and Mathematics; and was in vast reputation about the year 1226. Those of his Works that are come to our hands, are

Two Treatises, *De Chimia*, wrote in a plain style enough, without any design'd obscurities.

Speculum Alchemiæ, and another different from the printed one, the Manuscript of which is in the University Library at *Leyden*.

Thesaurum Chemicum.

De secretis artis, atque naturæ operibus, & de nullitate Magiæ. Specula Mathematica.

His Works *De Arte Chymiæ*, printed at *Francfort*, 1603. 12°. which contain a great many very beautiful observations in Mechanics, natural Magic, and various other Arts, the honour of which is unjustly given to modern Authors; and which were falsly imputed to Magic and Heresy. *Borrich. Ort. Ch.* p. 122. and *Borellus*.

George Ripley, a *Briton*, Canon of *Bridlington*, liv'd about the same time. He wrote *Duodecim portæ*. *Medulla Chimica*. *Alchemy*, the Manuscript of which is in the Library of the University of *Leyden*, in *English* verse. All his Works were printed at *Cassel*, in 8v°. 1649.

Hermesius, the Philosopher. He wrote a Treatise, *De Mercurio Philosophorum*. The Manuscript, in the Library of the University of *Leyden*.

Arnoldus, or *Arnaud de Ville Nieuve*, who liv'd in the thirteenth Century. His Writings are *Rosarium*. *Testamentum novum practicum*. *De Alchimia*. *Semita Semitarum*,

Rosa

Rosa Novella. A Letter to Pope *Pius.*

Novus Splendor, vel Lumen. Flos Florum. De Furno Philosophico. De Secretis Naturæ. De nova compositione Lapidis vitæ Philosophorum. De Principiis naturalibus to Pope *Clement. Opus in Arte Majore.* All these Treatises are in Manuscript, in the University Library at *Leyden.*

Raymond Lully, of *Majorca,* descended from a family of *Barcelona.* He was born in the year 1235, was a Scholar of *Arnaud de Ville Nieuve,* and died in *Africa* in 1315. He was one of the principal Writers of the universal Remedy for all diseases of the human Body, and of the *Lapis Aurificus,* in his Treatise *De Quintâ Essentiâ.* He wrote likewise, *De Secretis Naturæ, seu de Quintâ Essentiâ, & de Accurtatione Lapidis Philosophorum. Codicillum, seu vade mecum, de formatione Lapidum pretiosorum;* Manuscripts in the University Library at *Leyden. Claviculam de* L. P. *Testamentum Apertorium.* Some Letters to *Edward,* King of *England. Lux Mercuriorum. De Mercurio Speculum magnum. Testamentum Novissimum.* A Letter to * *Robert* King of *England. Aphorismi. Epistola Accurtationum. De investigatione occulti secreti. Exempla Accurtationis.* The Manuscripts of all these Treatises are in the Library of the University of *Leyden.* He is said to have wrote upon chemical Subjects, to the number of sixty Volumes.

* So in the original.

Joannes de Rupescissa a *Franciscan* Monk; he died in prison about the year 1375. He wrote various Treatises of Alchemy. See *Conr.* H. M. *Borellus. Paracelsus* said of him, that he asserted things that were both trifling and false.

Isaacus Hollandus, and *Joannes Isaacus Hollandus,* of *Stolk,* a little town in *Holland.* They wrote a good many things on Alchemistical Subjects, in which there are a great many very curious Experiments. *De Lapide Philosophorum. Scientia Chimiæ. De projectione infinitâ. De Mineralibus, & vera Metallorum Metamorposi. De Vino. De Vegetabilibus,* and other things.

Basil Valentine. It is commonly reported, he was a Monk of the *Benedictine* Order at *Erffurt;* tho' it is confidently affirm'd, that there never was any such Monastry there; and indeed, both names seem to be a fictitious composition from the *Latin* and *Greek:* This however is certain, that he was a most expert Artist in every Branch of common Chemistry. That single Treatise of his, intitled, *Currus triumphalis Antimonii,* is a sufficient proof of this Assertion; for that alone contains an exact description of almost all the chemical Artifices that are now-a-days unfairly put upon the world for new discoveries: In the more abstruse parts of the Art too, he discover'd a profound knowledge. His very great fault was, that he extolled every Preparation of Antimony, without exception, for its medicinal vertues; than which, nothing can be more weak, fallacious, or mischievous. And this fatal error has infected all the Schools of the Chemists, from that time, quite down to the present age. It appears by his writings, that he was both a Monk and Physician; and seems by his learning, to have gain'd a very great reputation in the Courts of several Princes. He is supposed to have flourished in the Century before *Paracelsus.* He was the Inventor of the three chemical principles, which *Paracelsus* afterwards made great use of. He wrote a great many things in a pretty prolix manner, and some of them upon medicinal Subjects.

Chemists and Alchemists become Physicians.

After these last five Authors had publish'd their Works, the opinion, as we just now took notice, every where got ground among the Chemists, that it was possible,

possible, by one alchemistical Medicine, perfectly to root every distemper out of the human body, to restore absolute health, and prolong life to a great series of years, without being impair'd by any diseases.

Who being puffed up with some good effects of their Art, especially in the venereal Disease by the influence of Mercury,

Puffed up therefore with these expectations, and grown vain with the success they had had from some of their strong chemical Medicines, in a short time they were for engrossing the Art of Physic intirely to themselves.

At the same time too, the Art of Physic had for a good while, by the subtle sophistry, and jargon of the Schools, been become intirely *Galenical*, and given up to the doctrines of the *Arabians:* Hence bleeding, purging, and a few efficacious Medicines, being the sum of the practice, and these not being sufficient to encounter with the venereal Disease that then made havock among them, it was forc'd to give way to the more powerful Preparations of the chemical Art; for *Carpus*, by the assistance of his Mercury, easily out-did the Shoolmen, and thus afforded the Chemists fresh occasion of triumph.

promised new and incredible cures.

By this means, the condition of the old Physicians seem'd now to grow very uncomfortable; for after they had taken a vast deal of pains to search into nature, in order to discover the origin, and cure of diseases, these boasting Alchemists condemn'd all their labours in Ætiologics, Diagnostics, Prognostics, Dietetics, and Therapeutics, as trifling, and of no manner of service; whilst they, without any regard to diet, or the cause and nature of the disorder, could intirely remove all manner of distempers, by the simple application of one and the same Medicine.

But perform very little.

This extravagant error, however, by sweeping away great numbers at the first onset, made it appear, upon maturer consideration, that the bold pretensions of those practitioners were not only vain, but did likewise a great deal of mischief.

This we learn plainly from the life and writings of *Paracelsus* and *Van Helmont*, as may be fairly collected from the hints they have given us.

History of *Paracelsus* from himself.

Aureolus Philippus Paracelsus Theophrastus Bombast de Hohenheim, was the Son of *William Hohenheim*, a man of Letters, and Licentiate in Physic, tho' not much noted for his practice, who had a very fine Library, being himself a natural Son of a Master of the *Teutonic Order*.

He was born in the year 1493, in a village called *Einsidlen*, which signifies a Desart, two *German* miles distant from *Zurich* in *Switzerland:* And hence he came to be called the Hermit; which appellation *Erasmus* gave him, in the letters he wrote to him.

He is said to have had his testicles bit off by a hog when he was but three years old; and from that time he was looked upon as an Eunuch. This is certain he always behaved with the greatest aversion to the female sex; and yet a picture of him drawn from the life when he was grown up, represents him with a beard. Under the advantage of the faithful instructions he received from his father, he made great progress, both in medicine and surgery; but having whilst he was very young a vast fondness for Alchemy, his father committed him to the care of *Trithemius*, abbot of *Spanheim*, who was at that time in great reputation. Under him he got an insight into a good many *Arcana*, and then quitting him applied himself to *Sigismund Fuggerus*, who at vast expence and with a great many servants, was then strenuously prosecuting the chemical Art in *Germany*; which he had very much improved by abundance of new Discoveries.

And

And here it was, as he himself confesses, he learned both the Theory and Practice of the Spagarite Art.

Afterwards he tells us, he sought out, and studied under all the tutors, that bore the greatest reputation at that time of day, and were deepest skilled in the adept Philosophy; and they, he says, concealed nothing at all from him, but revealed to him all their *Arcana*.

However not being satisfied with this, in order to get a better knowledge of Physic, he visited all the Universities in *Germany*, *Italy*, *France*, and *Spain*; and travelled into *Prussia*, *Lithuania*, *Poland*, *Walachia*, *Transylvania*, *Croatia*, *Portugal*, *Sclavonia*, and in short into all the Kingdoms of *Europe*; and wherever he went he made it his business to inquire among Physicians, Barbers, old Women, Conjurers, Chemists, rich and poor, for the best and surest remedies, and was always very well pleased to be informed by any person whatsoever.

From the writings of *Basil Valentine*, he learned the doctrine of the three Elements, *Salt*, *Sulphur*, and *Mercury*, which he afterwards, concealing the Author's name, published as his own.

When he was twenty years of age, he took a view of a great many mines in *Germany*; and whilst he was on this expedition, wandering quite up into *Muscovy*, he was upon the borders taken prisoner by the *Tartars* and carried before the *Cham*, who sent him with the Prince his son to *Constantinople*: and here in the eight and twentieth year of his age, he is said to have become master of the *Philosophers Stone*.

In the character both of Surgeon and Physician he was often in camps, battles and sieges.

He had a high esteem for *Hippocrates*, and the ancient Physicians: as for the Doctors of the schools he made very little of them; and had a particular aversion to the *Arabians*.

Mercurials and Opiates he used plentifully and boldly, and with these he cured the Leprosy and Venereal Disease, the Itch, Ulcers, the lighter sorts of Dropsies, and acute pains; which Distempers were at that time of day beyond the reach of the Physicians; as they knew nothing of Mercury, and were afraid of Opium, from an idle notion of its being cold in the fourth degree.

The first public professor of Alchemy.

By the cure of such distempers he grew bold and famous; but particularly by that which he performed upon *Frobenius* at *Basil*, which brought him acquainted with our great *Erasmus*. The Magistrates of *Basil* being on this account very well pleased with him, courted him with a very handsome salary to the Professorship of Physic and Philosophy in their University; which he accepted in the year 1527, and gave public Lectures for two hours every day, in the *Latin* tongue sometimes, but chiefly in the *German*.

He took this opportunity to explain his own books, *de Compositionibus*, *Gradibus*, and *Tartaro*; in which, as *Van Helmont* observes, there is a great deal of trifling, and very little of any real service. And here he burnt the works of *Galen* and *Avicen* publickly from the chair; and declared to his pupils, that if God would not assist him, he should not scruple to consult even the Devil himself.

At this place he got a great many Scholars, with whom he lived in a very friendly intimate manner. Three of them at his own expence he furnished both with diet and apparel, and let them into some of his *Arcana*; but they deserted their master, wrote reproachful things against him, and injudiciously making use of the observations he had communicated to them, did their patients a vast deal of mischief. He maintained in his family likewise, Surgeons and Barbers, to whom too he communicated some of his secrets; but these likewise soon forsook him, and became his enemies. As his proper faithful scholars, he only speaks handsomely of Doctor *Peter*, Doctor *Andrew*, Doctor *Ursing*, Licentiat *Pangratius*, and Master *Raphael*. When he had been in his office two years, with three Pills of his Laudanum he cured *Liechtensessius* a noble Canon of most terrible pains in his stomach, which had brought him so low that his Physicians had given him over. The Canon like other sick folks had from the beginning promised him an hundred Louis d'ors, if he restored him to health, but refused to pay it when he had got well; upon which *Paracelsus* in a merry manner told him, he had given him nothing else but three pills made of mouse dung; for which he was cited to appear in court by *Theophrastus*. The Judges proceeding according to their common law, and hence having regard not so much to his skill, as to the charge and trouble he had been at, decreed him but a trifling acknowledgment. This so provoked *Paracelsus*, that according to his custom he could not help accusing the Judges both of ignorance and injustice; and thus knowing himself guilty in some measure *læsæ majestatis*, he made what haste he could home, and by advice of his friends got privately out of the city, leaving his whole chemical *Apparatus* to *John Oporinus*. He did not however retire to any great distance, but for two years wandered up and down *Alsace*, *Oporinus* all the while bearing him company, and waiting upon him: And during this time he was as happy in his practice, as he was dissolute in his life. This *Zwinger* informs us (*Theatr.* 1422), who at that time lived at *Basil*, and frequently heard the story from *Oporinus* himself.

He had then taken *Oporinus* for his *Amanuensis*, and servant. He was a famous man, and master both of the *Greek* and *Latin* tongue, but was led away by the vain expectation of being let into *Paracelsus*'s *Arcana*. After rambling about with him however for two whole years, he found he could get nothing at all out of him, though he had left his own family purely on that account. Being quite tired therefore, and grown wiser at last, he left *Paracelsus*, and returned to *Basil*.

The immediate occasion, however, of his leaving him was the following accident. One evening as *Paracelsus* was merry making with some country fellows, he was sent for to a Peasant, that lay dangerously ill near *Colombaria* in *Alsace*; but he being set in for drinking, and not caring to break company, put off going to see him that night. In the morning however he went, and when he came into the room, with a stern countenance asked whether the sick man had taken any thing, having some of his *Laudanam* ready to give him. The persons about him answered, that nothing had been given him but the Sacrament, as he was now just upon the point of expiring. Upon which *Paracelsus* flew into a passion, and told them, if he had sent for any other Physician, he had no occasion for him, and left the house immediately. This impious behaviour so shocked *Oporinus*, that he was afraid, he himself should some time or other suffer for the monstrous inhumanity of his master, and therefore resolved to take a final leave of *Paracelsus*, though he had a very particular value for him. *Zwinger*, *Theatr.* 2275.

Paracelsus had now lost what knowledge he had of the *Latin* tongue, and never after this settled in any place, but kept rambling about; never sober, neither changing his clothes, nor so much as going to bed; till at length after a few days illness, in which he held perfectly sensible to the last, he died through extreme weakness at a publick inn at *Saltzberg*, on the four and twentieth of *September* 1541, and in the seven and fortieth year of his age, though by the assistance of his *Elixir Proprietatis* alone, he had flatter'd himself with the years of *Methusalem*.

Some of his works he publish'd himself, viz, The fourth part of his *Chirurgia Magna*, which he dedicated to *Hieronymus Bonerus* chief magistrate of the city of *Colmar*, the second day of June 1528. His Treatise *de Apostematibus*, which he presented to *Conrad Wiseram*, Consul at *Colmar* the 5th of July 1528, His books de *Gradibus*, *Compositionibus*, and *Tartaro*. *Chirurgia Magna*, which he addressed to *Ferdinand Cæsar*, from *Munchrath*, *May* the seventh 1536. The second part of this, which he inscribed to the same person the eleventh of *August*, 1536. In these he quotes those works of his, that were already published; *De Archidoxis*, *De Sanationibus*, *De Sanitate Microcosmi*, *& Elementorum*. *De Generatione Naturalium*. *De Suppuratione*. *De Signis*. *De Characteribus*, *& Adeptis*. *De Phlebotomiâ*. *De Origine novorum Morborum*. *De Magia*.

This whole History of *Paracelsus* I have extracted from his own writings, from *Oporinus*, *Zwinger*, and *Helmont* in particular; nor has it cost me a little trouble. See *Van Helmont*, (p. 187. § 3. p. 324, 325, 698, 699.) As for the accounts given of him by other Authors, I was afraid to subjoin them, as a mixture of ill nature or prejudice in his favour seems too evidently to appear amongst them.

The life of *Van Helmont* from his own Writings.

John Baptist Van Helmont, descended from a noble family at *Brussels*, was born in the year 1577, six and thirty years after the death of *Paracelsus*. In the year 1580, he lost his father, being the youngest of all the children, and then without the knowledge of his friends, and contrary to the inclination of his mother, he applied himself to the study of Physic, p. 833.

Who was learned in the liberal Sciences, Philosophy, and Medicine.

In the year 1594, he had gone through a Course of Philosophy, being then but seventeen years of age, (p. 12. § 1.) He was a prodigious lover of books, and had carefully read over *Galen* twice, *Hippocrates* once, other *Greek*, and all the *Arabian* Physicians; and whatever he thought worthy of notice in them he had collected into a common place book. And hence, at this time, he gave publick Lectures in Surgery in the College of Physicians at *Louvain*, being appointed to that office, by the Professors, *Thomas Fyenus*, *Gerard Villers*, and *Stornius*, (p. 833.)

Was made Doctor of Physic.

In the year 1599, he was made a Graduate at *Louvain*, in the two and twentieth year of his age, (p. 11. § 7.); and began to see the insufficiency of the schools, long before he was master of any good Medicines, (p. 423. § 2). In himself he experienced the unsuccesful method of cure of the schoolmen, being troubled with a slight Itch, which was happily removed by the assistance of Sulphur, (p. 256, 257). He then began to grow uneasy, that he being of a noble descent should be the first of the family, that had ever applied himself to the study of Physic; and for this reason he quitted his Profession, divided his effects among his relations, and went out of the country with a resolution never to return again, (p. 833). He threw away his library which cost him two hundred

despaired of doing any thing in Physic.

hundred Pistoles, (p. 666. § 12), and wandered about for ten whole years, (p. 11. § 7). He then, by the assistance of an illiterate person, got a notion of *Purotechny*, and applied himself intirely to Chemistry. Within two years after he made himself master of certain Chemical Medicines, by which he was able to cure some Distempers, (p. 833).

In the year 1609, he married a wealthy virtuous wife, of a noble family; and with her he retired to *Vilvorden*, where he gave himself wholly up to the Chemical Art, (p. 41. § 7. p. 833, 838.)

At first setting out, by making some very dangerous Experiments, he frequently run a risque of his life, p. 719, 948.

He neither visited any patients, or followed his Profession with views to advantage, (p. 693. § 3.)

Practised Physic.

And yet he tells us he relieved myriads of sick persons every year, (p. 835.)

He spent fifty whole years in distillations, (p. 241. § 1.) He was in great esteem with the Bishop and Elector of *Cologn*, who was vastly fond of Chemistry, and exceedingly well skilled in it. He was sent for by the Emperor *Rudolphus*; and invited to Court by two Emperors: but he would not accept their favours, (p. 833, 835.)

Could not cure many diseases.

He was not able to cure his two sons of the Plague, but lost them both, (p. 873); nor his eldest daughter of the Leprosy, though he spent two whole years about it, (p. 714. § 27); nor his wife, or maid, (p. 469); nor himself when somebody had given him poison, *Ibid*.

In the year 1624, he published a little treatise, *de Aquis Spadanis*, at *Liege*; and afterwards some other pieces.

Was ill himself, and endeavours his cure by the common methods,

* In the sixty fifth year of his age, (p. 720, 721.) after he had passed his sixty third, on the third of the Kalends of *January*, 1640, he was seized with a Fever, accompanied with a slight *Rigor* that made his teeth chatter. He had a pricking pain about his *Sternum*, attended with a difficulty of respiration. What he spit up, was at first streaked with blood, and afterwards pure blood itself. He took the *Penis* of a Stag scraped, and his pain abated. Afterwards he drank one drachm of goat's blood. In four days time the bloody *Sputum* left him; but he was still at times troubled with a slight cough, with some discharge. His Fever still continued, and a pain in his *Spleen* succeeded, which he removed by drinking some wine made hot with Crabs Eyes: And in a short time all the symptoms disappeared, (p. 322. § 35.) In the year 1643, being exposed to the fume of burning charcoal, he fell into a Syncope, (p. 242. § 19.) from the inconveniences of which he relieved himself by Sulphur of Vitriol, *ibid*. On the eighteenth of *November*, 1644, he was attacked by an Asthma and two Paroxysms of a Pleurisy: Under this disorder he laboured seven weeks, and then died of a slight Fever from extreme weakness, on the thirtieth day of *December*, 1644. See his son's Preface, who after his father's decease published all his works.

But without success, thence sinks under his distemper.

Hence therefore it appears evident beyond dispute, that neither of these Authors, who were the most famous of the Chemists that practised Physic, were masters

* The account given us here of *Van Helmont*'s age don't agree with the preceding one of his birth: for if he was born in 1577, he could not on the third of the kalends of January, 1640, be in his sixty fifth year. This, among other things, I mentioned to the learned Author, who is sensible of the disagreement, but says it stands so in the places quoted from *Van Helmont* himself.

of ſuch a univerſal Medicine as they every where boaſt of; tho' where the *Viſcera* of their Patients were ſound enough to bear the ſhock of their violent Remedies, it muſt be confeſs'd, they perform'd a great many noble cures.

And here we may likewiſe remark, that neither of theſe vain men, with all their pretenſions to longevity, arrived in reality to that ſtage of life, that one can properly call old age.

Afterwards the celebrated Phyſicians, *Franciſcus de le Boe Sylvius*, *Otto Tachenius*, and their followers, introduc'd the chemical Art into Medicine, and made this every where dependant upon it, both in Theory and Practice. Chemiſtry and Medicine united, and made one Academical Science.

Theſe things then being thus ſlightly gone through, it will be of ſervice to a beginner, at his ſetting out, to examine carefully thoſe Authors, who have digeſted the operations of Chemiſtry themſelves into a regular ſyſtem; and of theſe, the following are the moſt valuable.

Oſwald Crollius Baſilica Chemica cum notis Jo. Hartmanni. Genev. 1658. 8vo. A catalogue of Authors for the Practical part.

Beguinus Tirocinium Chemicum, often reprinted. 8vo. and 12mo.

John Hartmann. Opera Medico-chymica. Francf. 1690. fol°.

Glaſer. Traitè de la Chymie. Bruſſels 1676. 12mo.

Le Febre. Traitè de la Chymie. Leyden 1669. 12mo, 2 *vol. Paris* 1660. 2 vol. 8vo.

Le Mery. Cours de Chymie. Leyden 1716, 8vo.

Le Mort. Chymia Medico-Phyſica, &c. Leyden 1696, 4to.

Barchauſen. Puroſapia. Leyden 1698. 4to.

In the metallurgic part of the Art, the moſt celebrated are

Geber, often printed in various ſizes.

George Agricola. De Re Metallica, Lib. xii. &c. *Baſil*, 1657.

Lazarus Erkern. Beſchreibung aller furnemiſten Mineraliſchen ertz, und bergwerks arten, &c. Francf. 1629. fol°. The ſame in 4to. *Francf.* 1694, intitled, *Aula ſubterranea, alias Probirbuch Lazari Erker.*

John Rudolphus Glauber, throughout all his works publiſh'd ſeparately, at different times, and in various ſizes.

Joachim. Becher. Metallurgia Becheri. Francf. 1660. 8vo.

John Kunkel. Philoſophia Chymica, experimentis confirmata. Amſterdam 12mo.

Olaus Borrichius. Docimaſtica metallica. Copenhagen 1680. 8vo.

In Alchemy the following are of greateſt repute.

Geber, who *Bernardus* reckons amongſt the *Sophiſts*. Alchemiſts

Morienus.

Roger Bacon.

George Ripley.

Raymond Lully.

Bernardus, Count of *Treviſan*. He wrote in the year 1453.

Joannes Iſaacus Hollandus, and who perhaps is the ſame

Iſaacus Hollandus, who is more modern than *Arnaud de Ville Nieuve*, but ancienter than *Paracelſus*. *Penotus* had ſuch a value for him, that he imagin'd him, lying conceal'd in *Paracelſus*'s time, to be *Elias* the Artiſt, the promis'd revealer of ſecrets. *Libav. Alchimia Pharmaceut.* 122.

Baſil Valentine. Chymiſche Schrifften. Hamburg 1694. 8vo.

Artephius.

Theatrum Chemicum.

Turba Philosophorum.

Paracelsus. Opera omnia, in *Latin*, *Genev.* 1658. 2 vol. fol°.

———————————— *High-Dutch*, *Strasburg*, 1603. 2 vol. fol°.

———————————— *High-Dutch*, *Strasburg*, 1616. 2 vol. fol°.

Ireneus Philaletha.

Michael Sendivogius.

John Baptist Van Helmont. Opera omnia. Amsterdam, 1652. 4to.

Chemical Authors in Medicine and natural Philosophy.

For Chemistry apply'd to Medicine and Natural Philosophy.

The same *Van Helmont.*

Robert Boyle. In all his writings.

John Bohn. Dissert. Chymico-Physicæ, Leips. 1698.

Dr. *Cox* and Dr. *Slare.* In several of the *Philosophical Transactions of the Royal Society.*

Messieurs *Homberg*, *Geoffroy*, and *Le Mery*, the younger. In the *Memoirs of the Royal Academy of Sciences.*

Georg. Ernest. Stahl. In his *Fundamenta Chymiæ. Norimb.* 1723. 4to.

But above all, the very ingenious *Frederic Hoffman*, in his *Observationes Physico-Chemicæ selectiores, libris tribus comprehensæ*, publish'd at *Hall*, 1722; a Gentleman, who has done a vast deal of service to the chemical Art, and enriched both Chemistry and Physic, with abundance of beautiful observations.

COURSE

COURSE of CHEMESTRY.

PART II.

Which delineates the Theory.

CHEMISTRY is an Art, that teaches us how to perform certain physical operations, by which bodies that are discernible by the senses, or that may be rendered so, and that are capable of being contained in vessels, may by suitable instruments be so changed, that particular determin'd effects may be thence produced, and the causes of those effects understood by the effects themselves, to the manifold improvement of various Arts. Chemistry defined.

And certainly, it very justly deserves the name of an Art; inasmuch as it directs us to the performance of such actions, as the understanding certainly knows will produce such and such effects.

The objects, in observing or changing of which this Art is conversant, are all sensible bodies; and that whether they are so in their own nature, or such, as tho' they were before imperceptible, yet by the help of this Art, either in themselves, or by their effects, may be brought within the reach of our senses; especially, if they are naturally capable of being contain'd in vessels; or by the power of this Art, may be so managed, as to be confin'd therein. The objects of the Art.

Now, from an accurate consideration of these bodies, it appears, that they may commodiously enough be distributed into three Classes; and these have obtain'd the names of Kingdoms. Disposed into three Classes.

The first Class comprehends Fossils, or, as they are vulgarly called, Minerals; which are defined natural bodies, generated in the bowels, or on the surface of the earth, whose texture is so simple, that the most accurate observers, assisted by the nicest microscopes, have never been able to discover any difference in them of vessels and contained fluids, nor any part of them, but what is perfectly uniform, and similar to the whole; tho' at the same time we certainly know, that most of them are compounded of parts, both solid and fluid: These the Chemists call the Mineral Kingdom. The first including Fossils. Character of Fossils.

Of METALS.

And among these, the first place in order is given to Metals; whose character is, that they are the most ponderous Fossils, melting in the fire, uniting again in the cold, and then being ductile under the hammer. The first place given to Metals. Marks of Metals.

Now of these, if we consider them simply, there have never yet been discovered more than six, *viz.* Gold, Silver, Copper, Tin, Iron, and Lead.

The ancient Philoſophers indeed, added Mercury; but as that has neither Hardneſs, Ductility, or Fixity, it muſt certainly be of quite a different nature: The place however where it is found, its weight, ſimplicity, and eaſy union with Metals, naturally led them to think in this manner; and indeed, 'tis a very ancient, and has been a very prevailing opinion, that Mercury conſtitutes the principal part of all Metals.

The ancient characters of Metals. The moſt ancient among the *Perſians*, which is pretty remarkable, in their religious affairs, conſtantly made uſe of the ſame Names, for the ſeven Metals they ſaw produced in the Earth, which they had given to the Planets in the Heavens.

The Aſtronomers too, and Aſtrologers, have diſtinguiſhed the heavenly Planets by the very ſame Characters ☉, ☾, ☿, ♀, ♂, ♃, ♄, as the Chemiſts do their Metals.

The meaning of theſe characters. Which of them made uſe of theſe Marks firſt, it is not eaſy to determine; but this is certain, that the Chemiſts, by their hieroglyphical manner of writing, have aptly expreſs'd the Bodies they deſign'd to repreſent, as upon examination will eaſily appear.

✠ Denotes every thing that is ſharp and corroſive, Vinegar, Fire; and hence it has thoſe ſharp points which you ſee all round it.

☉ —whatever is perfect, immutable, and moſt ſimple: Such is Gold, in which there is nothing corroſive, or heterogeneous.

☾ —half-gold; whoſe inward part turn'd outwards makes pure gold, without any thing foreign, or corroſive. This the Alchemiſts have obſerv'd in Silver.

☿ —the inmoſt part pure Gold; but that at top there appears the colour of Silver, whilſt underneath there is ſomething ſharp and corroſive; both which being remov'd, there will remain pure Gold, but *Aurum vivum.* This the Adepts aſſert to hold good in Mercury.

♀ —the greateſt part to be gold; but that there is ſtill a conſiderable quantity of a crude, ſharp, corroſive matter join'd with it, which being ſeparated from it, the remainder will have the properties of Gold. This alſo the Adepts declare the truth of.

♂ —that this too is intimately Gold; but that it has with it a great deal of the ſharp, and corroſive; tho' with but half the degree of Acrimony as the former, as you ſee it has but half the ſign that expreſſes that quality. And what the Alchemiſts aſſert, the Phyſicians obſerve to be true: Indeed, it is almoſt the univerſal opinion of the Adepts, that the *Aurum vivum*, or *Philoſophorum*, does lye conceal'd in Iron; and that here therefore we muſt ſeek for metalline Medicines, and not in Gold itſelf.

♃ —that Tin is half Silver, the other half a crude corroſive Acrimony: And this every one who is uſed to docimaſtic trials experiences the truth of; for the Cupel ſhews, that it has pretty near the ſame fixedneſs in the fire with Silver; and that it contains abundance of crude Sulphur, well known to the Alchemiſts.

♄ —that it is nearly all corroſive, with ſome reſemblance of Silver; which to the ſkilful is ſufficient.

♁ —Chaos,

ȣ ——Chaos, τὸ πᾶν. The world. The one in which are all things. Gold, and a large quantity of an arsenical corrosive.

The individual proper character of Metals, is their extraordinary weight, which far exceeds that of all other bodies: And this, as it is of all properties the most difficult for Art to produce, affords us a certain mark of Metals.

Weight, the principal, and certain mark of Metals.

A catalogue of them, as they have been examined in the purest water, I have here inserted from the *Philosophical Transactions* N°. 169, p. 926. N°. 199, p. 694.

☉	19636.	♂	7852.
☿	14019.	♃	7321.
♄	11345.	Granate	3978.
☽	10535, 11087.	Glass	2805.
♀	8843.	Pump Water	1000.

Weight, the true mark that distinguishes Metals from one another. And from other very heavy bodies.

If we want therefore to be satisfied, whether bodies that we are not acquainted with, have any quantity of Metal in them, the consideration of their weight furnishes us with the best method of trial.

The rules drawn from the weight alone certain, and of great use.

Nay, and by this means it often appears too, of what sort it is.

How great therefore must be the difficulty of increasing the weights of bodies to such a degree, as to condense other Metals into Gold, or to convert other bodies into Metals?

Hence again we see farther, what substance comes nearest to Gold, in respect of its weight, and of consequence, is most likely to be transmuted into it.

And lastly, that the demonstration from weight is infallibly certain.

The true marks of Gold.

☉. 1. Of all bodies is the heaviest.

2. The most simple, or homogeneous.

3. The most fix'd, both in Air and Fire: Nay, it is so to such a degree, that an ounce of Gold has been kept in fusion for two months together, in the Eye of a Glass-house furnace, without losing one Grain of its weight. Hence it appears to be incorruptible.

4. It is the only body that is capable of resisting the power, both of Antimony and Lead; nor when it is melted with them, does it run into *Scoriæ* with 'em, like other Metals, but sinks to the bottom. Hence it is the most durable of all bodies we are hitherto acquainted with; nay, perhaps immutable, by any physical power: And for this reason, the wisest among the Alchemists, have unanimously agreed, that it is easier to produce Gold by Art, than it is to destroy it.

5. Of all bodies 'tis the most ductile. The workmen can hammer out a grain of Gold, between skins made of Ox's guts, into a leaf, that shall contain $36\frac{1}{2}$ square inches, and 24 square lines. Forty-eight ounces of Silver shap'd into a cylindrical form, may be gilt with one ounce of Gold; from this, Wire may be drawn so fine, that 2 ells of it shall weigh no more than one grain; and consequently, in the surface of these 2 ells, there must be extended $\frac{1}{49}$ of a grain of Gold; and yet upon examination with a Microscope, the Gold is found to be spread so thick, that there is not, in any part of the surface, the least appearance of Silver under it. Hence therefore it follows, that $\frac{1}{1000000}$ of a grain of Gold may be discern'd by the naked Eye; and that the thickness of this visible Foliage, is no more than $\frac{1}{134500}$ of an inch. *Halley. Philosoph. Transact.* N°. 194. p. 549.

And in the *Mem. de l' Acad. Roy. des Scien.* 'tis demonſtrated, that the gilding on the ſmalleſt Silver wire, is but $\frac{1}{1050000}$ of a line thick. A ſingle drop of a Solution of Gold in *Aq. Reg.* will give a metalline taſte to a pint of rectify'd Spirit of Wine; and will change ſome quarts of Water, that have two grains of Tin diſſolv'd in it, to a dark purple colour. *Hoffman.* A workman at *Auſburg*, by a particular Art of his own, could draw one grain of Gold into a wire of 500 feet long. *Caſſius de Auro*, pag. 77.

6. It is ſoft, ſcarcely elaſtic, or ſonorous.
7. When it is once red hot, it preſently melts; but in *Madagaſcar* there is a very ſoft ſort, which runs like Lead with a gentle Fire. *Flacourt. Hiſt. Inſ. Madagaſc. Borrich. Ort. Ch.* 49.
8. Nothing will diſſolve it, except Sea-Salt, or ſome *Menſtruum* prepared from it, all other Salts having no effect upon it; and hence it comes to paſs that it never ruſts, as there is no ſuch thing as *Aq. Regia*, or Spirit of Sea-Salt in the Air.
9. It very readily unites with Mercury, if it is pure; but not ſo eaſily with crude Mercury, as people generally imagine; no, not even by the aſſiſtance of Fire.
10. If it is diſſolv'd in *Aqua Regia*, and precipitated with Salt of Tartar, it will, like Gun-powder, acquire an exploſive Power. Gold is never corrupted by ruſt; or in the longeſt time, loſes any thing by exhalation: Nature gives it perfectly pure in grains and glebes, of which there have been ſome found, that have weighed two pounds; and this Gold is called *Obryzium*; but it often requires the management of the Fire, as there is ſcarcely any Glebe that contains pure Gold, without a Mixture of ſome other Metals; unleſs, when it is moſt intimately united; and even then, it has in it ſomething of Silver: But Silver and Copper excepted, 'tis rarely obſerv'd to be mixed with any other Metal: Almoſt all the world over it is diſtributed, more or leſs, and is found ſometimes in a white Glebe, with black ſpots, which is accounted the beſt; at others in black, red, or yellows. In the Glebes, as they are dug from the Mines, there is obſerv'd a white, blue, red, and green Vitriol; and what goes by the name of Antimony of Gold.

It is ſeparated from the Ore, 1. By torrifying it in a reverberating Furnace; by which means the volatile parts are carried off. 2. By boiling it in Water, that the ſaline and pinguious parts may ſwim at top, and ſo be eaſily taken away. 3. By rubbing it with Mercury, if the Maſs is not pinguious. 4. By rubbing it with Mercury, and *Calx* of Vitriol, if the Glebe is fattiſh, and then boiling it in Water. 5. By *Aqua Regia*. 6. By certain Salts, which ſerve to fix the volatile Oil, or Salt; for theſe would otherwiſe carry off with them a conſiberable part of the Gold. 7. By waſhing it with Water; which is practiſed chiefly with Gold Duſt.

See upon this head, *Lazarus Erker*, Lord *Verulam*, and the *Philoſophical Tranſactions*.

Proper marks of Mercury.

☿ 1. Of all bodies comes the neareſt in weight to Gold; and the more ſo, the more it is purified.

2. It is the most simple of all bodies*, Gold itself not excepted, if it be perfectly pure.
3. In the Fire, it intirely evaporates in form of Smoke, with a degree of Heat, little greater than that of boiling Water.
4. It is not at all ductile under the Hammer, but will, by a gentle stroke, be divided into very small Particles ; and the more so, the purer it is: No degree of cold has ever been observed to condense it into a solid Mass. Is it therefore fluid Gold ?
5. Of all Metals, it unites the easist with Gold, then with Lead, Silver, and Tin ; with more difficulty still with Copper ; and scarcely at all with Iron. In the union therefore of Mercury with Metals, as Mercury is the *Basis* of them all, is it not the Mercury, that by an affinity of nature, unites with itself? Hence, does it not unite so much the easier with any Metal, as that Metal contains more of Mercury, and less of any other Matter ? This certainly seems very probable.
6. Both *Aqua Fortis*, and *Aqua Regia*, will dissolve it.

Hence then we may conclude, how difficult a piece of work it must be, to convert Mercury into Gold, as we must first give it weight, fixity, and ductility: In its nature, however, it approaches the nearest to Gold.

The greatest quantity of it now a-days, is found in *Friuli* in *Italy*, where it is produc'd, 1. In a *Matrix*, hard like Stone, and of the colour of *Crocus Metallorum*. 2. In a soft Earth, which yields fluid Mercury. 3. In Stones of a globular figure. 4. In Cinnabar.

It is separated from its *Matrix* by distillation ; or by sifting it, and washing it with Water. That which in the Mines is found spontaneously fluid, without the assistance of Fire, is called *Virgin Mercury*.

♄. 1. Comes next in weight to Mercury. Marks of Lead.
2. It is found by every sort of trial to be exceeding simple.
3. It fumes in the Fire, and if kept melted a good while runs through most Vessels; nor is it of a fixed nature.
4. It is the softest and least elastic of all Metal ; not sonorous ; easily ductile.
5. Next to Tin it melts with the least degree of Fire long before it is red hot, throws out a Calx, and quickly turns into Glass, which put again into fusion no vessel in the Fire is able to contain. Any light things thrown into it, it casts up to the Surface. It vitrifies with impure Metals, and carries them with it out of the concave Surface of the Test, leaving Gold and Silver only, pure from all the others. The rest it either dissipates in Fumes, or draws with it through the pores of the Test. After fusion, it presently hardens again into a solid Mass, but not so quick as Tin.
6. It dissolves in *Aq. Fortis*, but not in *Aq. Regia*, and yields a sweet salt.

There is abundance of it in a great many Mines in *Europe* ; the consumption of it is very great ; and though it is cheap, it is a Metal vastly useful, as well

* This seems to contradict what was asserted before of Gold ; and indeed it does so, except you understand it in an Alchemistical sense, which was what our Author design'd. For these Gentlemen tell us, that Mercury is the *Basis* of all Metals ; and that Gold itself is compounded of Mercury and a fixing Sulphur, which consequently therefore must be less simple than pure Mercury, which they unanimously agree to be perfectly homogeneous.

as of a wonderful nature. In the Fables of the Mythologists, it is called the Origin and Father of all other Metals, and at the same time their Destroyer.

7. Its Ore is heavy, shining, and of a lead colour, and is half Lead; 'tis sometimes too, white, red, or yellow; but these are not so rich. It has frequently somewhat of Silver in it, which is apt to impose upon the Assayers, if they are not aware of it.

Marks of Silver.

☽ 1. Is the next heavy Metal to Lead.

2. This also is simple, nor shews the least dissimilarity in its parts by any common trials.

3. It is so fixed in the Fire, that it hardly diminishes, if it is perfectly pure. After keeping it fused in the Eye of a Glass-house Furnace for the space of two months it is said to have lost scarce $\frac{1}{12}$ of its weight; and it is a question whether that Silver was absolutely pure.

4. It is malleable, and may be drawn into exceeding fine Wire.

5. As soon as ever it is grown red hot, it melts.

6. It is dissolvable in *Aq. Fortis* alone.

7. It may be purified with Lead, being able to resist it.

8. With Antimony it runs into *Scoriæ*, and becomes volatile.

It is found in a great may places, in various, and very different beds, and has commonly a small quantity of Gold interspersed with it. There is often in the Ore a corrosive, bituminous Sulphur, which renders the Silver volatile, and carries it off; or changes it into glassy *Scoriæ*, much to the disadvantage of the Owners. It yields neither to Salt, nor Lead, and therefore they manage it with Mercury; and this they do by mixing it with the Ore after it has been torrified and reduced to powder, and then in rubbing them together for a considerable time, by which means the Silver unites with the Mercury, and this they afterwards draw off by distillation. *Phil. Trans.* 589, 590, 591.

Marks of Copper.

♀ 1. Is the next ponderous Metal to Silver.

2. It is simple likewise, though less so than the preceding.

3. In the Fire it is pretty fixed, but fumes, and discovers some volatile parts.

4. It is ductile under the hammer, and may be drawn out into very small Wire; it is very elastic too, and of a sharp sound.

5. It grows red hot before it melts, and requires the greatest degree of Fire to fuse it, next to Iron. When it is in fusion it wonderfully resists Water, and is agitated by it in a most violent manner, and hence if any Water happens to come to this Metal whilst it is melted, the event is exceedingly dangerous.

6. It is easily dissolved by any salt, and then becomes greenish, or blueish; but soon getting rid of its dissolvent, it grows of a dirty disagreable colour, losing all its former beauty: Hence both in Air and Water it contracts a greenish mould, which is nothing but a collection of small Crystals.

7. With Lead and Antimony it readily runs into *Scoriæ*, or is changed into Glass; and then leaves the Test, either going off in fumes, or running through the pores of it.

Mines every where abound with it, when it adheres so firmly to its stony Ore, that it commonly passes fourteen Fires before it is pure. It has frequently Silver mixt with it, especially, in the black or light blue Ore; the yellow, green, and brown contain less: In it veins are very often found, green, blue,

 reddish

reddish and white Vitriols; and very fine green and blue stones: So that there is no metallic fossil matter inriched with a greater variety of beautiful colours.

♂ 1. It too distinguishes itself by its weight. Properties of Iron.

2. It is less simple than the preceding, having manifest marks of a crude Sulphur, and a truly combustible matter, which may sometimes be raised into flame.
3. It is fixed indeed in the Fire, though not so much but that it fumes, throws out sparks like combustible Substances, and constantly loses of its weight.
4. It is ductile under the hammer, and may be drawn out into Wire, if you don't attempt it too fine; for then it will split, or discover its brittleness: It is hard, and sonorous.
5. It grows red long before it melts, requiring the strongest Fire, and being melted with most difficulty of all Metals. When it is perfectly red hot, it will bear the contact of cold Water.
6. All Salts readily dissolve it, with which it changes of a red colour; but it easily gets rid of its dissolvent, and then wastes into rusty *Scoriæ:* Hence it is scarce possible to preserve it from rusting.
7. Of all Metals, it is the most easily destroyed: with Lead, and Antimony it presently turns into *Scoriæ.*
8. It both attracts, and is attracted by the Loadstone.
9. It is endued with a medicinal vertue very beneficial to the Human Body, in which it may be nearly dissolved, and to which it seems to approach nearer in nature than any other Metal.

It is observed to be generated in all parts of the earth, dispersed through fat clayey earths, which being put into the Fire discover this Metal by their red colour. In the stony Ore it distinguishes itself by a rusty colour, or if the vein is extraordinary fine by a pale blue one; nay, and often by its magnetic vertue. It is evidently contained in the native green Vitriol. It requires, however, the greatest degree of Fire to procure it pure from the Ore, as well as the assistance of certain proper materials, and a previous torrefaction in the Fire.

♃ 1. Of all Metals is the lighest. Character of Tin.

2. It is much less simple than the former, emitting with a gentle Fire sulphureous fumes, which are easily separated from the metalline part, and are almost combustible.
3. Hence, it is much less durable in the Fire.
4. It is soft, easily bent, and ductile under the hammer, and may be drawn into Wire, but with much more difficulty than the former: It is not considerably sonorous, or elastic.
5. It melts much sooner than the other Metals, long before it is red hot, and in a degree of heat not much greater than that of boiling water; but grows hard again immediately in the cold.
6. Whilst it is crude, and retains its natural Sulphur it is dissoluble only in *Aq. Regia*; but if by Calcination it is purified from its Sulphur, even Vinegar will dissolve it; and a little matter of the Solvent is sufficient.
7. It resists Lead and Antimony so strongly in the Cupel, that it cannot be forced out of it without great difficulty; and not at all indeed, without the assistance of Copper.

8. In many of its properties it comes near to Silver.

The Ore which produces it, is exceeding ponderous, though the Metal itself is but light. The Glebe it is found in is of a brown colour inclining to yellow, or, which is the richest, of a black one, smooth and shining, and sometimes not unlike the Iron Stone: It is contained likewise in a rocky substance very heavy and porous.

After the Ore has been burnt, pounded, and washed, it is melted, and separated from its Dross. The best sort of it is found in *Great Britain*, which yields vast quantities; and hence *Bochart* was led to conjecture that the word *Bretania* was derived from the *Syriac Barat Anac*, which signifies a field of Tin.

This History of Metals, which is undeniably true, furnishes us with the following observations.

The true principles of the transmutation of Metals.

1. That Metals are absolutely different from all other bodies hitherto known, whether natural, or artificial; as we find that the lightest Metal weighs more than twice as much, as the heaviest body of any other kind.
2. That they must therefore be vastly in the wrong, who pretend to convert any other body into Metal; for as the weights of bodies shew us exactly the quantity of matter they contain, the condensing them must be infinitely difficult, and scarcely to be effected without a creating power.
3. That the most certain rule of judging, how nearly pure Metals are alike in their intimate substance, is to be drawn from the nearness of their weights.
4. That there is no Metal therefore that comes so near to Gold, as Mercury, if you consider only their matter; for as to the other principle which gives to each its particular form, it must be quite of a different nature, and therefore does not enter into our present inquiry.
5. That the other properties of Metals, such as, fixity, colour, malleability, and simplicity, may possibly be more easily changed and produced.
6. That Gold consists of a most pure, simple matter, very like Mercury, fastly held together by another exceeding subtil, pure, and simple principle, which being intimately dispersed through the whole, firmly unites the Particles of the former both with itself, and with one another: These two principles are supposed to be Mercury and Sulphur.
7. That the other Metals are compounded of the same principles, but that they have likewise a mixture of another lighter substance in them, which in every particular Metal is different, and is called Earth; and hence they appear to be composed of three sorts of matter, to which in some of them, as a fourth, you may add a crude Sulphur.
8. That they may be resolved therefore into these their compounding Elements, which in different Metals, both in nature, and number, will be different.
9. That this may be effected, by Mercury, a resuscitating Salt, or Fire; by various methods, in various Metals.
10. That there is very little reason therefore for asserting that Metals are easily transmutable into one another, except you confine it to their mercurial part alone, their original Texture being first perfectly destroyed; and that hence no more Gold can possibly be procured from any other Metal, than in proportion to the quantity of Mercury which that metal contains.

11. That

11. That it does not in reality appear, that there ever has been any Metal produced by Art, different from the six which have been mentioned; notwithstanding what *Van Helmont* boldly asserts of Mercury fixed by his *Alcahest*.

12. A person therefore acquainted with what has been said of Metals will not easily be imposed upon by empty promises, and specious appearances; since none of these deceitful Pretenders could ever truly counterfeit the weight of Gold, or produce a body that would be so fixed in the Fire as Gold or Silver: by these two properties then we shall be always secure against their cheats, or plausible reasonings, and be able to discover their spurious, artificial Metals; which brought to the anvil too generally want malleability.

13. That the six Metals, if they are melted in pure vessels, have all the very same appearance, and perfectly resemble Mercury, in colour, solidity, contraction of themselves into a spherical figure, attraction of their Particles, degree of fluidity, and mobility. Hence perhaps Mercury may be a Metal that requires the very least degree of heat to put it in fusion. Tin a Metal that won't run without a greater degree of fire; so that supposing the Air to have as much heat in it as is necessary to put Tin in fusion, then Tin would be Mercury, but would fume, and cast up a scum. Again, Lead would become Mercury, in a degree of heat still a little greater, but would throw out a scum too, and run through the vessels it was put into. A much stronger Fire still is necessary to reduce Gold and Silver to a state of fluidity, which would then be Mercury, and immutable. Copper requires yet a greater degree of heat to fuse it, and reduce it to Mercury, and then too it would be subject to change. And lastly, Iron which of all Metals runs in the Fire with the greatest difficulty, would then be fluid Mercury also, but as the former, would be likewise mutable.

Of SALTS.

Salts, sometimes called concreted Juices, claim the next place in order to Metals; inasmuch as they are exceeding simple and enter into the composition of Semi-metals, and other Fossils. Fossil Salts.

By Salt, we mean a Fossil, which dissolves both in Fire and Water, and is of so simple a nature, that every single particle of it is similar to the whole, and impresses a taste upon the tongue. Its different sorts.

The natural Salts are, Sea Salt, *Sal Gem*, or fossil Salt, Fountain Salt, Nitre, Borax, native *Sal-Ammoniac*, Alum, and a Vague-acid of the pits. Fossil Salt, *Sal-Gemmæ.*

Fossil Salt, the purer part of which is called *Sal Gem*, is found in different parts of the world, and is dug out of its pits perfectly pure, in vast quantities, and to prodigious depths.

Fountain Salt, is procured from running water, in which it is found dissolved, and when it is depurated, and inspissated, is exceedingly like Sea Salt. Fountain Salt.

Sea Salt, is dispersed throughout the Sea, and by simple evaporation, and purification is reduced into Chrystals. Sea Salt.

These three sorts of Salt, though they are different as to their manner of production, yet are found to be of the same nature; the same quantity of Water disſolves them all, *viz.* 3 $\frac{1}{4}$ times their own weight; in our air they all ſpontaneouſly melt away; the Chryſtals they form are nearly alike, being cubical, parallelopipedal, or pyramidal, tho' one chryſtallizes quicker, another ſlower; if they are put into *Aq. Fortis* they produce a *Menſtruum* that will diſſolve Gold; if they are urged by Fire they all yield an acid ſpirit, of the ſame nature; when they are diſſolved in moiſt air, they leave a great deal of earth, and a fat, ſharp, aſtringent liquor; they crackle in the Fire, which, if it is ſtrong, will melt them; and then, if they are very pure, they will remain fixed in it a great while without undergoing any alteration; they yield no ſpirit, and but very little water; no Alcali can be procured from them; nor are they ſuſceptible of putrefaction.

Nitre. Modern Nitre, or Salt-petre, whoſe chryſtals are octogonal priſms, is a ſemi-foſſil extracted from an acrid, nitrous earth: it is put into fuſion by a moderate Fire; ſcarce any water exhales from it, and 'tis pretty fixed: when it is melted it deflagrates with any inflammable ſubſtance: it diſſolves in 6 $\frac{1}{3}$ times its weight of water.

Nitrous earth, or ſtone, owes its vertues to the excrements of animals, or their putrified carcaſſes (thoſe eſpecially, whoſe food has nothing of Sea Salt in it, as birds in particular,) when the aſhes of burnt vegetables, and quick lime happen to be mixt with them: and the nitrous matter being thus produced, is diluted with a great deal of water, filtered through ſand, and then formed into chryſtals with octogonal baſes.

Nitre is generated from a fat alcaline earth, and air. *Hofm. de Eſt. Aq. Min.* T. II. p. 42.

Borax. The third Salt, is Borax, or *Chryſocolla*, which is a foſſil of various figures, requiring more than 20 times its weight of water, with a great degree of heat, to diſſolve it; its taſte is bitteriſh, but with a ſort of ſweetneſs at its going off; it melts very eaſily in the Fire, and then runs off in a riſing froth, by which means a great deal of water is ſeparated from it, whilſt the remainder ſubſides into a beautiful kind of glaſs: It very much forwards the fuſion of bodies that are mixt with it; and hence is of great ſervice in ſoldering of Metals, Gold in particular.

Foſſil *Sal Ammoniac.* Next in order comes *Sal Ammoniac*, or *Sal Arenarius*, which is produced in the moſt ſcorching parts of *Lybia*. The *Sal Cyrenaicus* of the ancients, which was in ſuch great abundance about the temple of *Jupiter Ammon*, appears by *Pliny*'s deſcription of the beſt ſort of it, to have been exceedingly like the *Sal Ammoniac* of the moderns. The burning mountains too in different parts of the world caſt out this ſort of Salt; of which that from *Veſuvius* even to this time is eſteemed the beſt.

And the modern factitious. It ought, therefore, to be referred to the claſs of foſſils; though that indeed which is brought to us now a-days from *Egypt*, is ſuppoſed to be an animal production. In reality, does it not every where owe its origin to ſoot?

An acid foſſil Salt. The fifth of the ſimple foſſil Salts, is an acid, vague, volatile, liquid one, diſperſed perhaps every where throughout the Mines: This being united with a foſſil Oil, as the *Petroleum*, *Oleum terræ*, and the like, may poſſibly produce the different ſorts of native foſſil pellucid Sulphurs, called quick Sulphurs; as well as thoſe which are found united with the Semi-metals, Cinnabar, Antimony, and other Foſſils; and that both the fluid and ſolid: with Metals it produces

produces the various forts of Vitriol; with earths abounding with Lime the different Alums; and laftly from the *pyrites*, which is the *matrix* of Vitriol, calcined in a quick Fire, it gives us the common Sulphur.

Is not this exceeding like that acid, which fumes from the blue flame of burning Sulphur, and is fo fuffocating and deftructive to all animals? certainly its analyfis, and refolution would lead one to think fo.

And for thefe reafons perhaps it may not improperly be looked upon as a male Salt, which feems to impregnate the female Salts, and earths.

The fixth, and laft is Alum, which is a true Foffil, procured either from a ftone that lies deep in the earth, which is hard, capable of being cleft, abounds with Bitumen and Sulphur, and is eafily inflammable; or from a bituminous combuftible earth, which in burning fends forth a fulphureous ftench, that is very pernicious: This matter expofed to the air for the fpace of a month, moulders into a powder, from which Alum may be then produced, though the earth was unfit for it before. Alum.

If the ftony fubftance is firft expofed to the air, and then burnt, it will flame, and by its fmell make it evidently appear it contains Sulphur.

The matter therefore being thus prepared, by the air only, if from the earth; but both by air and fire, if from the ftone; it is diffolved in water, and then by the addition of a fixt, or volatile Alcali is precipitated with an effervefcence; by which action the predominant acid being united with the Alcali produces a new Salt; which therefore owes its being to the air, the Alcali, and the Foffil.

The precipitated matter being then feparated from its *Lixivium*, and diffolved in boiling water, is infpiffated in a leaden veffel and put into a tub, where after fome time it fhoots into white, or reddifh octogonal chryftals; of a fweet roughifh tafte; not eafily diffoluble in the air; and that require fourteen times their weight of water to diffolve them.

The acid of this Salt when it is forced out by the Fire, is like the acid vapour collected from burning Sulphur, in almoft every property.

After the acid is drawn off, the *fæces* that are left behind, yield a large quantity of a light, fubtil earth, which very much refembles bole.

If it is burnt with triple its weight of charcoal, it gives the Phofphorus of *Homberg*; and hence it feems to poffefs a particular power of exciting fire with the affiftance of air.

In the formation therefore of foffil Salts, nature feems to have made ufe of a threefold acid; fpirit of Salt; fpirit of Nitre; and fpirit of Sulphur; and that, in a very large quantity: with which fhe has likewife joined, a fmall portion of Sulphur; as well as water, and earth.

Of SULPHUR.

The third clafs of Foffils, is compofed principally of Sulphurs, though fome other bodies are referred thither likewife. Sulphur.

Sulphur, is a foffil body; hard in the cold, and eafily reducible to powder; but in a moderate degree of heat running like melted wax; it may be raifed by fire in a clofe veffel, intirely, and without any alteration; but if any air comes to it whilft it is melted, it will burn all away, with a blue flame, and a volatil fume, that is fatal to animals.

True Sulphur, as fuch, is found but feldom in the earth, and but in fmall quantities; Quick.

quantities; and there, it is either pellucid and yellow, like Amber; or pellucid and red, like a ruby, which is called Sulphur of Gold; or opake, yellow, grey, or of various colours, and these go by the name of *Sulphur vivum*, or Virgin Sulphur.

Common. As to all the common Sulphur, which is sold in *Europe*, it is an artificial production, from the stone called *Pyrites*; which nevertheless seems scarce to contain any naturally in it; for no Sulphur rises from its *matrix* when urged by fine but an acid liquor like the acid of Vitriol.

This fossil matter however, if it is first prepared by Art, will afterwards by the assistance of fire afford a true Sulphur.

And this is effected by keeping the *Pyrites* for a considerable time in a strong fire; where it softens, calcines, cleaves asunder, and discharges a perfect Sulphur.

But if there is true Sulphur actually existing in the *matrix*, then it is only melted down in crucibles, which are placed in such a sloping manner, that the Sulphur as it melts may distill into proper receivers.

Now the vein of the *matrix* both of Sulphur and Vitriol, is the same.

And hence, Sulphur is artificially made too, from Oil of Vitriol, Alum, or Sulphur *per campanam*, united with some pinguious vegetable substance.

Sulphur therefore has not improperly been called by the Artists, resin of earth.

When it has been purified by repeated fusions, from what rises to the top, or subsides to the bottom, it is poured into cylindrical wooden moulds, and is then the common Sulphur of the shops; of which that of a lemon colour is esteemed the best.

Auripigmentum, or Orpiment. Orpiment, in a great many of its properties very much resembles Sulphur; it is friable; fusible; easily inflammable; and then becomes hurtful from its disagreable sulphureous smell, not from a volatile acid; it is unactive, and innocent, and does not do that harm to the bodies of animals, as is commonly reported; it grows red by fusion, and then yields a volatile matter of an emetic quality. This improperly goes by the name of yellow Arsenic

This native Orpiment melted in a close vessel is converted into a brittle mass, easily reducible to powder; of a beautiful bright colour, like that of red Lead; not very acrid; nor of a very poisonous quality; and yet both the ancients and moderns have called it Realgar, red Arsenic, and Sandarach; and by this confusion of names have given occasion to some errors, that have happened in the Art.

White Arsenic of the moderns. As for the white, chrystalline, pulverizable Arsenic, which is such a strong poison, it is an artificial production of the moderns, not having been known above two hundred years; and it is made in the preparation of Smalt from Cobalt, Flints, and a fixed Alcali: for whilst these materials are melting together, the flowers that rise in the operation are a crude white Arsenic; which being afterwards put in fusion, with a strong fire, and in a close vessel, is the common white Arsenic of the shops. See *Kunkel*, *De Arte Vitriaria*, where he has given a cut of the furnace made use of for this purpose.

Modern yellow Arsenic. If the Arsenical Flowers of Cobalt are melted down with a tenth part of common Sulphur, you have then a poisonous yellow Arsenic, which ought carefully to be distinguish'd from Orpiment, as it is a most insuperable poison.

But if you melt the same Flowers with a fifth part of Sulphur, you produce the

the poisonous red Arsenic of the Moderns, which we must take care too not to confound with the Arsenic of the Ancients, for the reasons already mentioned.

Hence therefore the modern Arsenic does not so much resemble Sulphur, but seems to possess a very particular quality peculiar to itself, and destructive to all animals: This the Ancients were not acquainted with; nor is it easily reducible to any *Genus* of known bodies: As it comes nearer, however, to Sulphur, than any thing else, it is referr'd thither. See by all means on this head, *Hofm. Obs. Phys. Chem.*

Those pinguious substances likewise, which are the natural production of the Earth, should be look'd upon as bodies that are near akin to Sulphur, inasmuch, as they contribute the greatest part towards its composition. Of this kind is *Petroleum*, whose name speaks both its nature and origin: This is expressed from melted *Bitumen*; drips down the rocks; is exceeding thin; very light; of a fetid smell, and perfectly inflammable; often swims at the top of fountains, and is so like a distill'd Oil in most of its properties, that many persons will have it to be prepared by a subterraneous Fire. This Liquid is often called *Bitumen*, tho' they differ in colour, smell, and transparency. Fossil liquid Sulphurs. Petroleum.

Napththa very much resembles *Petroleum*, but is more diluted, thinner, and brighter; it is vastly inflammable; continues burning a long time, when it is once set on fire; nor can it be easily extinguish'd: It is the *Flos*, or most pure and subtil part of *Bitumen*. Napththa.

The *Bitumen* of the *Latins*, and *Asphaltum* of the *Greeks*, is thicker than *Napththa*, and *Petroleum*; very tenacious; but in its first form nevertheless, somewhat fluid; so long as it remains in its natural state, it generally swims upon Water; it burns exceedingly furious. Bitumens.

This however being concocted, and dried by the heat of the Sun or Fire, or even by time itself, grows harder than Pitch; shining; ponderous; melts again in the Fire; will mix with any thing oily; is inflammable; and is then called, *Pix Judæa* or *Bitumen Judaicum*. Jews Pitch

Pissaphaltum, as its name indicates, is of a middle nature, between Pitch and *Bitumen*; black; earthy; fetid, and seems only in degree to differ from the former: And possibly it may be, either an artificial, or natural production, from a mixture of various fat substances with melted *Bitumen*. Pissaphaltum.

This, when it is brought by nature to such perfection, as to become black; hard; earthy; capable of being cleft; smooth; fetid, and shining; it then seems to form the Jet-stone, or the *Lapis Thracius* of *Nicander*. Jet.

And again, if the pinguious parts of *Bitumen* happen to be mix'd and concreted with a rocky Glebe, or perhaps the *Scoriæ* of Metals, and forms a hard Mass; disposed in flakes or *lamina*; black; fat; cleavable, and inflammable; it then seems to produce the *Lithanthrax*, or fossil Coal, which must also be referr'd hither. Lithanthrax

Ambarum, *Carabe*, *Succinum*, *Electorrum*, Amber, belongs likewise to this class, which seems to owe its origin to a bituminous Sulphur; it both burns and melts in the Fire; it consists of an acid Salt, both solid and fluid, and a fossil Oil, which very much resembles *Petroleum*: Of this there are different sorts, as the white, lemon-coloured, yellow, black, and red. Amber.

The *Oleum Terræ* of the *Indies*, described by *Neuhovius*, is seldom brought to us, being secured by the Princes in *Asia*; whether therefore this is a species of *Petroleum*, or *Naphtha*, I can't pretend to determine. Oil of Earth.

As

As for the common Oil which comes from the *Indies* under that name, I am inform'd, by a Gentleman perfectly acquainted with the affair, that it is nothing elſe but an expreſſed Oil from the Caco-nut, mix'd up with ſome medicated Earths, and therefore belongs entirely to the claſs of Vegetables. Is not what goes by the name of *Barbadoes* Oil, prepared too in the ſame manner?

Of STONES.

Stone. A Stone is a hard Foſſil; not ductile; brittle; fixed in the Fire; ſcarcely fuſible by any Fire; nor diſſoluble in Water.

By which marks it is perfectly diſtinguiſhed from Metal, Salt, and Sulphur.

Stones may conveniently enough be divided into pellucid; ſemi-pellucid; and opake.

Gems. Pellucid Stones may not improperly be called Gems, and ſo reduced to a *Genus* under that name.

Theſe, in all their properties, approach very near to Glaſs; tho' they exceed it in hardneſs, ſolidity, ſimplicity, and very difficult fuſion in the Fire, and ſeem to conſiſt of a moſt perfect fine Salt and Earth, intimately united together; as we ſee Aſhes, which have a Salt in them, when melted in the Fire, run into Glaſs.

A tranſparent Gem, without the leaſt mixture of colour, as nearly as poſſible reſembles Glaſs.

The white, bright, pure Chryſtal, that cuts Glaſs, is ſcarcely fuſible in the Fire, is much like Glaſs, and is form'd by a certain particular concourſe and application of *Radii* and *Strata*, ſeems to claim the firſt place in this claſs.

The true Diamond, is an exceeding pure Gem; vaſtly hard; remarkably ſolid; perfectly tranſparent; very refulgent; of great value; coming neareſt to the Chryſtal which (perhaps of all Gems is the moſt perfect) and excelling every other body in its particular reflection of the rays of light. This will continue a very conſiderable time in a ſtrong Fire, without being deſtroy'd.

The moſt pure of the Baſtard-Diamonds, have ſomewhat of the nature of the true ones; but are ſofter; leſs ſolid, and leſs pellucid.

The white Saphir, is akin to the Diamond.

As likewiſe, the Oriental Amethiſt, when it is either naturally or artificially colourleſs.

The Topaz too, and Chryſolite, when perfectly free from colour, are nearly of the nature of Diamonds.

The true *Aſtroites*, which by a certain law reflects the ſolar rays from one common point, belongs likewiſe to the claſs of Pellucids.

The exceeding hardneſs, ſolidity, and perfect tranſparency of theſe Gems, make them vaſtly eſteem'd.

Gems that are pellucid, but inrich'd too with ſome beautiful colour, ſeem to conſiſt of the ſame matter with the former, but to have receiv'd likewiſe in their firſt formation, a tinge from ſome metalline in particular, or other fix'd foſſil mixture, which by this means becomes intimately united with them: This the reſemblance of their colours to the tinctures of Metals, and the artificial manner of making them, ſufficiently evinces. To this claſs are referr'd chiefly,

The Amethiſt, Beryl, Carbuncle, Chryſolite, Granate, Jacinth, Opal, Ruby, by, Saphire, Emerald, and Topaz: Nor ſhould, I think, the colour'd Chryſtals be left out.

The exceeding great value of theſe too ariſes from their vaſt hardneſs, remarkable ſolidity, pure ſimplicity, and beautiful brightneſs of colour.

There is another ſort likewiſe of a middle nature, betwixt Gems and opake Stones, which may therefore be called the Semi-opake, and ſeem of a more compound nature than the former: The chief of theſe are the following, which differ in degree of opacity.

Agat. Sand. One ſort of the *Aſtroites*. The true *Lapis Armenius*. The Toad-ſtone. The Cornelian. The Chalcedony. The *Heliotropium*, or true oriental Jaſper. Jaſper. The true *Lapis Lazuli*. The *Lapis Nephriticus*. The *Leucophthalmus*. The *Malachites*. The Onyx. The *Sardius*. The *Sardonyx*. The *Selinites*, and the Turquoiſe.

Theſe too, are eſteemed in proportion to their ſolidity, hardneſs, tranſparency, and the beauty of their colours.

The opake Stones are the Eagle-ſtone. Alabaſter. The *Amianthus*. The *Belemnites*. *Gypſum*. The *Hæmatites*. Jaſper. The *Lapis Judaicus*. The Touch-ſtone. The Load-ſtone. White, Grey, Yellow, Brown, Black, Porphyrian, Red, and Green Marble. The *Ophites*. The *Oſteocolla*, Pumice-ſtone, Lime-ſtone, Whet-ſtone, Mill-ſtone. Flint. The *Specularis*. Emeril, Talc, and *Tripoli*.

Theſe laſt are of very different natures; ſome of them vitrifying in the Fire, and others turning into an exceeding fix'd calx.

Laſt of all come the foſſil, native Earths, which for the moſt part are of a pinguious nature, and may with Water be work'd into a paſte, whence they are commonly called Boles; but are not diſſoluble, either in Water, or Fire. Theſe are, Clay. The *Axungia Terræ*, or *Lunæ*. The *Cimolia*. Fuller's-earth. The White Bole. The *Armenian*, *Chian*, *Etrerian*, *Lemnian*, Yellow, *Maltan*, Red. Ruddle. The *Samian*. The *Selinuſian*. All the ſeald Earths, and the *Tocavienſis*. Earths.

There are ſome likewiſe of a poorer ſort; as White Chalk. Marl, and Ochre.

Of SEMI-METALS.

The ſeventh claſs of Foſſils, comprehends thoſe bodies, which evidently contain ſome true Metal in them; or at leaſt ſomething ſo like it, that it may almoſt be look'd upon as Metal, and indeed, has been rank'd under that denomination by very good Authors. Theſe, if they are of the more ſimple ſort, may properly enough be reduced to three ſpecies.

1. Semi-Metals, that conſiſt of a true Metal, and a Salt, united together.

And theſe are generally called *Atramenta Sutoria*, *Calcantha*, Vitriols.

Theſe now are obſerv'd to be of two ſorts; one which owes its origin to Iron, and is of a green colour; the other produced from Copper, of a beautiful blue. As for the other Metals, they are ſcarce ever found in the Mines, in a ſtate of ſolution; their diſſolving *Menſtrua*, the Acids of Nitre, and Spirit of Sea Salt, being never diſcovered there: And hence, you will hardly ever meet with the ſolutions of Gold, Silver, Mercury, Lead, or Tin, either fluid or concreted; at leaſt in but a very ſmall quantity.

Lead, it is true, may be diſſolv'd by a weak Acid; but then the chemical Art informs us, how very difficult it is, to reduce it into Chryſtals, as it preſently gets rid of its acid, and turns into a powder, which goes by the name of Ceruſs: And this is likewiſe true of Tin.

Every foſſil Vitriol therefore that has hitherto been dug out of the Earth, owes its origin ſolely to Iron and Copper.

We don't deny, however, but that it is poſſible, that ſome particles of other Metals may be mix'd with Vitriol in a ſtate of fluidity, and by this means become concreted with it; but that any other than Iron and Copper, has ever been actually diſſolv'd by it, and ſo, equably and intimately united with it, wants hitherto confirmation.

This diſſolvent, both of Iron and Copper, is that Acid, which when drawn off by a very ſtrong Fire, goes by the name of the Spirit, or Oil of Vitriol; and is the very ſame that is ſeparated by art from Alum, or collected from the fumes of burning Sulphur.

And indeed, both Vitriol and Sulphur, are generated, grow, and are procured from the ſame *Matrix*, *viz.* the Pyrites; which after it is dug, is expoſed to the Air, freed from its great quantity of Sulphur, reduc'd to Powder, diſſolv'd in Water, and then ſuffer'd to form its Chryſtals about Sticks that are plac'd in it for that purpoſe.

It may readily likewiſe be produc'd from the *Miſy* of the Ancients, by ſimple Solution, and Chryſtallization.

Hence therefore Vitriol is of five ſorts. 1. The green; which owes its origin intirely to Iron, and Spirit of Sulphur: This is extoll'd for its medicinal vertues, and is the beſt for making Ink. 2. The bluiſh, which conſiſts of a great deal of Iron, and a little Copper, diſſolv'd by Spirit of Sulphur; for if you make a ſolution of it with Water, and then immerge plates of Iron into it, you will find them ting'd of a Copper colour; which makes it evident, that it contains a ſmall mixture of that Metal. 3. The white, which ſeems to be very little different from the green, and poſſibly owes its particular nature, only to a greater degree of Heat, as we ſee in the factitious; for in every reſpect but its colour, it perfectly reſembles it. 4. The *Chalcites*, true *Calcanthum*, or red Vitriol; and this too is exceedingly like the green, and may be reſolv'd into the ſame principles; it ſeems compounded chiefly of Iron, and an acid of Sulphur, with, perhaps, a little mixture of Copper. 5. The *Cyprian*, or *Hungarian*, which is perfectly blue, and conſiſts purely of Copper, and the ſame Acid of Sulphur. The *Sory* too, which is an exceeding acrid, hard, coarſe, fat glebe, ſeems to be nothing but a grey or black concreted juice of Vitriol; and hence will produce a Vitriol, by the help of Water alone.

The *Melenteria* alſo, which is a grey, or black glebe, of a cauſtic quality, is of the ſame vein, nature, and family.

Theſe all therefore, for their *Baſis*, have Iron or Copper; for their diſſolving *Menſtruum*, an acid of Sulphur; whilſt Water, which dilutes the acid, and diſpoſes in a proper manner the particles of the Metal, gives them their figure and tranſparency: And hence, according to the different proportion of theſe three principles, may all the variety of them, deliver'd by the Ancients, be underſtood.

The native Vitriols therefore conſiſt of Water; an acid Spirit of Sulphur;

and the Metals, Iron and Copper, mix'd in a certain proportion, and concreted into one mafs.

2. Other Semi-metals are compounded of Sulphur and Metal, intimately united together: Of thefe the following are the chief. **Sulphureous Semi-metals.**

Native Cinnabar, or the *Minium* of the Ancients, which is a compofition of Sulphur and Mercury, fufed and brought into union in the Mines, by fome fubterraneous Fire: This the artificial Cinnabar is a proof of. It is eafily refolvable into true Sulphur and Mercury; from whence it appears, that there is in reality abundance of Sulphur in the Mines, which owes its production intirely to nature. **Cinnabar.**

The *Stibium* of the Ancients, the *ςίμμι* of the *Greeks*, and Antimony of the Moderns, confifts of a true foffil Sulphur, and another matter exceedingly refembling Metal; which, could it be render'd malleable, would be truly of a metalline nature, and be a feventh ductile Metal: But it is univerfally acknowledged, that this manner of purifying Antimony, has not yet been difcover'd. Mr. *Boyle* however, afferts, that by fome fecret methods, true fluid Mercury has been produc'd from it: And indeed, every modern dabler in the Art pretends to it. It is fufible in the Fire, and makes other Foffils melt with a great deal more eafe than they would without it. **Antimony.**

Being brittle too itfelf, if it is mix'd with bodies that were ductile before, it will render them brittle.

And again, if it is put among bodies that are fix'd in the Fire, by its volatile Difpofition, it will make them volatile alfo; fcarce any one being perfectly excepted.

It very much too increafes the brightnefs and beauty of Gold.

And laftly, in its nature it feems nearly to approach to white Arfenic.

Bifmuthum, *Bifemutum*, Bifmuth, is akin to Antimony, and confifts of *lamina*, or flakes difpofed one upon another; in its white, bright colour, it refembles Silver; it is harder, and lefs friable than the former; nor ductile under the hammer; has evident marks of Sulphur in it; and by the action of an acid upon it, lets fall a bituminous matter; it is lefs fixed in the Fire than Metals; and being mix'd with them, renders them more volatile and friable. **Bifmuth.**

Zinetum, Zincq is very much like the former, but lefs friable. **Zincq.**

3. To this clafs of Semi-metals, may be referr'd all foffil, chryftalline, ftony, or earthy bodies, which have a mixture of true Metal in their compofition; of which fort fome are found interfperfed thro' the veins of moft Metals.

This clafs therefore will include a very large number of bodies, out of which we fhall only take notice of the following, which are the moft remarkable.

The *Lapis Armenus*, *Cyaneus*, *Lazulus*, which is a fmooth blue Stone, fpangled with golden ftars, and is faid to contain a great deal of Gold. *Lapis Lazuli.*

The *Lapis Hæmatites*, which abounds with a metalline fubftance; is exceedingly like Iron; and fublimed with *Sal-Ammoniac*, fmells very ftrong of an aromatic Sulphur, for which reafon fome perfons have called it *Aroph*, or *Aroma Philofophorum*. *Lapis Hæmatites.*

The Loadftone, which has a particular tendency towards Iron, is almoft of the fame colour, and very much of the fame nature. **The Magnet.**

Ochre too, perhaps, may come into this tribe, as it appears to be a precipitation of Iron from chalybeate Waters. **Ochre.**

From what has been ſaid then upon this head, we may be able to form a juſt notion of the principles of Foſſils; for upon examination it appears, that they may be reduc'd chiefly to Mercury, Metallic Sulphurs, Salt, Combuſtible Sulphurs, Earth, and Stones; tho' it muſt be confeſs'd, that theſe are vaſtly different, if they come to be nicely examined in particular Foſſils. We learn farther too, that they contain an acid Salt in them, which is exceedingly active; beſides which, they are acted upon by no other moving power, but Fire.

Of VEGETABLES.

The next kind of bodies that come under the conſideration of Chemiſtry, are Vegetables, or as they are commonly called, Plants.

A Plant in general. By a Plant now we mean a Hydraulic body, which contains different ſorts of juices, in various veſſels, and by ſome external part of it, ſo adheres to another body, that through this part it is capable of drawing in the matter, both of its growth and nouriſhment.

By this definition then, we evidently ſee the difference between a Plant, and the foſſil ſubſtances afore deſcribed; and that whether you conſider the variety of its ſolid parts; the different nature of its juices; or its whole compoſition together, as made up, both of ſolids, and fluids.

The Root. And again, the external part called the Root, which attracts its nouriſhment from the body to which it is join'd, ſufficiently diſtinguiſhes it from every Animal we are hitherto acquainted with.

The ſolid parts of Vegetables are a mere Earth, ſo faſtly united together by a tenacious, oily, glutinous matter, that they cannot be ſeparated from one another, without the aſſiſtance of an open, flaming Fire.

The veſſels of Plants, as they are exceedingly different in their make and poſition, ſo they are alſo in their contents and vertues.

The buſineſs of the Root, is to faſten the Plant to its ſoil, or (in which ſenſe only we have here to conſider it) to take in its nouriſhment; and hence ſometimes, its whole ſurface is obſerved to perform this office; as we ſee evidently in the Muſhroom and Puff.

For this purpoſe therefore, it conſiſts of an infinite number of apertures of veſſels diſperſed through its whole ſurface, by which the nutritious juice is ſuck'd in, and ſo receiv'd into its veſſels, and by theſe convey'd through every part of the Plant. Theſe veſſels may not improperly be compared to the Meſenteric Lacteals, and other abſorbent veins in Animals.

This juice, however, at its firſt reception into Plants, is not of the ſame nature with the Plants themſelves, but crude, and of the nature of the bodies, by which they are ſuſtain'd and nouriſhed. Theſe now in general, ſeem to be either Earth or Water; which upon examination we ſhall find, receive again, ſooner or later, the very ſame matter which the Plants had before drawn from them: For whether they are produc'd in the Waters, or on the Earth, when they come to die, they drop again into the ſame Waters, or Earth; or elſe are diſperſed into the Air, whence, in form of Dew, Miſt, Snow, Hail, Hoarfroſt, and Rain, they deſcend again into the boſom of the Earth. Hence then it appears, that the Earth is a Chaos, of paſt, preſent, and future bodies, from which all receive their birth, and to which all do certainly return again.

The Water, Spirits, Oils, Salts, and whatever lies hid in the bowels of the Earth,

Earth, are put into motion, by ſubterraneous, artificial, and celeſtial Fire; by which means they are rendered capable of being mixed with Water, and conſequently of being applied to the roots of Vegetables, that are inſerted into the Earth.

The Water again, of the Sea, Rivers, and Lakes, receives, as the Earth does, the bodies that float about in the Air; and contains beſides a variety of other matter, which it waſhes off from the Earth.

Theſe crude Juices circulate through Vegetables in the greateſt quantity, and with the ſwifteſt motion in the Spring-ſeaſon, and are then particularly obſerved to be watery, thin, and inclining to the acid; as the liquor, that upon inciſion diſtils from the Birch, Walnut-tree, or Vine in the month of *March* demonſtrates.

Afterwards however, as they are propelled through the various organs of the Plant, from the make of the Plant itſelf, from the effects they have impreſſed upon them by the Fire in the Earth and Heavens, from the changes of Moiſture, Drought, Cold, and Heat, and laſtly from the viciſſitude of day and night, and the various ſeaſons of the year, they are by degrees concocted, and made more perfect, and in particular parts of the Plant putting on different natures, become the proper Juices of the Plant.

The Leaves from the make, number, and fineneſs of their veſſels, receive the moſt ſubtil of the Juices, and in a very large Surface expoſe them almoſt naked to the Air, which various cauſes renders very active; here therefore they undergo very great alterations, and being perfected according to their particular natures are returned back again to the Plant; the Leaves performing the ſame office in Vegetables, as the lungs do in Animals, as we learn from the elegant Obſervations of *Malpighi*. The Leaves.

The Juices that properly belong to the Leaves themſelves, are the honey Dew that is ſpread over them in ſummer nights, a wax that oozes out of them, Manna, and the *Thereniabin* of the *Arabians*, which being put into motion and concocted by the heat of the Sun, are condenſed by the Cold of the ſucceeding night, and ſo may be gathered from their Surface.

Afterwards the Cups, *Petala*, or Leaves, *Stamina*, and *Apices* of the Flowers, bring the Juices thus prepared by the Leaves to greater perfection, and impreſs upon them, more certainly, that diſtinguiſhing character, which is peculiar to the Plant; as well as fit them for producing, preſerving, and nouriſhing a new Embryo: this certainly, the affinity between the Leaves and Flowers, their near ſituation, the origin of the Buds, and the make of the Flowers, induce us to believe. The flowers.

Here is generated that fragrant, reviving, almoſt vital *Aura*, that Flowers in their perfection ſo delightfully breath forth; which, probably, by its prolific odour may be grateful to the Embryo: this is certain, that it is a very pure, and moſt excellent liquor, and if it is mixed with any thing elſe, loſes it former beauty and excellence.

In the Flowers too is produced true honey, which oozees out into receptacles that provident nature has joined to the bottoms of the Leaves: this the Bees ſuck up, convey into their little bags, diſtil into their combs, and then ſecure with wax.

On the *Apices* of the *Stamina*, and on the *petala* there is obſerved likewiſe a

wax,

wax, which the Bees ſcrape off with their rough feet, roll up into balls, diſpoſe under the hinder part of their bodies, and ſo carry to their hives, in order to form and cloſe up their combs.

The Seed. The fruit, is the repoſitory of the Seed, and its contents. The Seed, is the Embryo of the Plant, with a uterine *placenta*, or one, two, or more Cotyledons, to which the Embryo is faſtened by an umbilical cord. The Cotyledons for the moſt part abound with a Balſam diſpoſed in proper cells; and this ſeems to be Oil brought to its greateſt perfection whilſt it remains humid, and then lodged in theſe repoſitories. One part of the compoſition of this Balſam is oily, and tenacious, and ſerves to defend the Embryo from any extraneous moiſture, and by its viſcidity, to entangle and retain that fine, pure, volatile ſpirit, which is the ultimate production of the Plant: This the Alchemiſts have ſtiled, the *Spiritus Rector*, the inhabitant of Sulphur, the *Archæus*, and the ſervant of nature.

This Oil is never obſerved to enter into the veſſels of the Embryo, which are too fine to admit ſo thick a fluid. The ſpirit however being quickened by an active power may poſſibly breath a vital principle into the Juices that nouriſh the Embryo, and ſtamp upon it the character that diſtinguiſhes the family; after which, every thing is changed into the proper nature of that particular plant. That this ſpirit now, is truly the efficacious part, is evident, for when that is gone off, the Oil that remains is quite vapid and unactive. 'Tis this that gives Plants their fragrant ſmell, and peculiar taſtes; nor do their particular colours a little depend upon it. This Spirit *Iſaac Hollandus* called the *Quinta Eſſentia*, or quinteſcence of Plants.

Again, as the dry, brittle, fibres of Vegetables, require ſomething to ſoften them, that they may bend eaſily without danger of breaking, they are provided with another ſort of Oil running in its proper veſſels by the ſides of the woody Filaments; this may be diſcerned to drop from the middle of the wood, when it is heated, and by warmth, or length of time, is eaſily changed into a Balſam, and Reſin.

The Bark. This Oil, which is much leſs volatile than the other Juices, being concocted by the heat of Summer, is carried into the Bark, which like the *Membrana adipoſa* of Animals is furniſhed with proper cells for its reception; in theſe receptacles it is firſt detained, and collected by the Cold of Autumn, that by thus forming a pinguious covering, it may ſecure the whole body of the Vegetable, from the injuries of Froſt and Rain during the Winter Seaſon. This always contains in it an acid ſpirit; which is a preſervative againſt putrefaction. In this Oil of the Bark conſiſts intirely the value of ſome of the *Aſiatic* and *Indian* Plants; as we ſee in the Cinnamon of *Aſia*, in the Bark of whoſe trunk and branches reſides that choice Oil, which is ſo vaſtly valuable; whilſt the Bark of the root affords us that wonderfully medicinal Oil, called falſly from its ſmell, Oil of Camphire. The Saſſafras too of *America*, from its Bark yields us a very beautiful Oil; as in this part lies the vertue of that noble Febrifuge the Quinquina of the ſame country. Nay and the vertues of the *European* medicinal Vegetables likewiſe are very often to be ſought for in the Bark; witneſs, the Caper-tree, the Tamariſk, and the Aſh. In the winter time therefore, the Bark contains a large quantity of theſe Oils; whereas in the Spring, and Summer, the other Juices, which abound with a Water, Salt, and *Sapo*, proper to the

the whole Plant, paſs through it in great abundance likewiſe; and hence at thoſe times what it yields by a chemical Analyſis, is very different from what is procured from it at others. The true Oil that belongs properly to the Bark, in its natural ſtate is liquid, though by time and the heat of the Sun it will alter its conſiſtence, and thicken into a Balſam. This again by longer time and a greater degree of Heat, being yet more inſpiſſated, becomes a pinguious ſort of a Reſin; and by a continuation or increaſe of the ſame cauſes, acquires both the name, and nature of a Reſin: This therefore owes its origin to the Oil, but is freed in a greater degree from its acid ſpirit; and it then melts, and burns all away in the Fire, may eaſily be diſſolved and mixed with Oil, never ſuffers any ſolution from Water, hardens in the cold, and then loſes its oily tenacity, and grows brittle. This Reſin being yet further concocted, grows ſtill harder, and then it is called Colophony. In this part of Vegetables, there is obſerved too, a thick tenacious Juice, which goes by the name of a Gum; this likewiſe will melt and conſume in the fire, but in the cold, except it be extreme, retains its tenacity, and is intirely diſſoluble in water. This oily Mucilage ſerves like a Pigment to cover over and defend the Buds of Trees, but will melt with a moiſt warmth, and eaſily runs from them, nor is ever ſo far hardened into a cruſt as to do any injury to the tender twigs.

About the bark of Plants, eſpecially the umbelliferous kind, there is found ſtill another Juice, which is a mixture of a Gum, and Reſin, and therefore called a Gum-reſin. Hence one part of it like a Gum eaſily melts in water; whilſt the other is not at all affected by it, but in the manner of a Reſin is readily diſſolved and mixed with Oil: Of this ſort are Aloes, Myrrh, Galbanum and a great many others.

The proper Juice.

And laſtly every Plant contains in it a particular and peculiar Juice, which is produced by the whole efficacy of every part of the Plant ſucceſſively applied to the crude Juices it is continually receiving. This therefore, when it is thus prepared, poſſeſſes the true nature and vertues of the Plant. This Juice can ſcarcely be reduced to any claſs of things yet known, and therefore muſt be looked upon as ſomething perfectly ſingular.

If you examine the Leaf of the *Chelidonium Majus* in a live, flouriſhing Plant, you may obſerve a parcel of Fibres ariſing from the Stalk, which unfold, and diſperſe themſelves all over the Leaf. You may perceive too that theſe are every where ſending off branches, which joining with one another compoſe a curious kind of net work, which almoſt fills up the whole *Area* of the Leaf. If you gently now prick any one of theſe little ramifications, there preſently iſſues out a Juice of a golden colour, which has the true vertues of the *Chelidonium*. In the ſame manner in the Spring you may procure from the common Aloe, a yellow, bitter Juice, which circulates through the Plant, in its proper veſſels. The Poppy too upon making an inciſion diſtils a pure milky Opium. But here it is proper to obſerve, that theſe Juices, whilſt thus ſimple, and ſeparate, are vaſtly different from the mixture that ariſes from the confuſion of all the Juices of the Plant together.

This then, Gentlemen, is what I thought proper to lay before you of the Hiſtory of Plants, before I proceed to explain to you the methods in which they are managed by the chemical Art; nor do I ſee that more is neceſſary. For hence you may ſee how vain the endeavours of thoſe Chemiſts muſt appear, who

pretend

pretend by their Art to be able to exhibit to you those parts of Vegetables in which their particular vertues consist, without a mixture of any of the other parts with them. If they would do this, they must certainly make use of very different methods from what they do at present, or else they will take a great deal of pains to no valuable purpose; but on the contrary will lead us into mistakes. And indeed, with submission to some famous Authors, I must take the liberty to declare, That Distillation, Fermentation, Putrefaction, and Combustion, produce such considerable alterations, in the particular *crasis* or constitution of Plants, and consequently in the medicinal vertues which depend upon it, that we ought to use a great deal of caution, and circumspection, before we can pretend, from these Operations, to determine the true causes of those vertues: Not that on this account this noble Science ought by any means to be neglected; Nay, for this very reason it should be more vigorously cultivated: For by this Art alone we are instructed, what such, and such particular Operations are capable of producing from any given bodies; and this alone corrects the error of those who practise it: These two advantages therefore, sufficiently recommend it; and by these alone it is capable of leading us to an infinite number of beautiful Discoveries.

The *Spiritus Rector*; an exceeding fine Oil which is the true seat of this spirit; an acid Salt; a neutral Salt; a fixt, or volatile, alcaline Salt; an Oil mixt with a Salt in form of a *Sapo*; and a saponaceous Juice arising hence; an Oil which is most firmly united to an Earth, nor is easily separable from it; and lastly a pure simple Earth, which is the firm *Basis* of them all; are those principles, which Chemistry applied in a proper manner, has really discovered and produced from Vegetables.

Of ANIMALS.

Of Animals. The third class of bodies, that have engaged the labours of the Chemists, are Animals, called the Animal Kingdom: But as of these the corporeal part only, has come under their consideration; hence when we speak of Animals, we mean only their bodies, and the parts of them, neglecting intirely their other principle, which is a subject of a very different inquiry. In this sense then, an Animal is defined a hydraulic body, which subsists by a constant and determin'd motion of humours through its vessels, and which contains within itself certain vessels, like the roots of Vegetables, by which it draws in that nutriment, which supports its being, and increases its magnitude.

Now the vessels, which thus perform the office of roots, are observ'd in almost every kind of Animal, and that chiefly in the small guts, going by the name of the lacteal and mesenteric veins. The food, and drink which Animals take in, being applied to the mouths of these absorbent vessels, is the matter by which they subsist, and is the same to them, that the Earth is to Vegetables; and the concave *superficies* of the mouth, *æsophagus*, stomach, and small guts, which is in the inside of all Animals, are the parts to which the nourishment is apply'd, and through which they receive it. Hence then it appears, that Vegetables suck in their nutritious juices by external roots, Animals by internal; and that the Earth, which is the support of Vegetables, is always without them, whilst Animals receive their nourishment constantly from within. And this observation holds true, even in that kind of Animals, which naturally

turally grow, and are ſtrongly join'd to ſome other body, as is evident in the Limpins, Oyſters, and other *Zoophyta*, whoſe ſhells adhering to rocks, or pieces of wood, contain an Animal firmly faſten'd to them by a very tenacious ligament: For theſe very ſhells, ſo long as the Animal lives, receive from this incloſed body, by certain veſſels deſtin'd intirely to this office, their nouriſhment, ſupport, and increaſe, whilſt the Animal itſelf takes its food in at its mouth, and conveys it into its inteſtines, in the ſame manner as all others do, that are at liberty to move about from one place to another.

But farther, even the *Fœtus* of oviparous Animals, which reſide, and are confin'd in their ſhell, till cheriſh'd by a pregnant warmth, and nouriſh'd by their own white, being ſtill planted as it were in their yolk, they grow to maturity enough to break their ſhell, get out of their priſon, and ſhift for themſelves: Nay and laſtly, thoſe, whoſe eggs are lodg'd within the *Uterus* of the mother, to which they grow as it were by means of cotyledons, or a *placenta*, and umbilical cord, and are thus cheriſhed and ſupported: I ſay, both theſe, tho' in regard of their Cotyledons, *Placenta*, yolk, umbilical cord, and *omphalo-hepatic* veſſels, they then very much reſemble a Plant; yet during the very ſame time, they take in at their mouths the liquor contain'd in the *Amnion*, convey it into their inteſtines, and by this means are nouriſhed in the manner of other Animals.

Hence then, as we ſee evidently, that there is a great analogy betwixt Plants and Animals; ſo we perceive likewiſe, that there are ſome circumſtances, wherein they evidently differ.

But farther, as we obſerve among Vegetables, that ſome are fix'd in the Earth, others fluctuate about in the Water, and a third ſort grow in both; in like manner we learn from the Zoographers, that there are ſome Animals that live on the Land, ſome in the Water, and others, that to anſwer their different neceſſities, are equally ſuited either to Land or Water.

And laſtly, as Plants, by the apertures of the veſſels on their ſurface, draw in the humours that float about in the Air; ſo likewiſe the bodies of Animals are known to do the ſame.

But we ſhall yet again find a farther agreement between them, if we conſider that they are both ſupported by the ſame kind of nouriſhment: For as Plants flouriſh and increaſe by the juices they draw out of the Earth, ſo Animals live either upon Vegetables, or the parts of other Animals, which upon examination, we ſhall find to have been fed with Vegetable juices: The matter therefore of both is the ſame.

And as the juice, which Vegetables receive from the Earth, is not of their nature, but crude, at its firſt reception; in the ſame manner, the food, which Animals take in, and the chyle which is produced from it, does not preſently put on the Animal nature, but retains a conſiderable time the properties of thoſe bodies from whence it was derived.

Indeed afterwards, by the ſurpriſing effect of the animal machine upon them, and the mixture of the juices with them that are already concocted, the crude ones by degrees are wonderfully chang'd, and in every part of the body put on new appearances, as will be taken notice of in its proper place. It is ſufficient to our preſent purpoſe to obſerve, that the longer the food has been taken into the Animal, the oftener it has circulated through every part of its body, and the greater number of its juices it has been mix'd and incorporated with, the more it conſtantly recedes from its own nature, and approaches to that of the body into which it is received.

The Spirits in Animals. Among the humours of Animals there is one that is vaſtly more ſubtil than all the reſt; and this is called the exhaling Spirit, and ſeems to contain that ſingular quality which is peculiar to every particular Animal, and diſtinguiſhes it from every other. This we learn evidently from your Hounds, who will ſingle out, and purſue over a great deal of ground, and through a vaſt confuſion of tracks, that particular Animal which they firſt got freſh ſcent of, without any regard to the reſt of the herd. We ſee the ſame thing too in their following their maſters through common ways, where there is a great number of perſons paſſing every minute backwards and forwards, and yet moſt certainly finding them out. Hence therefore it appears, that theſe *Effluvia* muſt be exceedingly ſubtil, and perfectly diſtinct from every thing elſe. Theſe ſeem to be of an oily nature, or to reſide in a moſt ſubtil vehicle, which owes its origin to an oil; as the analogy of things, and the reſt of their properties induce one to believe.

Their Water. Water conſtitutes the greateſt part of the animal fluids, as in reality it does of moſt others; and indeed, it is ſo intimately united even with their moſt ſolid parts, that there are ſcarce any of them that are intirely without it; as the chemical Art has long ago informed us.

Their Salt. There is a Salt too diſcovered in them peculiar to the Animal Kingdom, beſides thoſe Salts which they take in with their food, which from the power of the body ſuffer no alteration.

Now this Salt was never obſerved to be a fix'd one.

Nor yet ſo volatile, as ever to exhale from the body of the hotteſt Animal, ſo long as it continued in a ſtate of health.

However, if for a good while you apply to it a degree of Heat, little greater than that of boiling Water, it will become intirely volatile.

Again, no perſon living, has ever diſcovered this Salt to be acid, unleſs it happens ſo, from things of that nature, which the Animal had received from without into its body.

Nor laſtly has it ever appeared by any experiment that it is alcalious, ſo long as the Animal is in health, nay, nor even when it is ſick; for upon a very careful examination that I made upon ſome urine, which had been retained five days in the body by a diſorder in the urinary paſſages, I found, that even in that time, it was not become of an alcaline nature.

The ſame, however, by putrefaction, or a greater degree of heat, will be changed into a perfect alcali; but whenever in its natural ſtate, by inſpiſſation, and letting it ſtand undiſturbed, you can artfully reduce it into little glebes, it appears to be a Salt different from every one that we are yet acquainted with: It comes neareſt, indeed, to *Sal-Ammoniac* of any, but ſtill, in ſome of its properties, it differs from that too; for *Sal-Ammoniac*, if put in a ſtrong Fire, will be all raiſed without undergoing any alteration, whilſt that which is drawn by Fire from urine, which is the *Lixivium* of the animal Salts, becomes immediately and intirely alcalious.

In ſhort, after a great many experiments made on purpoſe to determine the true nature of this animal Salt, as it really exiſts in ſound bodies, and acts there

by

by its own peculiar vertue, it appears to be of a mild disposition; possessing a saponaceous quality from an Oil that is united with it; being a kind of middle Salt, between a fixt and volatile one; having not the least mark either of an Alcali, or an Acid; being easily, however, resolvable into a volatile fetid Oil, and a volatile alcaline Salt, and hence very much disposed to putrefaction.

Nor let any one be here led into a mistake by the fixt Salt, which is produc'd from the ashes of urine when burnt in the Fire; for this is nothing else but the Sea Salt, that was first taken into the body, which is able to bear all the actions, and powers, of the animal machine, without suffering any alteration in its nature.

And to the same cause do we owe that small quantity of acid, which after so much trouble, and with so strong a Fire we are able to extract from human blood; for it certainly appears to be only an acid Spirit of Sea Salt that was united with an Earth, and is now forced out by this excessive degree of Heat.

And hence Animals, in whose food there is no mixture of Sea Salt, have neither this fixt Salt in their urine, nor latent acid in their blood.

The Oils which upon careful examination Chemistry has discovered in Animals are of a very different nature: Some, for instance, are so subtil, that they'll bear to be mixed with Water, and become volatile with a small degree of heat, in which respect they very much resemble the spirits of Vegetables, in their natural state; but they differ vastly from those which are produced from them by the help of Fermentation.

There is another sort of Oil, which contains but a very small quantity of Salt in it, and is of an exceeding soft and smooth nature, serving to lubricate and supple the more rigid parts of the body: This in the cavities of the bones, is called marrow, in the *Membrana adiposa*, fat; in both which it is collected, and reserved for proper uses: It is this, that helps to sheath, and soften, the sharp humours of the animal body; and 'tis this that has sometimes been observed swimming upon the top of blood.

Again, there has been discovered another Oil which differs from the former, being concreted with the animal Salts, and so rendering them of a saponaceous quality, peculiar to the animal body: This, if you separate it, appears of a different nature from those already mentioned, being more acrid, fetid, and volatile.

There is yet a fourth kind of Oil, whose office is firmly to unite together the Elements of the solids, but so, as still to leave them a requisite degree of flexibility. This was originally form'd, and always continues in intimate union, with these Elements of Earth, not suffering itself easily to be separated from them: This dissolution, indeed, a strong Fire will effect, as well as putrefaction produced by a long continued action of the Air, Water, or Heat upon it; for then it becomes volatile and flies off, leaving nothing behind it but Ashes, which easily moulder away. Whenever this Oil is alone, it always discovers itself by an intolerable noisome smell.

But of all the Oils that are discovered in the animal body, there is none so wonderful as that which is drawn from their inspissated juices, when they are exposed for a great length of time to an exceeding strong Fire, and goes by the name of *Phosphorus*. This naturally takes fire in the Air, and burns away, eaving a fixed, acid, fluid behind it. Earth of Animals.

Earth of Animals. In the laſt place, there is found in Animals an Earth likewiſe, which ſerves as a *Baſis* to the whole body, connects all the other particles together, and retains the fluids within their proper bounds.

This now differs very little, if at all, from the pure Earth of Vegetables; for whenever you ſeparate them carefully, and examine them nicely, they appear to be perfectly alike. A plain proof of this we ſee in the docimaſtic Teſts, and the little Furnaces made uſe of in aſſaying of Metals; for nothing is fit for this purpoſe, but a moſt ſimple earthy matter, that will neither melt in the Fire, nor run into Glaſs: But whether now you procure this from the Aſhes of burnt Plants or Animals, if you do but take care to ſeparate it perfectly from every thing elſe, it equally anſwers the end: Nor indeed in the Earth thus procur'd, does there ſeem to be the leaſt difference in any of its properties.

Their chemical Elements. Thus then I have explained to you the principles, which enter into the compoſition of the animal body; thoſe at leaſt which Art has been able to diſcover, and lay before us; nor has there hitherto been obſerved any greater variety.

'Tis idle, however, hence to imagine, that the moſt accurate mixture of theſe Elements together, after they have been nicely ſeparated, will ever produce the natural humours from whence they were extracted: On the contrary, the compoſition will moſt certainly be vaſtly different: For in every part of the animal Body, we find the humours of ſo ſingular a nature, that every one appears perfectly diſtinct from all the reſt. The particular ſeat, for inſtance, of the bitter Bile is in one place; that of the Hepatic in another; the Seed is formed and perfected in its own proper organs; whilſt another part gives being to the animal Spirits; the Chyle again of the Stomach, Inteſtines, Meſentery, Thoracic Duct, *Vena cava*, Heart, Lungs, and Arteries, is different in every one of theſe parts of the Body; not to mention the Milk, Fat, Lymph, *Serum*, Saliva, Blood, and Urine which are produced from it.

From what has been ſaid then, it plainly appears, that there is an extraordinary agreement between the Elements of Animals, and Plants, ſo that the former ſeem almoſt to be made up with the matter of the latter; and likewiſe, that the chief difference between them, conſiſts in the variety of their ſtructure, and the ſwifter circulation of the aliments through the Animal.

And thus much for the Objects of Chemiſtry.

Actions of Chemiſtry. Chemiſtry then is engaged in the examination of the Bodies comprehended in the three Claſſes we have hitherto treated of. Now the alteration that is induc'd upon theſe by this Art, is owing intirely to motion: And here either a new one muſt be produc'd; or elſe one that was in being before, muſt be deſtroy'd, chang'd in degree, or alter'd in directions. Theſe changes now happen ſometimes to the whole Maſs, its form remaining perfectly the ſame; and at others, to the particular Particles alſo, of which the Body is compounded. And on theſe very ſimple actions depend all the effects produc'd in the chemical Art; which, tho' they are ſo ſimple, yet from the vaſt number, and great variety of the conſtituent Particles of Bodies, they preſent us with an infinite number of new and ſurprizing appearances: Nor can we, upon the moſt ſtrict inquiry, diſcover any other cauſes of theſe alterations; nor indeed, is it poſſible to conceive, how the Art of Chemiſtry can effect any thing more. Let us conſider, for inſtance, one ſingle Body, and ſuppoſe both the whole Maſs to continue at reſt, and all the Particles of it one among another; will it not for ever continue the ſame without any alteration? Certainly, tho' all the powers of Chemiſtry ſhould be exerted upon it, yet if no motion is excited, either in the whole, or any of the parts, they would leave it perfectly the ſame as they found it: But again, let us imagine a motion to be impreſſed upon the Body, ſo as to move the whole Maſs, without inducing any alteration in its compounding Particles; why then too we ſhall have perfectly the ſame idea of the Body as we had before, except, that in every point of time it changes its ſituation: But now, ſhould the Particles of the Body themſelves be put into motion, then it's eaſy to conceive how an infinite variety of effects may be produc'd, which it is impoſſible for us to determine. The whole buſineſs of Chemiſtry therefore is to unite, or ſeparate; nor is there a third thing that it is capable of performing; and hence all its operations may be reduc'd hither, without exception. Nor let any one be offended at this ſimplicity, as if it was impoſſible, that from this alone, ſhould ariſe ſo great a number of very different and wonderful effects, which we obſerve no where elſe; for it is a known, and ſettled truth, that the ſimple mechanical union of different Bodies with one another, is capable of producing very ſurprizing varieties in the compound. The Arithmeticians too evidently demonſtrate, that from a few Elements, diſpos'd, and chang'd, according to the laws of combination, may be form'd an infinite ſeries of new Bodies. And laſtly, from the application of one Body to another, there often appears a new power, which before lay intirely concealed. If, for inſtance, no two Loadſtones had ever been brought ſo near together, as to be within the ſphere of each other's activity, we ſhould never have had a notion of any ſuch thing in nature as a magnetic Power: If again, no Iron had ever been ſeen in contact with the Magnet, certainly, the peculiar, and ſtupendous tendency that is obſerved betwixt theſe two Bodies towards one another, had never been diſcover'd: And laſtly, if Iron touch'd by the Loadſtone had never been applied to another piece of the ſame Metal, either touch'd, or not touch'd, what perſon living had ever been able to find out thoſe hidden vertues, which in this caſe are the cauſe of ſuch ſingular motions? But it will farther appear in the Hiſtory of *Menſtruums*, that a greater number of Bodies have this mutual tendency towards each other, which whilſt they are at a diſtance is not perceptible, but upon their near approach, diſcovers itſelf immediately. From what has been obſerv'd then, it evidently appears, that by the reſolution of compound Bodies into their Simples, and the compoſition of Simples with one another, may ariſe an infinite number of appearances, that we were not acquainted with before.

If a Body undergoes any alteration, but ſtill retains the ſame quantity of matter, then, the figure only will be changed, or the ſurface altered; but even this ſo ſimple a change preſently endues it with new powers. This we ſee plainly in the mechanical Art, which by changing the figure only can work the ſame piece of Steel into inſtruments of vaſtly different properties. Let an ounce of Steel, for inſtance, be nicely formed into a Wedge, Knife, Dagger, Lancet, Sphere, Cube, Cylinder, Priſm, Pyramid, and Cone; will it not then, under every one of theſe ſhapes, acquire new and peculiar powers? The power of Bodies from their change of figure alone.

On all theſe accounts, then, it is evident that the ſimplicity of the actions of the chemical Art, is no hindrance to their producing an infinite number of different effects.

And,

And, indeed, it is of ſome conſequence to conceive of this affair in a proper manner, as the Chemiſts are always prejudiced in an opinion, that their Art does really contain in it ſomething yet more myſterious: If you examine their performances, however, you will perceive the truth of what has been aſſerted. Certainly, Calcination, Fixation, Vitrification, Sublimation, Fermentation, Putrefaction, Digeſtion, Depuration, and Adunation, with whatever other Operations they reckon proper to their Art, may be reduced hither.

A chemical Analyſis does not exhibit the parts of Bodies as they exiſted in the Bodies themſelves.

We muſt not, however, pretend to affirm, that thoſe very parts, into which a Body may be ſeparated, did really exiſt in the Body, in the ſame manner as they appear to us after their ſeparation: For ſince the ſame powers that diſunite theſe Corpuſcles, may produce in them likewiſe a very great alteration, we ſhall often fall into an error if we ſuppoſe that the compound bodies in reality do contain theſe very Elements.

And, indeed, upon the reſolution of Bodies, there often ariſes in the parts of them new vertues, which never diſcovered themſelves by any effect in the bodies whilſt they were intire; of which there is an infinite number of examples.

From both theſe reaſons therefore it appears, that the Chemiſts are not altogether in the right, when they pretend to exhibit to us the firſt Elements of bodies, and think they can determine the nature of Compounds, from the knowledge they have of the Elements which by chemical Operations may be extracted from them.

Phyſical Atoms.

The examination of Bodies, it is true, informs us, that there are in nature certain Corpuſcles, which when perfectly ſeparated from all others, are not mutable by any cauſe we are hitherto acquainted with; whether it proceeds from their exceſſive, and more than adamantine hardneſs, which prevents any farther diviſion or change; or ariſes from their very great ſubtlety, by which they are capable of eluding the force of all natural Powers.

When the reſolution therefore of Bodies is carried ſo far as to reduce them to theſe fine Elements exceeding, there is a ſtop put intirely to any farther diviſion, till theſe again are either united with one another, or with ſome other compound Body.

Scarcely aſcertained by Chemiſtry.

Theſe principles the Philoſophers call, Elements of Bodies; and into theſe the Chemiſts have often aſſerted that they have reduced them; but they themſelves confute their own opinions. We can't, indeed, but allow them, that the Elements of Fire, Air, Water, Earth, Alcohol of Wine, Mercury, and the *Spiritus Rector* of every body, and ſome other things, do appear exceedingly, ſubtil, and durable, when they are abſolutely ſimple; but that theſe particles can ever be collected, and exhibited to us pure and without any mixture, no Art hitherto has been able to demonſtrate: And indeed, that there is nothing of this ſimplicity in the common chemical Operations, has long ago been paſt diſpute.

The productions of which are ſeldom ſimple.

Fire pehaps, and that only, whilſt it paſſes through Gold, or the like ſubſtances, may give us its Elements perfectly pure: But what perſon living can by any Art ever ſhow us one drop of pure ſimple Water? and this in the reſt is ſtill more difficult. There is no need to mention Air, Earth, and the others.

Nay farther, the parts into which the greateſt maſters pretend to have reſolved compound bodies, are not themſelves of a ſimple nature, but mutable, and capable of farther division. This the Water, Spirits, Salt, Oil, and Earth extracted from animal, or vegetable bodies plainly evinces, Nay Alcohol itself is separated in burning into different principles.

Nor will these again united produce the same compound.

And lastly, from a composition of the Elements, which the Art of Chemistry is capable of reducing bodies to, we can scarce ever again produce the original compound. This we have a proof of in the *Analysis* of Blood, Wine, and many other things.

The just Conclusion from a chemical Analysis.

It is necessary therefore to fix some sure limits to our Art, which we must not exceed if we would avoid mistakes, and come at the truth. It must be allowed indeed, that certain chemical Operations, do always produce in Animals, Vegetables, and Fossils, some determined effects, which by their proper marks may be easily distinguished; but whether the things they lay before us did really exist in the same manner in the bodies themselves before these Operations, we cannot always rightly determine, without borrowing arguments somewhere else. Alcohol of Wine, for instance, by the help of a proper fermentation and distillation, may be always procured from certain sorts of Vegetables, in the same manner, and perfectly of the same nature. Nor was it ever possible to draw this spirit from any other substance whatever; nor from this, but by means of this double Operation. This liquor therefore, that the Chemist exhibits to us, was never discovered in Vegetables, till they had undergone both a due fermentation, and distillation. Hence too, nobody, can give any tolerable account of its matter, cause, nature, and vertues, besides the Chemist. The same thing holds true likewise in a great many other instances. This Art therefore we circumscribe within a narrow compass; on this account we assert it to be more valuable, excellent, useful, and necessary; and 'tis under these limitations that we are ambitious of professing it.

The *Spiritus Rector* of the Alchemists in compound Bodies.

It appears then at length by the help of the chemical Art only, that there really is in every single Animal, and Vegetable, a kind of *Aura*, or Vapour, that is proper only to that particular body; and that this is of so subtil a nature, that it discovers itself only by its scent, taste, or some peculiar effects. This Spirit expresses the true genius of the Body in which it resides; and it is this chiefly that accurately distinguishes it from all others. The infinite fineness of this Vapour makes it invisible to the eye, though assisted by the most perfect glasses; nor can the most exquisite Art detain, and collect it by reason of its vast volatility: When it is pure therefore, and separated from every thing else, it grows impatient of rest, flies off, and mixes with the Air, and so returns to the grand Chaos of all volatile bodies. There, however, it still retains its own proper nature, and floats about till it descends again with Snow, Hail, Rain, or Dew: It then sinks down into the bosom of the Earth, impregnates it with its prolific seed, mixes with its fluids, and so at last unites itself again with the animal and vegetable Juices; and thus by this revolution returns into new bodies, in order to govern them and render them active. This Spirit, from its vast penetrability, exquisite subtlety, and prodigious volatility, the ancient Alchemists, who were certainly the top masters of the Art, and the most consummate Examiners of natural bodies, called the *Spiritus Rector*, or Governing Spirit.

An Oil the true seat of this Spirit.

Now that this Spirit should be confined, and remain in its proper body, the all wise Creator has united it with a tenacious, durable Oil, which neither, Air, Water, or natural heat can easily dissipate; that by this means, being intangled in its viscidity, it might not too readily fly off, and so leave the body it was designed to govern, and moderate. Hence the same famous Authors loudly assert, that this Spirit resides in a Sulphur.

On which account it is more volatile.

Again, the Oil that thus serves to hold down and secure this Spirit is found to be more volatile than any other of the oily substances in the same body: and it seems formed of such a nature, to the end, that it might almost spontaneously exhale with its Spirit, as the body tends towards its dissolution; lest the Spirit which is so vastly useful, should remain unactive in the body after death.

Of this Oil the Spirit is but an exceeding small particle.

And lastly, nature is so sparing in the distribution of this Spirit, that it allows to every Body but an exceeding small particle of it; which, however, is of so noble a nature, that it is abundantly sufficient. The antient Adepts have been bold enough to pretend to measure the quantity of this Spirit, and tell us that it is $\frac{1}{8200}$ part of its seminal Body; and that it is always found in this proportion in every seed in which it resides.

But prodigiously active.

They assure us farther too, that they have observed it to be vastly active, and have learned by repeated observations that if you cherish it with a pregnant warmth, and support it with proper nourishment, it will still increase in activity, and in a wonderful manner continually acquire new strength for the production of an Offspring like itself. Hence they stiled it the Vital Spark, the Son of the Sun, the Spirit that nourishes within, with many other appellations of the like nature.

This wonderful affair illustrated by an Example.

Now before I proceed any farther, give me leave to illustrate this whole affair by one single Example: To this purpose let us pitch upon a Vegetable, that evidently distinguishes itself from every thing else. Let it, for instance, be Cinnamon, that noble Aromatic, which is of so fragrant a smell, and so delightful a taste, far excelling almost all others, even the most precious. If you cautiously then, and according to Art, distill a pound of the choicest of this Spice with boiling Water, and take care that nothing of it be lost, it will yield you a milky Liquor of a fine smell and taste, and at the bottom of it, a small quantity of a red Oil, which is exceedingly fragrant, and possesses in a very great degree the true vertues of the Cinnamon; as indeed does this milky Liquor. If you then remove both these, and boil up the Cinnamon that remains with fresh Water, you will draw off a clear, watery Liquor, of an acid taste and faint smell, which is so far from containing any signs of Cinnamon, that it is so like many others, you won't be able to distinguish one from the other. Examine now the *Residuum* of the Decoction, and you will find it of a brownish red colour, an acid austere taste, without smell, or any thing that gives the least Indication of Cinnamon. The body of the Spice, indeed, that remains in the Decoction, you would swear to be Cinnamon, it represents it so exactly in its figure, and outward appearance; but upon farther examination, you will find that this is the whole it retains of this noble Bark, having lost all its former excellencies: And indeed, there is a little difference betwixt this, and any other Bark or Wood, that has been treated in the same manner.

The true peculiar vertue, therefore, of the Cinnamon is contained in the distilled Water, and the Oil that subsides to the bottom of it. If you let, now, this Water remain at rest for a good while in a close vessel, it will let fall an Oil, grow clearer, and become less aromatic: In the Oil therefore chiefly

resides

resides this choice noble vertue. But again, if you separate this water from the subsiding Oil whilst it yet remains strong of the Cinnamon, and put it into an open bottle with a small mouth, the whole place will smell strong of Cinnamon, and in a little time you will have the Water quite vapid, without any of the properties of the Spice; and yet you will find that it has lost no more of its weight, than common Water would have exhaled in the same time, in the same vessel, and in the same place: The fine vertue therefore of this Water is really lodged in an exceeding small quantity of it, which consequently, must be extremely efficacious. Lastly, if you expose the Oil abovementioned to the Air in a wide-mouth'd glass vessel, there will be diffused through the whole place a most fragrant, delightful smell of Cinnamon; but in the mean while the Oil will lose its peculiar vertue, and after a short time there will remain an Oil, almost of the same weight with the former, but perfectly exhausted and deprived of all its original qualities.

Hence then it is evident, that all the proper aromatic vertue of Cinnamon resides in a very small quantity of Oil; and that even of this, it constitutes but an infinitely small part. And this particular demonstration will almost universally hold good.

A *Spiritus Rector* in Metals and other Bodies.

The masters of this Science who have been most happy in their discoveries, tell us, that they have seen these Spirits even in Metals, and every kind of Fossil; that they are locked up in their proper Bodies, and confined there in their fixed Sulphur; and that whenever they can extricate themselves from their fetters, and become free, they then grow vastly active, insinuate themselves into other kind of Bodies, and are exceeding efficacious in the cure of diseases. But enough of this; if your curiosity about these things leads you any farther, consult the Adepts in these mysteries. For my own part, I don't choose to say any thing more upon this head, lest I should be suspected of recommending, and imposing on others, those things to which I myself am not equal.

The classes of chemical Productions.

The effects of this Art the Chemists have reduced principally to four *classes*; which are all produced either by adunation, or separation. When, for instance, they resolve a Body into any distinct parts which they collect and separate from it, they call this Operation extraction, and to those parts chiefly which are the most considerable they give the name of an *Extract:* Thus, when they draw from Wormwood the penetrating, bitter part only, they call it the Extract of Wormwood; as the most subtil part of Iron artificially separated from it goes always by the name of the Extract of Iron. Hither therefore are referred a great number of Operations, which may be performed on the same Body, as Distillation with Water, or without it; Decoction, and the inspissation of this Decoction through different degrees; Tinctures, let the *Menstruum* made use of be what it will; &c.

Extract.

Clyssus.

But when an Extract is drawn from several Bodies mixed together, in the same manner as the former was from a single one, it then changes its name for that of a *Clyssus*. And this appellation serves likewise for different Extracts prepared from the same Body, and afterwards mixt together; as when the Water, Spirit, Oil, Salt, and Tincture of Wormwood are artfully compounded into one mass, which possesses the united vertues of them all. Under this head therefore may be reduced a great number of beautiful productions of this Art; as the artificial Soaps, &c.

Magistery. A *Magistery* seems at first to have signified among the greatest Masters of Chemistry the most excellent production, or masterpiece of their Art: For they tell us, they can change any simple Body into a matter very different from the former, and that commonly a liquid one, without any alteration in its weight, or the least separation of its parts. Thus, for instance, they assert they can reduce an ounce of Gold into a fluid of the same weight without the least admixture of any thing else; just in the manner as we see it when put in fusion by Fire. This, certainly, were we Masters of it, would be a most noble Art; but it lies hitherto out of our reach, unless you will suppose, that the effects produced by Fire are something like it. This however we must allow, that wax brought once over the helm, undergoes a surprizing alteration without any separation of its parts.

Elixir. Lastly by the word *Elixir*, seems to have been meant the composition of different Bodies into one, so as perfectly to change their form, without making any alteration in their weight: And hence 'tis a kind of Magistery from several Bodies, as the former was from one. This *Paracelsus* asserts he has performed in Aloes, Saffron, and Myrrh, but conceals the only solvent which is able to effect this wonderful Operation; for which *Van Helmont* blames him, though he has not at all mended the matter himself. What reason is there however that we may not expect this from the chemical Art? Certainly, the preparation with tartarized Tartar, setting aside the skins of the Saffron, pretty nearly effects it: Nor do we make any doubt but that other Chemists are acquainted with better Solvents. It is certainly an argument of a weak mind to measure and limit other persons understanding by our own; though it must be confessed too, that the Artists by their too great pretensions very much lessen the opinion we should otherwise have of them.

I am well apprised that the terms abovementioned have been used in a different sense by very good Authors; but then, there are famous ones too, that have understood them in the manner, in which I have explained them. Let every one make choice of that, which pleases him best.

The service of the Art to Natural Philosophy.

The use of Chemistry in Physics; As it makes use of Fire, As Chemistry is engaged in the examination of all sensible Bodies, it is evident it must necessarily enter into, and be of use in all the branches of Natural Philosophy. And as Fire chiefly is the *Medium* by which it brings about the changes it produces in the Bodies that come under its management, in this very respect it must be of service to Physics, since Fire too, is the very instrument that Nature herself generally makes use of in the Operations it performs upon material Beings. As Natural Philosophy therefore is the knowledge of created Bodies with all their different modes of existence, it must certainly be promoted by the chemical Art. Give me leave to explain this a little more clearly. 'Tis the business of the Philosopher to deliver a true and accurate account of natural Bodies together with all their affections and properties. Now this knowledge cannot otherwise be obtained, than by carefully making observations upon all those Beings which the great Creator has formed within the compass of our senses. The first therefore, and indeed the principal part of this Science, consists in collecting together all those *Phænomena* of Bodies, which our senses are able to discover; and then reducing them into

And discovers that which we were not before acquainted with.

 a natural

a natural Hiſtory. Now there are two different ways of coming at theſe Obſervations: The firſt, when we regard the appearances of things only as they happen indifferently to all in the common courſe of nature without any deſign in the human mind towards their production; and this is not of ſo great ſervice to the Art, as in this caſe it is chance only that diſcovers to us certain properties, which happened to be produced at thoſe particular times: The other, when we deſignedly apply different Bodies to one another that we are well acquainted with, purely with a view to obſerve the new *Phænomena* that will ariſe from them. And this now, is of vaſtly more ſervice to the Philoſopher than the former: For, to mention no other reaſon, there are an infinite number of properties of Bodies, and thoſe too very efficacious ones, that could never been found out in the common order of nature, but then only diſcover themſelves, when the Artiſt with his Fire in particular, comes to examine them, either jointly or ſeparately, on purpoſe to know what will be the reſult. And, indeed, Chemiſtry is almoſt the only Art, that ſeems ſuited to cultivate this ſecond, and moſt valuable method of making phyſical Obſervations. 'Tis this that reſolves compound Bodies into their ſimple parts, and after it has carefully examined them combines them together again, in order to know, what new appearances, and powers, will thence ariſe: 'Tis this, that ſeparates, or compounds various Bodies, and then examines them nicely with a determinate, and well obſerved degree of Heat, in order to find out if poſſible, what it is in them that nature is chiefly engaged about: And laſtly, 'Tis Chemiſtry that by theſe means diſcovering how it may exactly imitate the natural and common *Phænomena* abovementioned, hence truly explains, and exhibits to us the inſtruments by which nature ſo efficaciouſly operates; and thus pries into her moſt ſecret methods of working, and very often prudently directs and improves them to its own advantage.

Not only taking notice of common Phænomena,

But making Experiments with views to new Diſcoveries;

And that more than any other Art.

A proof of this we have in Gunpowder, Phoſphorus, liquors that upon mixture raiſe violent Ebullitions, and break out into flames, and an infinite number of other inſtances. We muſt, indeed, acknowledge that perſons ſkilled in Mechanics, Hydroſtatics, and Hydraulics, from certain general and univerſal properties of Bodies, may moſt certainly explain a great many phyſical Actions: But ſtill, let them be ever ſo much maſters of theſe Sciences, they will never hence be able to diſcover thoſe effects of Bodies, which depend intirely upon the proper, and particular nature of ſome certain Bodies only, and which had never exiſted had it not been for thoſe peculiar vertues. Whenever, for inſtance, the Loadſtone, and Iron touched by the Loaſtone, come near one another, what ſwift, and ſurprizing motions are immediately produced, which are no where to be ſeen in nature beſides? Now that Chemiſtry is much more likely to help us to the knowledge of theſe particular qualities than any other Science is evident paſt all diſpute; as this Art is vaſtly the beſt ſuited to the diſpoſing of Bodies towards theſe kind of Diſcoveries. We may very juſtly therefore conclude, that of all Arts ours is the principal, and moſt efficacious in the promoting of natural Knowledge. A perſon that is maſter of this, will in reality make uſe of his Knowledge for the producing of its proper phyſical Effects, and not ſit down ſatisfied with ſubtle words, or idle ſpeculations. When the Chemiſt explains to you the nature of Glaſs, he at the ſame time teaches you the ſure way of making it. If he talks to you of Fermentation, he gives you an inſtance of it likewiſe to make it more evident. In ſhort he never pretends to any thing more, than what he is willing to let you ſee he is able to perform. He don't trouble his head with fruitleſs Inquiries into ultimate cauſes; the preſent cauſes of things are what he ſtudies, and what he teaches. He never invokes Demons, Hobgoblins, or Spirits, to his aſſiſtance; but performs all his Operations by the ſimple application of natural Bodies to one another. Nor does he concern himſelf at all about ſubſtantial forms; but, more to the purpoſe, takes pains to diſcover to us by their effects, thoſe peculiar qualities and powers which nature has implanted in every particular Body; and then informs us how we may make uſe of them for the performing many ſurprizing Operations. Nor will he ever when at a loſs, fly to, and take refuge in occult qualities; no, inſtead of that, by the help of his Art, he will ſearch out, and diſcover thoſe effects, which are falſly aſcribed to thoſe names, and then produce them into practice. The creation of the ſeeds of things, and the proper formation of every Body in its firſt original, he readily confeſſes he is not acquainted with; but takes a great deal of care to obſerve all the appearances that ariſe thence, and having faithfully collected them, makes a prudent uſe of them in the managing and changing of natural Bodies. Theſe happy fruits is Chemiſtry capable of producing for the ſervice of the Philoſopher; and this Art, was it properly cultivated, would lead us to that knowledge of natural things, which the famous Lord *Bacon* ſo much wiſhed for, and gave us a ſketch of, and which afterwards, upon the beautiful deſign of that great Maſter, was improved and carried on by the immortal *Robert Boyle.*

The uſe of Chemiſtry in Phyſic.

The great ſervice of Chemiſtry in the medicinal Art,

Now all that has been aſſerted of the uſefulneſs of Chemiſtry in natural Philoſophy, will hold equally true in the Art of Medicine: For this treats of the Human Body, and the powers, and effects of other Bodies upon it, neither of which can be thoroughly underſtood without the aſſiſtance of Chemiſtry. It will not however ſuit with our preſent deſign to enter into this affair too minutely, and therefore we ſhall only curſorily hint at ſome of its ſervices in this Science.

As it teaches us the nature of the Solids,

Chemiſtry, then, alone informs us, that the firſt Elements of which the ſolid parts of the Body are compounded, are a mere Earth firmly united together by an oily glutinous matter, which cannot be ſeparated from them but by the extreme force of an open Fire. 'Tis this teaches us too, that Water alſo inſinuating itſelf among theſe Elements, ſerves to bind them together, and being conſolidated and concreted with them will not be expelled without a great deal of difficulty. 'Tis this farther that firſt explained to us the origin of this Earth, Oil, Water, and all the humours of the animal Body, from the Aliments it receives, theſe being firſt carefully examined according to Art; of which without this aſſiſtance we

And Fluids.

ſhould have been intirely ignorant. And as for the parts, kinds, powers, and changes, obſerved in theſe humours, who can give any tolerable account of them without a thorough acquaintance with this Science? And laſtly, as there is a certain degree of Heat that conſtantly accompanies a perfect ſtate of health, which now a-days we are able to determine by the Thermometer; and as this when rightly diſcovered is the true meaſure of its active power: Chemiſtry far excels all other Sciences in explaining the proper effects of this Heat.

'Tis

'Tis true, indeed, that Mechanics, Hydroſtatics, Hydraulics, and the other parts of Natural Philoſophy, help us to the knowledge of a great many things that happen in the animal Body, whilſt it continues in a ſtate of health; but then, Chemiſtry leads us to a great many likewiſe, that we could not poſſibly have learn'd any where elſe: So that we are oblig'd to confeſs, that there are abundance of truths, and thoſe of the greateſt importance too, in the whole phyſiological branch of Medicine, that we could never come at, without the aſſiſtance of the chemical Art. But the greateſt glory of this valuable Art conſiſts in its being able to diſcover and correct thoſe errors, which ſome whimſical dablers in Chemiſtry had introduc'd into Medicine, as *Boyle*, *Bohn*, *Hoffman*, *Homberg*, and others, have by beautiful examples made appear. Thoſe vain, trifling Chemiſts, were certainly in the wrong, when they pretended by their Art alone to explain phyſiology in all its parts; nor however are they leſs miſtaken, who imagine they can do the ſame thing without it. No; let Anatomy faithfully deſcribe the parts, and ſtructure of the Body; let the Mechanic, by his particular ſcience, examine the Solids, whilſt Hydroſtatics helps us to the laws of Fluids in general; and the actions of them, as they move through given canals, are explained to us by that beauiful Science Hydraulics; and laſtly, let the Chemiſt add to all theſe, whatever his Art, when fairly and carefully apply'd, has been able to diſcover: And then, if I am not miſtaken, we ſhall have a complete account of the phyſiological part of Phyſic.

In which it alone makes the moſt uſeful diſcoveries,

And corrects its own errors.

Nor is Pathology, as I apprehend, leſs beholden to the chemical Art than the former. Would you underſtand the cauſes, modes, and effects of the degeneration of the humours in the animal Body? Would you know how the juices are vitiated, when they move too ſlowly, are perfectly at reſt in their veſſels, or run out of them, and ſtagnate in the cavities? Or would you form a juſt notion of the alterations, that the Oils, Salts, Spirits, and Earth, that are mixed with our Fluids undergo, when they circulate through the Arteries with too great rapidity? You muſt go to Chemiſtry, and that only, for your information. Here too you will plainly diſcover, what Acrimony there is in the Body, how many ſorts of it there are, whence it had its origin, and what are the effects of it after it is produced; which in vain you will ſeek for any where elſe. This will inform you farther, how the conſtituent parts of the Blood are compacted together, and by what means they are again reſolved. And laſtly, here you may learn the nature of *Pus*, *Ichor*, *Sanies*, virulent Fluids, and a putrid Gangrene, and what is the certain event of a *Sphacelus*. Now ſearch after theſe things in any other way, and I am certain, with your utmoſt endeavours, you will never be able to give any tolerable account of them: Nay, the very Diſeaſes of the Bones themſelves cannot be rightly underſtood, without calling to our aſſiſtance the labours of the Chemiſts.

Aſſiſts Pathology.

But ſome perſons will be ready to ſay, we allow you, indeed, that Chemiſtry may be of ſervice in the phyſiological, and pathological parts of Medicine; but as to that part which treats of the ſigns of Health, Sickneſs, and Life, this was cultivated ſo accurately by the ancient *Greeks*, that there can be no room left for its aſſiſtance here. To this we anſwer, It cannot be denied, but that they did take an infinite deal of pains in collecting together the Signs of Diſeaſes, and afterwards communicated them with as much integrity; but ſtill, all their labours were confined to the examination of thoſe things only, which

Of uſe in Semiotice.

which nature ſpontaneouſly offered to their obſervation. In this, we confeſs, they were ſurprizingly careful and accurate, even to that degree, that they ſcarce left any thing to be added by thoſe that came after them. All theſe things therefore muſt the Chemiſt borrow from them, and them only, before he pretends to make uſe of his Art for gaining a knowledge of Diſeaſes; and theſe he muſt gratefully acknowledge, as the effects intirely of their wiſdom. But then, if we would rightly underſtand what every individual ſign truly ſignifies, we ſhall be at a loſs without the aſſiſtance of our Art, which alone is able clearly to explain it. This I could particularly demonſtrate in every ſingle inſtance, would the nature of our preſent buſineſs admit of it. But to mention only a few. The Ancients knew, that the more frequent Pulſe of the Arteries, was a certain indication of a preſent Fever; and taught us, that the degree of it was to be meaſured by the number of ſtrokes within a given time: By this means they tell us, the native Heat is increaſed, the radical Moiſture deſtroy'd; and hence, according to the different degrees of it, Life itſelf is brought more or leſs in danger. The famous *Harvey* has farther inform'd us, that the quickneſs of the Pulſe is owing to the more frequent reception of the vital Blood from the Veins into the Heart, and expulſion of it thence into the Arteries: And here their obſervations reſted, nor ſerv'd us any farther. The Chemiſt, however, by the aſſiſtance of unexceptionable experiments, is ſtill able to proceed, and teaches us, that by this increaſe of Heat from the celerity of the Pulſe, the more fluid parts of the Humours muſt neceſſarily be diſſipated, and the remainder inſpiſſated; that the Oils will be diſſolv'd and mix'd with the Blood, and by the attrition they ſuffer in the courſe of circulation, will become acrid, volatile, and putrid, and in this condition, being ſtrongly preſs'd againſt the fine veſſels of the Brain, will of conſequence, wonderfully diſturb it, nor will be eaſily again diſengag'd from their union with Blood; that the Salts of the Humours will loſe their natural ineptitude to motion, and become almoſt volatile; from an innocent, mild, diſpoſition, will grow vaſtly acrimonious; and change their ſoft ſaponacious quality into a fiery, corroſive one, and become, as ſome have aſſerted, a perfect Alcali. By this means, therefore, the Chemiſt comes to a right underſtanding of this Sign; and at the ſame time explains to us the uſe of it. With regard to the Urine, the Ancient Phyſicians were very careful in inſpecting it, in order to diſcover, if poſſible, the internal diſpoſition of the Body, and the more occult Symptoms of Diſeaſes; and the Moderns are obliged to do the ſame: But of what ſervice has this been to Phyſic? certainly of very little, as the judgment form'd from thence is very precarious: But let now a Phyſician, that is verſed in Chemiſtry, examine it according to the rules of that Art, and how many, and how uſeful will be his diſcoveries? The quantity, colour, taſte, contents, whether ſwimming at top, the middle, or ſubſiding to the bottom, and the ſpume, will make appear the true diſpoſition of the Water, Salt, Oil, and Earth in the Urine, and conſequently in the Blood at that time; and hence they diſcover to us the intimate diſorders of the Humours, which are otherwiſe out of our reach, and ſerve as Prognoſtics, to point out to us the good or bad event, that in a ſhort time is likely to follow. Here therefore, and here only can the Phyſician truly learn, both how to manage the preſent Symptoms, and foreſee and provide againſt future events, in ſuch a manner, that nature may be ſupported, and not left to ſink under them.

them. 'Tis the Chemiſt, farther, that is alone capable of accurately diſtinguiſhing by their Signs, the true nature of ſweat, *pus*, *ichor*, the *ſputa*, and the excrements diſcharg'd by ſtool: Not that he is able to perform all this by the aſſiſtance of his own Art alone; but when to this he likewiſe joins a competent knowledge of Medicine, then it is he becomes truly qualified to diſcover, by the help of them both together, a great many things, which, otherwiſe, muſt certainly have eſcaped our obſervation. And it were much to be wiſhed, that thoſe Gentlemen of the faculty, who are ſuch enemies to the Chemiſts, would conſider this affair in a proper light; and then they would not ſo raſhly condemn an Art, whoſe aſſiſtance may be of ſervice to Medicine, but cannot poſſibly do it any prejudice. We confeſs, indeed, that ſome of the chemical Profeſſion have done a great deal of miſchief, by boldly venturing upon the practice of Phyſic, without ſufficiently underſtanding it; but then, this was the fault of the Men, and not of the Science.

Nor leſs in Diætetics.

Again, its impoſſible for any perſon rightly to determine the diet that's proper for people in health, unleſs he knows what kind of corruption our meat and drink will naturally undergo, from the peculiar temperament of the Body that receives them, or the particular degree of exerciſe to which it is accuſtomed. In running-footmen, huſbandmen, and all perſons uſed to hard labour, fiſh, and freſh meats, putrify immediately from the violent motion of their Bodies, if they are not eat with a good deal of Salt: For ſuch therefore, brown Bread inclining to be ſoweriſh, Corn food, Milk, and Fiſh or Fleſh dried in the Air or Smoke, and well ſeaſoned with Salt, or Vinegar, is the beſt food; as Water, or ſtale ſmall Beer, is the moſt proper drink: For ſince, by this exceſſive motion, the Bile, and the whole maſs of Blood, neceſſarily tend towards putrefaction, this muſt be guarded againſt by thoſe foods, which by their acidity, ſaltneſs, or firmneſs, are leaſt diſpoſed to this kind of corruption. On the contrary, your pale ſtudious perſons, who ſit long at their books, and deny themſelves proper exerciſe, ſhould eat only thoſe meats that are eaſiſt of digeſtion, and are ſooneſt converted into the proper nature of the animal Humours: For theſe therefore, as Chemiſtry teaches us, the ſofter kinds of freſh meat, fiſh, and eggs, with a little ſalt, are the moſt convenient. And in ſhort, if there's any Science that truly explains the nature of our Meat, and Drink, their Matter, and the method of pickling and preparing them; Motion, Sleep, the Excretions; and thoſe paſſions of the Mind, that are of ſervice towards the preſervation of Health; it is, beyond all contradiction, that of Chemiſtry.

But principally in Therapeutics.

If we conſider, laſtly, the Therapeutick part of Medicine, we ſhall find, that the chemical Art is here of vaſt ſervice alſo: For where ſhall we procure a ſuitable diet for our patients? Where ſhall we find Medicines proper for ſupporting of life, or recovering of health? Or where ſhall we be furniſh'd with thoſe Remedies that are capable of correcting things foreign, and hurtful in the Body, or expelling them out of it; or that will ſoften and ſooth whatever is ſo ſharp or ſtimulating? I ſay, how ſhall we come at all theſe, except by ſuitable helps, which Chemiſtry chiefly explains; which that alone digeſts in order, and beſt adapts to their proper uſes? And indeed, it would be nothing abſurd, ſhould I aſſert, that it is this Art that moſt accurately points out to us thoſe methods, by which we may learn from the Symptons of the ſick, whether, in what manner, and by what methods, we ought to act, in order to ſecure and

and establish the life of the patient, and to correct or remove both the cause of the Disease, and the Disease itself. And here give me leave to recommend to your reading those things I formerly wrote, *de Methodo Medendi*, for the use of young Physicians.

Now the truth of what has been asserted, is confirmed by the authority of the great Lord *Verulam*, who by experiments, being thoroughly convinced of it, every where strenuously recommends the chemical Art, as proper for the fully completeing every branch of Medicine. I might mention too the illustrious *Boyle*, who in his elaborate pieces, The *Sceptical Chemist*, which he himself inlarg'd and illustrated, *Of the uncertain success of Experiments*, *Of specific Remedies*, *Of the history of human Blood*, *Of the usefulness of experimental Philosophy*, *Of the mechanical production of Qualities*, and a great many other Tracts, has evidently demonstrated the use of Chemistry, in every part of Physic. It is needless sure, after these two, to mention any body else: However, for your farther satisfaction, you may consult the *Philosophical Transactions* of the *English*, and the *Memoirs de l'Acad. roy des Sc.* of the *French*; and there you will see how industriously this Art has been cultivated for the improvement of the knowledge of Medicine. But the *Ephemerides* of the *Germans* are particularly stor'd with elegant arguments to the same purpose. It is, however, our great misfortune, that the most expert and learned Physicians, have very seldom been thoroughly acquainted with Chemistry; as on the other hand, the greatest masters of Chemistry have hardly ever had a true notion of Physic, to the great detriment of both these noble Arts. *John Bohn*, and *Frediric Hoffman*, indeed, excell in both; and by this means distinguish themselves above all the rest, and deserve the highest praises. I don't mention with these *Otto Tachenius*, and *Francis de le Boe Sylvius*; because out of an excessive, and rash fondness for the chemical Art, they would not allow it to be the servant of Medicine; but judging more from their own inclination, than the nature of the thing, would have it her mistress. Whatever I have been able to collect from this Art, that may be safely, and usefully applied to Physic, you have, in a little Treatise I wrote *De cognoscendis & curandis Morbis*, and in my *Materia Medica*, which I published afterwards.

Usefulness of Chemistry in the Mechanic Arts.

Chemistry of service to Mechanics.

By which are commonly understood those Arts, that are cultivated and performed by manual operation, and which are perfectly different from that mechanical Science that is the business of the Geometrician, which explains the powers of Bodies, from the properties that belong to Bodies in general. To this latter, Chemistry is of no manner of service; but the former, which consist in the managing, and changing of Bodies, are very much promoted by it.

To Painting.

The Art of Painting, which by Colours can, to the life, truly express all visible objects, and hence is able to represent the most beautiful parts of the creation, and transmit them down to posterity, is of so fine and noble a nature, that it has always been honoured with the regard, and esteem of Princes. Consult on this head *Junius*, in that vastly laborious work, *De Pictura Veterum*. Now this, tho' it receives the assistance of a great many other Arts, yet in that part, which consists in the preparation of beautiful, and durable Colours, Chemistry very far excells them all: A few examples of this will be sufficient. The Pigment, called the *Ultramarine*, which is of so charming a blue, and infinitely lasting,

lasting, is prepared from the *Lapis Lazuli*, intirely by the help of Chemistry. The common Blue Smalt likewise, is a beautiful production of the same Art. See *Antonius Neri.* L. VII. 115. and Dr. *Merret*'s Notes upon the same. What is it that the greatest masters of Painting are fonder of, than a fine durable Green? Why the lovely Ultra-marine Blue, mixt with a holding Yellow, will give you one that will retain its beauty for many ages. Was it not therefore for Chemistry, Painting would intirely want these two delightful Colours.

What shall we say of those Colours, called *Laccæ*, which are chemically prepared by coction, and precipitation? Do not these, by their brightness and clearness, give Pictures a vast deal of lustre and beauty? But for these, we are intirely indebted to Chemistry, as you may see in the same *Neri* L. VII. 116. 120.

Not to mention Cinnabar, Orpiment, Ochre, or that Preparation of Bones that the Painters make use of, which is made by calcining them in a close vessel to an intense Blackness. It appears therefore evident, that tho' the Arts of Chemistry, and Painting, are in their nature perfectly different, yet this, without the assistance of the former, would want its greatest ornaments: Nor indeed, could the Painter well do without it; tho' the Chemist stands in no manner of need of the Art of Painting.

The industry of the Chemists has discover'd an invention, by which they are able to incrustate Metals, Gold in particular, with most pleasant, beautiful Pigments, which shine like Glass, and are composed chiefly of a metalline or glassy Matter, and a most penetrating fix'd alcaline Salt. These, they call *Emausta*, *Amausa*, *Esmaillades*, *Smalta*, Enamels; which by the brightness, and elegant variety of their Colours, are vastly agreeable; nor will any length of time destroy them. Consult again the famous *Neri* in all his *sixth Book*, and you'll think your time very well employ'd; but more particularly *Isaac Hollandus*, who has treated so largely and finely of this noble Art, which vies with the most magnificent tesselated works of antiquity. It is certain, the fair Sex are indebted to it for most of their valuable ornaments. In Enamelling.

There is yet a third sort of Painting, *viz.* that upon Glass, which is exceeding beautiful, representing its figures in Colours that are wonderfully strong, and at the same time transparent. A noble instance of this surprizing Art, we have in the Windows of a Church at *Tergou*, in our Province of *Holland*, which now-a-days can hardly be imitated. For formerly they were masters of a particular method, by which, after they had laid their Pigments on the Glass, they could, by the assistance of Fire, vastly heighten their Colours, and dispose them to a perfect transparency, and at the same time make them penetrate into the very substance of the Glass, without running beyond their proper lines, or confounding themselves in the least with one another. And indeed, I don't see that any thing can possibly be invented more curious, and ornamental, for the decorations of Courts, and Churches. We have not, however, a great deal of reason to hope, that this Art will ever be again retriev'd, unless the Chemists will diligently employ all the productions of their Art, in order to discover it. In staining of Glass.

Akin to Painting, is the Art of Dying, which consists chiefly in tinging Silk, Cotton, Flax, and Wool, with beautiful Colours, and so furnishes us with curious Garments, Tapestry, Banners, *&c.* Now this Art depends principally In Dying.

cipally upon three things. First, the materials to be dy'd must be perfectly clean'd, that they may easily suck in, and retain the Dye; which is done by soaking, beating, and scouring them with various *Lixiviums*. And here, putrified human Urine, the acrimonious Salt of Ashes, divers sorts of Soaps, and the Gaul of Animals, are of principal service. By these the viscous kind of Glue of the Silk-worms, that firmly adheres to the threads of the silk, which are always double, is diluted and wash'd off, by which means they become pure, and fit to receive their Colours; and by these the fetid oily impurities of the Wool, and the tenacious greasy matter, which has long been concreted with the Flax, is intirely discharged. Now in the choosing, preparing, and applying all these materials, the knowledge of the skilful Chemist is of a vast deal of service, so that he is continually improving them by the discovery of something new, and useful. The second thing requisite in Dying, is a proper preparation of the Dye, that it may perfectly penetrate into the substance of the thing to be dy'd, and then may retain its beauty without any alteration. *Cornelius Drebbelius* of *Alcmar*, in our Province, a man of remarkable integrity, and so perfectly skill'd in the most profound parts of Chemistry, that he was rank'd amongst the Adeps, and was in great esteem with one of the Kings of *England*, besides other things, left behind in writing, a particular method of dying Wool of a bright flame Colour; by which secret, *Kustelaer*, his Son-in-law, afterwards got a great deal of money. The rich Colour of Cochineal may be heighten'd by Spirit of Nitre, till it is perfectly bright as Fire; but then, by its Acrimony, it too much corrodes the Wool; you may soften it, however, by the assistance of Tin, and then you have a Dye that is no ways injurious either to Silk or Wool, whose beauty is exceedingly durable. The third thing necessary in Dying is fine Colours; and those our Art is capable of procuring. I remember, as I was formerly shewing a famous Dyer some liquors prepared from a solution of Copper, he seem'd surpriz'd at the elegance of the appearance, and declared he would give any thing for those Colours, were it possible to make Cloth take them in their proper strength and brightness. And no wonder; for in the Azure, Violet, and Green, Colours from Copper, which at the Will of the Artist are in a moment made fuller, or paler, there is such a vast deal of beauty and variety, that any person, who had the Art of Dying Wool, Silk, Linnen, and Cotton, with these Colours, in such a manner as to make them hold and not fly off, might certainly get an immense sum of money. It is therefore past all dispute, that the knowledge of Chemistry would be of great service to the Dyer, since by the help of it, he might be continually improving his Art by new and beautiful discoveries.

In making Glass.

But if there's any Art that is greatly beneficial to mankind, it is certainly that of making Glass. 'Tis this, that by the Polisher's assistance, so comfortably helps the defects of our Eyes, and lengthens out our pleasure of reading, even to great old age. 'Tis by this alone that we are secured from scorching Heat, and piercing Cold, kept free from Dust, and preserved from the inconveniency of the Wind, in our Houses, Coaches, and Ships; and at the same time have light enough perfectly to distinguish the Objects about us. Pure Glass does not easily stain, and when it is, may be clean'd again with all the ease imaginable. This exposes to our view the things it incloses, and keeps them for ages; nor makes any alteration in them, or rarely suffers any from them.

And indeed, whatever is preserved in a Glass vessel, that is perfectly closed, and intire on every part, becomes immutable, and incorruptible. Glass eludes the power of all corrosives, even the *Alcahest* itself, if there ever was any such thing, which it is said it is able to confine, whether it boils in it, or agitated by the Fire flies about in it; whereas the *Alcahest* dissolves every thing else into a pure Water. Glass is the principal instrument in the Art of Chemistry; is of a very ancient invention; was cultivated chiefly among the *Egyptians*; in the time of *Tiberius* was rendered malleable; and is at present, and has for some ages past, been made in the greatest perfection among the *Venetians* and *English*. And certainly, was it not for its great abundance, it would be more valuable than any kind of Metal. Now the choice of the Materials for this noble work, the artful preparation of them, and the proper mixing, melting, and bringing them to their greatest purity, depend so much upon Chemistry, that they really receive no assistance any where else, but hence are capable of daily improvement. From Flint, Sand, and Stones, are made the various kinds of Glass; and the different methods made use of in the burning, and calcining them, in order to reduce them to a *Calx*, make a vast deal of difference in their beauty. The diversity of the Ashes too, as they are procured from Plants of various kinds, will make a considerable alteration in its goodness. That made from a pure, acrid, fixt alcaline Salt, melted with the best sort of *Calx* of Flint-stones, is of all the finest and most perfect. And here, the more there is of the Salt, and the less of the Flint, the more fine and perfectly transparent will the Glass be: But then its charms are not of long continuance, as it is very ready to crack and flaw, either by Fire, or Water, by which means it loses both its beauty and transparency: It is apt too to damage things that are put in it, and very often quite spoils them; as Tea, which in a green Glass suffers no manner of alteration, in the most beautiful sort loses all its vertue. For our business therefore we always choose the green Glass, which is most durable, and is composed of a larger proportion of Sand, and a lesser of Salt, kept melted for a considerable time in a strong Fire. But these hints are sufficient; as you may consult upon this head, the valuable *Antonius Neri* of *Florence*, in his Book *De Arte Vitriaria*; the famous *George Agricola*, in his seventh Book of Fossils; that celebrated *Englishman*, Dr. *Christopher Merret*, in his observations and Notes upon *Neri*; and *John Kunkel*, who, at the vast expence of that truly generous Prince, the Duke of *Brandenburg*, brought this Art almost to its greatest degree of perfection; as appears by his commentary upon *Neri*, which he publish'd at *Leipsic* in 4to, in the year 1679; but more especially in the Tract *De Gemmis Artificialibus*, which is annexed to it.

There is another kind of Glass, that is transparent likewise, but at the same time so inriched with some beautiful Colour, that it almost vies with the brightest natural Gems. This noble invention now owes its origin to the chemical Art, and truly imitates nature, by intimately mixing the infinitely divided particles of Metals with the purest, and most perfect Glass; and by this means, giving it a lasting beauty. So that, in reality, there are scarce any stones, valuable on account of their Colour, whose agreeable appearance this Glass cannot be made to resemble. And indeed, should ever any person happily improve the Art of Glass to that degree, as to be able to increase its weight by Fire in a sesquialter proportion, we may then, by the assistance of Metals, make

In making artificial Gems.

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artificial Gems of the ſame brightneſs, with thoſe that are the true production of nature; for the more denſe and ſolid the pellucid matter is, the ſtronger will the colour of the Metal appear, that is diſperſed through it: But as this condenſation of Glaſs has hitherto been beyond the reach of Art, the ſubſtance of the artificial Gems is leſs denſe than that of the natural ones; and conſequently the vibrations of the rays of light are more weak and languid, and want that vividneſs that is peculiar to the other. Some have, indeed, attempted to increaſe its weight by a mixture of Lead; but then, it grows too ſoft. It is well worth while therefore, for the lovers of Chemiſtry, to employ their utmoſt endeavours for finding out a method of condenſing of Glaſs; for it certainly will abundantly recompenſe all their labours. There is yet a ſecond thing requiſite to the perfection of artificial Gems, and that is, the giving Glaſs ſuch a degree of hardneſs, that it may not by wearing, loſe the luſtre of its poliſh, but retain its beauty, and put on the incorruptible nature of a natural Unit. And laſtly, when we have communicated to it a proper ſolidity, and hardneſs, we muſt afterwards colour it with ſome rich metalline Tinctures; and then, we might by Fire form the Maſs thus prepared into multangular Bodies, that would excell the natural Gems, both in magnitude, and variety. For we have an incredible number of the choiceſt colours, that might be either intimately mix'd with the Glaſs when 'tis in fuſion; or be diſpoſed upon its ſurface, and by the aſſiſtance of Fire, be made to penetrate into its ſubſtance, if that ancient Art ſhould again be reſtored. Now it is Chemiſtry alone that furniſhes us with theſe three principles, on which the artificial way of making Gems intirely depends, and gives us frequent opportunities of improving this beautiful Art.

As the greateſt maſters, however, in the chemical Art, have never been able to give artificial Glaſs a requiſite weight, and hardneſs, ſome of the ſubtleſt of them took it into their heads, that the moſt clear and perfectly pellucid foſſil Chryſtal, might poſſibly anſwer the ſame purpoſe; for this being naturally very heavy, and hard enough to cut Glaſs, wants only colouring with ſome metalline Tincture, without deſtroying its tranſparency, or the beauty of its poliſh, to make it nearly reſemble natural Gems. This therefore they attempted by heating the Chryſtal red hot, and then extinguiſhing it in colour'd Liquors; but the flaws that were occaſion'd in this operation diſappointed their expectation, which would otherwiſe in ſome meaſure have been anſwered. See *Boyle of Gems*, p. 19. 44. Others have endeavour'd the ſame thing, by cementing Chryſtals with different kinds of Metals, and not without ſucceſs; for the Metal being afterwards melted, and forc'd up by Fire, penetrated intimately into their ſubſtance. And it is poſſible, that ſome time or other, there may be diſcover'd ſome artificial Pigment rich with a metalline Colour, which being incruſtated over Chryſtal, may by Fire, be perfectly diffuſed through its whole Maſs, and give it a moſt beautiful brightneſs. Now theſe methods, which ſeem the moſt likely to produce ſomething conſiderable in this elegant Art, depend ſo intirely upon Chemiſtry, that there is not the leaſt reaſon to expect any aſſiſtance in this affair from any other Science.

In Metallurgy.

As for the Art of Metals, the knowledge of Chemiſtry is ſo neceſſary to this, that it ſeems to claim it wholly to itſelf. I don't mean here that Art, which conſiſts in the boaſted production, and tranſmutation of Metals; of this

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I ſhall honeſtly relate thoſe few things, I have, upon mature deliberation, been able to diſcover, when I come to diſcourſe of the uſefulneſs of the chemical Art in Alchemy. In this place I would be underſtood to treat purely of that Art, which teaches us how to prepare Metals for the ornaments and uſes of life. Gold, for inſtance, is frequently of a pale colour, and that from a great many cauſes; now this the Chemiſt, by a cement, or *Regulus* of Antimony, can heighten in the Fire to a moſt beautiful yellow. This we ſee at preſent in the gold coin of *Holland*, which far excels all other in its particular luſtre; for which, we are beholden to the curious and peculiar ſkill of the maſter of the Mint. The ſame Metal, when it is perfectly pure, is from its natural ſoftneſs unfit for coining; but tempered with a proper alloy of Copper chiefly, or Silver, it excellently anſwers that valuable purpoſe. Silver, in like manner, is too ſoft, and ductile, either for coin, or the common uſes of life; but is eaſily rendered fit for both by a due admixture of Copper. 'Tis needleſs to mention Braſs, which is a compoſition of Copper and *Lapis Calaminaris*, and much reſembles Gold in the brightneſs of its colour; or that Metal made of Copper and Zincq, called Prince *Robert's* Metal, which being nicely gilt vies in luſtre with the moſt beautiful *Obrizum* Gold. As for the Art of Gilding the baſer Metals with Silver, or Gold, how curious is that Art, and how valuable? Theſe now are all inſtances of the ſervice of Chemiſtry in the metallic Art; and though they are few indeed, yet they ſufficiently demonſtrate what an infinite number of effects might be produced, would the ſkilful Chemiſt make a proper uſe of his Art in the various compoſitions of Metals. Nor even in this affair don't Medicine receive ſome advantage; witneſs the cups made of *Regulus* of Antimony tempered with other Metals, which communicate a medicinal quality to the Wine that is put in them. And it is ten thouſand pities the famous *Van Helmont* ſhould have been ſo unkind to his poor fellow creatures in diſtreſs, as to conceal from us the Art of making a particular Metal, which he tells us made into rings, and worn only whilſt one might ſay the Lord's Prayer, would remove the moſt exquiſite hæmorrhoidal pains, both internal and external, quiet the moſt violent hyſteric diſorders, and give eaſe in the ſevereſt Spaſms of the Muſcles. p. 745. § 39. 'Tis right, therefore, I think, to proſecute Inquiries of this nature; for there is very frequently ſome hidden vertues in theſe Compoſitions; and we may make a vaſt many Experiments of this kind without any danger or inconvenience. Metallurgy again, that conſiſts in the knowing and diſtinguiſhing the foſſil glebes as they are found in their ſubterraneous veins, and thence producing pure and perfectly diſtinct Metals, depends intirely upon our Art. This is plain, even from this conſideration, that Chemiſtry owed its origin principally to Metallurgy; and this, by modern inventions, it now again vaſtly aſſiſts and improves. But we need not ſtay much upon this Head, if you will carefully conſult *George Agricola*, *Lazarus Erkerus*, *John Rudolphus*, *Glauber*, and others, who have for the moſt part borrowed what they have, from theſe. For your greater ſatisfaction, however, I will give you three or four Examples. It is a known thing among the Chemiſts, that it is very eaſy to prepare a matter, which being mixt with Gold, Silver, and other Metals will render them ſo volatile, that they may in a glaſs veſſel be brought over the helm with a moderate heat. And experience as certainly evinces, that there is very often in the native Glebes that contain the richest Metals a certain substance, which, when the fossil is exposed to the management of the Fire, carries off a great deal of the Metal with it, to the prodigious loss of the Owners. There is, for instance, a volatile, noxious Sulphur very often united with Gold aud Silver, which disperses vast quantities of these Metals into the Air whilst they are only torrified by the Fire. But the industry of the Chemists has discovered certain methods, by which they can at once render these volatile Glebes so fixt, that they will bear fusing in the strongest Fire; and by this means the Metals will be separated from every thing else. You know that *Regulus* of Antimony, mixt with a double quantity of the corrosive Sublimate of Mercury, will by a gentle Fire be changed into a fat substance that is extremely volatile; and that this by a moderate degree of heat will rise in deadly Vapours, and by the repeated action of the Fire become at last a limpid Oil that fumes spontaneously. This, I remember, I have frequently both explained to you, and demonstrated before you. Pour, now, upon this Oil an equal quantity of pure Water, and it will presently in a surprizing manner turn of a white colour, and precipitate a white metallic *Calx* of Antimony, which is so capable of bearing the Fire, that it may be intirely melted into a mass like Silver, and is the finest *Regulus* of Antimony that Art can produce. Let us therefore, from this simple Experiment, learn to mix Water with the volatile Glebes, and obeserve whether by this manner of treating them, they won't yield a greater quantity of the richer Metals than they did before. Iron likewise being added to these Pores in their calcination, oftentimes so absorbs the Sulphur, that it cannot carry off the metalline Particles along with it. And the fixt alcaline Salts too have saved a great deal of treasure by subduing and resolving the Sulphurs, or Acids, which being dispersed through the metallic substance made it volatile in the Fire. The richest Silver Mines of *Peru* are unfortunately infested with a pinguious matter, which makes the Glebe of a volatile nature when it comes to the Fire, by which means there was formerly an incredible quantity of Silver intirely lost. But the Chemists have now instructed us, first, to torrify the Ore with a gentle Fire, then, to reduce it into powder and rub it with Mercury, afterwards to wash it in a proper manner with water, and lastly to collect the Silver together into one mass, by putting the matter thus prepared into a Retort, and forcing out the mercurial Particles with which it was united; and since this has been practised there has been scarcely a grain lost; by which means there is an infinite deal of wealth preserved, which would otherwise have been dissipated into the Air. The difficulty of perfectly separating Silver from the Tin that is found mixt with it, used to be a matter of great concern, both to the Miners, and the persons employed in the docimastic Art: But since we have learned from the Chemists that by the admixture of melted Copper the Tin may be easily disingaged, and carried off, we can collect the Silver pure from the ashes with a great deal of ease, and little expence. There are a thousand other advantages for which Metallurgy is indebted to the Art of Chemistry; but you don't expect that I should be more particular upon this subject; nor indeed will our present business permit it.

In the Art of War.

Again, the chemical Art alone furnishes us with a great number of instruments of War, that were intirely unknown to the ancients, and which, indeed, are so destructive to the moderns, that we should have been happier without their discovery. But

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as the evil and reſtleſs ſpirits of ſome part of mankind are perpetually the occaſion of War, and violence; hence 'tis abſolutely neceſſary that we ſhould be able to repel force by force, in order to defend and ſecure ourſelves; and in this, money excepted, the whole ſtreſs lies at preſent upon the Inventions of Chemiſtry. In the twelfth century Gunpowder was found out by *Roger Bacon* in *England*; and with this he imitated Thunder and Lightning, but to the happineſs of that age did not employ this wonderful diſcovery for the deſtruction of his fellow creatures. About two hundred years after, *Bartholdus Schwartz* of *Germany*, a Monk and Chemiſt, accidentally obſerving the ſudden expanſive power of this powder, whilſt he was preparing it for medicinal uſes, immediately made a trial of its ſurprizing force in an iron Tube, and ſoon applied it to the Art of War, and taught it the *Venetians*. And indeed the whole force of War now a-days conſiſts ſo much in this chemical Invention, that by the help of this the weakeſt boy may overcome the moſt valiant hero; nor is there any thing, be it ever ſo ſtrong, that is able to ſtand againſt its ſtupendous power. The great *Coehorn*, therefore, General of the *Dutch* forces, wiſely conſidering the efficacy of this chemical Diſcovery, immediately changed the whole Art of War, and all the methods of defence; ſo that thoſe fortifications which were formerly looked upon as impregnable, are now not able to ſecure the perſons that defend them, or preſerve them from danger even within their own walls. And indeed the power of this wonderful Powder, is yet more and more to be dreaded. As for that Powder which is compounded of Sulphur, Nitre, and the burnt *Fæces* of Wine, the force of it is ſo prodigious, I can ſcarce mention it without ſhuddering. Who can think of the violent exploſive faculty of *Aurum Fulminans*, and not be aſtoniſhed? When we mix the chemical Oils of the moſt fragrant Aromatics, with a liquor extracted from Salt of Nitre, we produce ſomething vaſtly more powerful than Gunpowder itſelf, which ſpontaneouſly, without the application of Fire, rages in a moſt furious manner. And laſtly, which it gives me pain to mention, let me here put you in mind of that melancholy accident, which happened in *Germany* from ſome *Balſamum Sulphuris terebinthinatum*, which being unfortunately quite ſtopped up in a Bolthead, the glaſs burſt by the heat of the Fire with a prodigious exploſion, far ſuperiour to any of the former. Heaven grant that the noble Inventions of this valuable Science may be no farther improved by the craftineſs of mankind to the deſtruction of one another; the fear of which obliges me to conceal many things, I could otherwiſe mention, that are ſtill much more pernicious, and deteſtable.

In natural Magic.

That the ancient *Magi* of *Aſia* were men of ſuperiour wiſdom, I think is ſufficiently agreed by the learned world. And that this name has not always ſignified evil Agents, Contrivers of miſchief, and Slaves of the Devil, is evident from the Μάγοι ἀπὸ ἀνατολῶν, mentioned by St. *Matthew*, who were famous for their knowledge of the Stars, and ſincerely worſhipped the true God, by whom they were accepted. That they were in great eſteem too with the Princes of that country, in ancient times, and conſulted in their moſt weighty affairs, we have related in abundance of places of Hiſtory. And we find that *Zoroaſtres* himſelf, the King of the *Bactrii*, who was the founder of this ſect, is chiefly extolled for his knowledge of the heavenly bodies, whoſe motions, and the principles of the world, he is ſaid to have ſtudied with a great deal of application. *Juſtin*. l. 1. For this reaſon therefore, as *Cicero* tells us, the *Perſian* Kings were instructed in the Art of Magic, before they were admitted to the government. *De Divinat.* I. 91. And he likewise assures us, that the *Magi* in *Persia* were looked upon as persons of great wisdom, and learning. *De Divinat.* I. 47. It happened afterwards that an illiterate set of men, greedy of fame and riches, endeavoured by their deceitful cunning, and jugling tricks, to imitate the profound knowledge of these Wise Men; but their frauds being often openly detected, the Magic Art came to be basely exploded; which has frequently too, though undeservedly, been the fate of Mathematics. The employment of the true *Magi* was to search carefully, and curiously into nature; by which means they often discovered things that were concealed from the observation of others, and which the all-wise Being designed as the proper rewards of laborious study and application. Hence the ignorant regarded them as men endued with more than human knowledge, which they imagined therefore they received by the intercourse and instructions of Dæmons, and for that reason paid them great reverence, tho' more out of fear than any real respect. And this they were the more naturally led into, as it has been a prevailing opinion of all ages, that there are two kinds of Spirits, the one good, the other evil; and that these being perfectly skilled in natural knowledge, and moved the one with love, the other with enmity to mankind, endeavour by their skill to allure them into their service, the good, in order to make them happy; the evil, with a design to make them miserable. Whether this way of thinking be just, or no, I do not here examine. The perfections, powers, instruments, and hidden faculties of nature, the production of supreme Wisdom, vastly, I confess, exceed my comprehension. By that little however which we do know, we are disposed to believe, that there lies hid in the bosom of futurity, an infinite number of things, that will some time or other be clearly revealed to mankind, of which at present there is not the least shadow of appearance. Who can deny, that there may be beings, who have a faculty of looking more intimately into nature than the most sagacious human mind was ever capable of? Who can demonstrate but that these Spirits, without corporeal assistance, may be able to get acquainted with Bodies, understand their powers, perceive the chain or order of causes, see things present, foresee things future, and know things that are past? Nor is there any absurdity in supposing, that these Dæmons may insinuate their thoughts into human minds; since we at present are no more acquainted with the connexion, and mutual intercourse of thinking beings, than we are with the number of different kinds of beings, that are endued with understanding, will and affections. Nay even the manner of motion's passing from the moving body into the body it strikes against, is more than we are able hitherto to explain. Will any person dare to assert that it is impossible for thin incorporeal images to fly about in a hollow empty form, that has in the open Air seen the Spectres reflected from a concave *Speculum*, which so strongly, and perfectly represent the dimensions, colours, and every thing that appears in the solid bodies, that one can't help being surprized even though one is aware of it; and yet if you offer to touch them, you find them a perfect shadow? And as our soul is united to a body, by whose assistance it perceives things without us, why may not every one of these volatile *Species* have a spirit implanted in it, capable of penetrating, moving, and changing every thing? Whether these things are so, or not, I don't pretend to determine; 'tis possible

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time may diſcover it. Nor will I aſſert, that there have been perſons who by the aſſiſtance of Dæmons have been able to know, and do more, than they could have done by their own natural powers; nor yet will I abſolutely deny it. 'Tis an argument of too much preſumption and vanity in us, who ſcarcely know any thing, to take the liberty to ſpeak confidently of things that are far above our reach. I would not have you imagine, however, that I deſign by this to perſuade you to believe, a parcel of old wives fables, the reveries of idle perſons, the ſtories of credulous ones, or the fictions of thoſe that deſign to delude us. Nothing leſs! I am too ſenſible that it is with the ignorant chiefly that theſe things find credit; with men of ſenſe very rarely; and that always the leſs, the more cautious we are, and the more circumſpection we uſe, that we are not impoſed upon. As for the foretelling things future; the diſcovering of ſecrets; the raiſing the paſſions of the mind, and fixing them upon any object one has a mind to; the creating, removing, or aſſwaging diſtempers by numbers, words, ſigns, figures, inarticulate murmurs, charms, little images, a look, or laying on of hands; the changing one's ſelf, or others, into different forms; the making perſons inviſible that are in your company; riding through the Air at one's pleaſure; the giving life, ſenſe, motion, voice, and affections to inanimate beings; the calling up of Ghoſts, Dæmons, Spirits, and the Bodies of the departed; the maſtering, driving away, and binding of Spectres; the obtaining of honours; the finding of treaſures; the making money always return back again into its maſter's pocket; the rendering Bodies invulnerable; the getting the better of one's enemies; the fixing them like ſtatues at one's pleaſure; the ruling the Elements; the overcoming even nature herſelf, ſo that neither Fire or Water ſhall have any power over us; the raiſing meteors in the Air by a command; the taming and governing the moſt furious wild beaſts, purely by incantation; and the producing ludicrous appearances only with a word; theſe, and ſuch like things, are what the true *Magi* never pretended to, but are only the boaſts of crazy-headed people, which the ſuperſtitious are apt to believe, and the wicked ſometimes invent in order to delude the credulous, and get them into their power. Againſt ſuch fooliſh notions as theſe, that famous Author, whom I have before mentioned with reſpect, *Roger Bacon*, wrote with a great deal of ſtrength, and ſhews us that there is in reality no ſuch magic Art in the world; nor does he believe there ever was. On the contrary, he carefully inculcates, that there do actually reſide in natural Bodies, certain latent and hidden powers implanted in them by their Creator, by which as wonderful effects may be produced, as were ever aſcribed to the borrowed aſſiſtance of the Devil: That theſe qualities however cannot be diſcovered without a very laborious, and diligent inquiry; but that when by aſſiduous Study, and proper repeated Experiments, they have been once found out, they may then, by a due application of them to one another, be made uſe of for the production of ſuch things as, to perſons unacquainted with theſe properties, will ſeem contrary to the laws of nature, and will therefore be concluded to be the effects of a preternatural power. And this kind of true ſubſtantial knowledge may properly be called natural Magic. This is that magical Art which I would endeavour to recommend; and this in reality is very ſerviceable to mankind, very entertaining to perſons that are acquainted with it, and by its wonderful Operations very well ſuited to ſhew forth the praiſe and glory of the great

Creator. Indulge me a little, and I'll give you a few Examples of this, which intirely depend upon the chemical Art. Suppose an Author of undoubted veracity that lived a thousand years ago, should have told his posterity, that there was in his time a man who publickly gave out before a vast number of witnesses, that a prodigious tower, which they there saw at twenty furlongs distance, should at a certain point of time spontaneously rise into Air, and presently fall down again in ruins; and that it happened exactly as he had foretold; would not every one that read this look upon it as a fabulous story, or else, regard it as the effect of a power superiour to that of men, or even nature itself, and consequently ascribe it either to the Divine Being, or some infernal Spirit? And yet if you imagine that at that time there was but one man in the world, such a one for instance as *Mahomet*, or *Haly*, that was acquainted with the force of Gunpowder, and that he had conveyed a sufficient quantity of it under the tower, and according to the modern invention had artfully disposed a piece of clockwork in such a manner among it, that at the very moment of time that he had fixed, it should by striking a flint against a piece of Steel set fire to the Gunpowder; you see with how much ease he might have performed this surprizing miracle, by which he would certainly have gained so much credit, not only with the common people, but even with men of understanding, that he might have influenced their minds in what manner he had pleased. When the secret indeed comes to be discovered, our admiration ceases; and we then look upon these things as the production only of natural powers, which before we thought superiour to any magical Miracles that have ever been related. Not that even at this time the most sagacious person living can truly comprehend the cause of this surprizing effect; but we are falsly apt to imagine that we perfectly understand those things, which we see very frequently happen. It is possible in the same manner for a person to foretel, that in an hour's time there shall happen an Earthquake in a certain part of the earth, which shall at first send forth a prodigious black smoke, and afterwards burst out into crackling flames. People indeed that heard it would be apt to laugh at us; but then certainly they would be as much surprized when they found it to be true. And in order to this, take only equal parts of fresh filings of Iron and pure Sulphur, rub them together, and with a little Water make them into a paste of about fifty pounds weight, then put this a foot and a half under ground, and ram the earth hard down upon it, and your prediction will be fully compleated. Surprizing effect! that cold Iron, inactive Sulphur, and cold Water, only by being mixt together, should, under a weight of earth, be capable of producing Heat, Smoke, Fire, and Flame, without the least assistance of Fire. But again, there is a story of a Tutor, who after all other endeavours to no purpose, by a contrivance borrowed from Chemistry, happily reclaimed a noble youth, who by his dissolute life brought disgrace both upon himself and family, and seemed past all hopes of amendment; and this was in the following manner: One night as he lay in the same room with this young Gentleman who was fast asleep, he got out of bed softly, and with some English Phosphorus wrote his name in large letters on a board that was at the feet of the bed, and added three words, intimating that if he did not immediately repent, he must expect to die in a very short time: When he had done, without disturbing his pupil he stole gently to his bed again, but

then

then made a great noiſe on purpoſe to wake him, and laid himſelf down as if he was aſleep. The youth preſently ſtarted up in his bed, and liſtened attentively in order to diſcover the occaſion of his ſurprize, but heard nothing except the ſnoring of the other, who feigned himſelf aſleep; but looking accidentally towards the feet of the bed, he ſaw ſome letters ſhining with a blue light which vaſtly aſtoniſhed him. Upon this, he calls to his companion, and ſhews him the writing; who making as if he knew nothing at all of the matter, profeſſed that he did not ſee any thing; which ſo much the more increaſed his terrour. The ſervants who were not in the ſecret, were then called to bring in ſome candles, upon which the letters diſappearing, they declared too that they ſaw nothing; and indeed the youth himſelf was aſtoniſhed to find that the writing was vaniſhed. The ſervants went away again, but left a candle which happened to ſhine upon the board; the tutor ſets down by his pupil and perſuades him to go to ſleep, tells him 'twas only a dream, and then goes to bed himſelf, and puts out the candle. As ſoon as ever the room was dark, the youth no ſooner looked towards the fatal place, but he again ſaw the ſame letters, at which being vaſtly frightened, he cries out, and begs his tutor to come to him; who then pretending himſelf to be afraid, confeſſed that he did indeed ſee the writing, and that not without a great deal of aſtoniſhment; and then took this occaſion to admoniſh him ſincerely to repent, in obedience to this Miracle, and calling for a candle ſpent the remainder of the night with his pupil, who was under great concern, and was brought by this means to a better way of life. Now this ſtory, if it is true, as I have frequently heard it affirmed, is an Example of natural Magic from the chemical Art: If it is only a fiction, it is certainly a poſſible one, ſince ſuch things may at any time be effected by the help of Phoſphorus, as nobody that knows any thing of the matter will deny. If the power of Phoſphorus be ſo far weakened by a ſoft Oil, that it may be applied to the ſkin without burning it; then the face being rubbed with this Oil will ſhine terribly in the dark; and yet upon the approach of a light the ſhining will intirely diſappear; which being again removed, the countenance will regain its former brightneſs, than which nothing certainly can be more ſurprizing. Suppoſe now a perſon was to anoint his face, hands, hair, and beard with this ſort of Oil, and then diſpoſe himſelf in ſome dark place; would not the credulous vulgar preſently imagine there was ſomething in it celeſtial, angelical, or divine, and be ready to believe any thing upon ſuch a one's authority? Give me leave yet to mention another thing, which you yourſelves have been here often eye-witneſſes to, and that is, the ſurprizing effect of mixing together two liquors perfectly cold, which in a moment boil up in the moſt furious manner, and burſt out into a beautiful flame. Now if the thickneſs and blackneſs of the ſmoke, and the brightneſs of the flame is ſo aſtoniſhing in the middle of the day, would it not to appearance be vaſtly more terrible, if the Experiment was performed in the dark, when the flaſhes of the light muſt be abundantly more viſible? And, indeed, if we compare this wonderful *Phænomenon*, with the ſtories that are told of magical Spectres, I verily believe we ſhall ſcarcely find any of them that will equal it. Now this is the effect only of one drachm of one of the liquors and two of the other; what therefore muſt be the event ſhould pounds of them be mixed together? Certainly the force of the ſmoke, and flame, would be infinitely great, nor any ways to be reſtrained, but would overthrow every obſtacle that ſtood in its way, and deſtroy, and conſume every thing about it with a Fire not to be extinguiſhed. And which is ſtill more ſurprizing, if the ſame Experiment is performed *in vacuo*, it acts with ſo much the more violence, and in the very inſtant of mixing, tears every thing to pieces, and flies about with a force ſuperiour to the ſtrongeſt Whirlwind. The *impetus* of this Fire is certainly of a vaſtly different nature from that which was raiſed about *Creuſa*'s head by *Medea*; for by the ſtrength of this even the whole court might have been blown down and turned into aſhes. But again, who has ever heard, or read of any thing ſo wonderful and terrible aſcribed to the magic Art, as we have known effected by *Balſamum Sulphuris terebinthinatum?* which being cloſely confined in a Bolthead, and forced by a ſtrong Fire, burſt the veſſel with a ſtupendous noiſe, and produced ſuch ſtrange and peculiar effects, that in all the extraordinary *Phænomena* I have read of Thunder and Lightning, I don't remember ever to have met with any thing that equalled them. See the *Obſervationes Phyſico-Chemicæ* of the famous *Frediric Hoffman*, lib. III. Obſ. 15. where you will find an account of many things which you would have thought abſolutely impoſſible to be effected by the powers of nature. Among others, you have there ſome very ſurprizing effects of Spirit of Wine, which a Cooper putting into a ſtrong caſk with ſome lighted Sulphur, and then perfectly cloſing it up, there followed a moſt violent exploſion, that tore the veſſel to pieces, and was the occaſion of ſome accidents that are almoſt incredible. But laſtly, when we ſee the ſkilful Chemiſt take a parcel of clean glaſſes, and in a moment's time produce all ſorts of colours, and as ſuddenly deſtroy them, then renew them again, and vary them at his pleaſure, does not this, to a perſon that never ſaw it before, or knew any thing at all of the matter, appear ſupernatural, and even greater than the power of Magic? There are an infinite number of other inſtances to the ſame purpoſe; but let theſe ſuffice to demonſtrate the uſefulneſs of the chemical Art in natural Magic. Give me leave, however, to treſpaſs upon your patience a little longer, whilſt I add a few more obſervations upon this ſubject. The Divine Being has created the human Species in ſuch a manner, that thoſe in particular, who are in ſome meaſure adult, and enjoy a perfect ſtate of health, are capable of perceiving and underſtanding the changes and properties of the things about us, that have a power of producing ſome alteration in the Organs of our Bodies, and by this means exciting ideas in our minds. This is evident beyond all contradiction, let the immediate cauſe of it be what it will. Now the firſt time that this happens to us in our life in any extraordinary inſtance, it generally affects our minds in ſuch a wonderful manner, that it engroſſes all our faculties, and often gives us an infinite deal of pleaſure; though ſometimes indeed it proves too ſtrong for our mortal powers, and quite overwhelms us. The *Illuſtrious Boyle* tells us a ſtory of a man that was totally blind from his childhood, occaſioned by a Cataract in each eye, which afterwards being happily couched by a ſkilful hand, he was inſtantly reſtored to his ſight. But what was the conſequence? Why, the man was at firſt ſo vaſtly tranſported with the pleaſure of ſeeing, that his ſenſations were raiſed to ſuch a degree, and his Nerves ſo ſtrongly affected, that he narrowly eſcaped falling into a *Deliquium*. They were forced therefore immediately to cover up his eyes, and afterwards to let in the light a little at a time, and thus accuſtom him to it by degrees; by which means, never any thing like it happen'd to him afterwards.

For the ſame reaſon, the Author of Nature has wiſely provided, that the aqueous humour of the eyes of children ſhould be always turbid, and ſomewhat opake, when they are firſt born, and afterwards by degrees become pellucid. And in like manner the external orifice of the *Meatus Auditorius* is conſtantly cloſed up with a ſort of callous membrane, and the paſſage itſelf has not its proper length and curvature, by which the force of every ſound would be vaſtly increaſed; by which means the child, when it comes firſt into the world, is ſecured from any inconvenience that might otherwiſe ariſe from the noiſes about it. Afterwards, indeed, as it grows able by degrees to bear ſtronger ſounds, the acouſtic tube is lengthen'd, and the membrane drops off of its own accord. And here give me leave to obſerve, how imprudently thoſe people act, who ſuffer the children of Princes and great men, to be expoſed to the light of abundance of candles, and ſhock'd with the noiſe of cannon fired at a ſmall diſtance from them, as ſoon as ever they are born. If perſons therefore of this rank, ſhould ever be committed to any of your care, as ſeems promiſing from your Genius's, and indefatigable application, be ſure take care, that the tender infants are not injured in this manner; either by wholly forbidding it, or at leaſt adviſing, that it may be put off till a more proper opportunity. But to return: You know that we are affected in a different manner by things we are uſed to, and by things that happen but ſeldom: Hence it comes to paſs, that being deceived by cuſtom, we are apt to think we perfectly underſtand the nature, and cauſes of the former, whilſt we look upon the latter as ſomething miraculous, and are ready to believe, that they cannot be accounted for by the common laws of Nature. Thoſe appearances therefore, that fall frequently under our obſervation, tho' in reality we are perfectly ignorant of their cauſes, we readily call natural; and on the other hand, thoſe, that offer themſelves to us, in a manner quite uncommon, we conclude to be above the power of Nature. And hence, when we ſee any phyſical *Phænomena*, which are not produced by the natural Powers which we obſerve in thoſe Bodies which we have chiefly to do with, but depend on the ſingular properties of ſome particular Bodies which we are perfectly unacquainted with, there preſently ariſes in us a ſuſpicion of Magic. Of this, give me leave to mention the following inſtance. Count *Furſtemburg*, a military officer, coming one day into a ſhop, where they were filing ſome iron and braſs, and ſeeing the filings promiſcuouſly ſcattered one among another, he ſmil'd upon *Zwinger*, who was then at his work, and ask'd him in a joking manner, what he ſhould give him to ſeparate the particles of Iron and Braſs perfectly from one another? *Zwinger* merrily anſwer'd, he would do it for a very ſmall matter; nay, even for a bottle of wine. This being agreed to, he took a Loadſtone, and applying it to the heap, with a ſort of incantation, to amuſe the Count, call'd the filings of Iron, which came leaping and running to the Stone, and left the Braſs intirely by itſelf. The *Count*, who had never ſeen or heard of any thing of this nature, tho' a wiſe officer, and brave ſoldier, immediately cry'd out, that it was done by the power of the magic Art. See *Zwinger*'s *Treatiſe*, 239. But laſtly, and I have done, when we obſerve any uncommon changes in the appearances of the Bodies about us, which depend upon some qualities of those Bodies, which nature never discovers of herself, but which then only appear, when the Bodies have been properly prepared, either by art or accident, we are then, too, ready to look upon such *Phænomena*, as the effects of Magic; which the following example may serve to illustrate. If you take the very cold Salt of Nitre well dried, and mix it with half its quantity of the purest Oil of Vitriol, and then put this mixture into a Retort, and by the help of Fire force it into a dry Receiver, in form of a very red, volatile, acid, fiery Spirit, you will then have such a Liquor, as has never been produced either by Nature or Art, in any other manner than this, which was discover'd by *Glauber*. Again, take any of the choicest strongest aromatic Vegetables that grow in the hottest Climates, boil them strongly in pure Water, and confine the Vapour with a proper head in such a manner, that it may pass through a Tin worm every way surrounded with cold Water, and it will be condensed in form of Water, at the bottom of which you will find a fragrant heavy Oil, that perfectly expresses the qualities of the Spice from which it was distilled. And this Liquor too, is the sole production of this operation. Take now one part of this Oil, and pour upon it in a quiet vessel, two parts of the abovementioned Spirit, and there will immediately arise a most violent conflict between them, they'll puff up, cause a furious ebullition, and throw out a kind of lightening, that consumes every thing that is near it. Here then you see a *Phænomenon*, the causes of which are implanted in these Bodies, but in such a manner, that they never discover themselves, except they are first managed and prepared in the manner describ'd; and consequently, the knowledge of producing these extraordinary Motions, and Flame, depends intirely upon the three circumstances taken notice of; nor can they be effected in any other natural way. Hence then we conclude, with how little reason we can pretend to limit, and determine, the powers of created beings, whatever age we live in: For there may always lie conceal'd in the bosom of Nature, infinite numbers of properties of Bodies, vastly more wonderful than any that have been yet discover'd; nay, and even those things that in one age are vulgarly known, in the succeeding are frequently lost, and when in after-time they come again to be found out, are look'd upon and extoll'd as new and wonderful discoveries. But we must quit this subject, which would carry us to a very great length, were it accurately treated in the manner it deserves.

In Cookery. How comfortably are the necessities of mankind provided for, by the Art call'd Cookery, which preserves and prepares our Food, for the easy support of life, and is as serviceable to people in health, as Medicine is to those that are sick. Now this, tho' exceeding ancient, nay, possibly coeval with mankind, may receive a great deal of assistance from Chemistry. The acid Liquor, for instance, drawn by Fire from Sea Salt, if it is diluted with a proper quantity of Water, wonderfully preserves Fish, Flesh, and other things that easily putrify, prevents their being corrupted, gives them an agreeable taste, fits them for the easiest digestion, guards them against the bad effects of excessive hot weather, and even cures the distempers that this heat is apt to produce. And hence it is of infinite service to Sailors that are obliged to go into those parts of the world, where the Water and Fish putrify, Flesh stinks, and Bacon grows rancid, with the extreme heat of the Climate. Upon this head *John Rudolphus Glauber*, who wrote some Treatises, *De Consolatione Navigantium*, *De Prosperitate*

tate Germaniæ, and others upon the ſame kind of ſubjects, deſerves the higheſt commendation. He, in thoſe informs us, how a man, without any trouble, may in a little veſſel carry about with him a Liquor, which only being made uſe of to the quantity of a few drops, will anſwer very valuable purpoſes. There too he teaches us, that by proper ſolution, depuration, inſpiſſation, and preſervation from the Air, we may prepare a Liquor from corrupted Corn, now-a-days called Malt, a little of which contains a good deal of nouriſhment; and farther, how this, with a mixture of Wheat-flour, may be made into Biſcuits that will keep a conſiderable time, and are very hearty Food. The illuſtrious *Boyle*, in that excellent Piece, *Of the Uſe of Experimental Philoſophy*, gives us an account of ſome ſimple methods, borrowed chiefly from the chemical Art, by which Fleſh, Fiſh, and Eggs, either freſh, roaſted, or boiled, may for a vaſt while be preſerv'd from corruption. And it is this Art that furniſhes us with thoſe Pickles, that will even correct and prevent the progreſs of putrefaction, after it is but juſt begun.

The juice of Grapes, Apples, and almoſt all ſummer Fruits, if you boil and inſpiſſate it when it is freſh preſs'd, may be thicken'd into a durable Maſs, a bit of which being again diluted with Water, will even in winter nearly regain its native ſweetneſs; and that, whether it is prepar'd with Sugar, or without it. If this ſame Juice is preſs'd in the time of vintage, and ſuffer'd to ferment, work, and depoſite its Lees, it then becomes good Wine; and here, upon examination we ſhall find, that in almoſt every ſtep, from the beginning to the end, we are obliged to proceed according to the rules laid down by our Art: Nay, and even the faults which are apt to happen in the making, and which the Wine is liable to after it comes to perfection, are chiefly prevented, and corrected, by the helps we borrow from Chemiſtry. If it begins to fret again, inclines to be tart, or is growing foul, it is this Science that preſently furniſhes us with ſuitable Remedies; or if you would make it into Vinegar, this will teach you by what means you may effect it. The ſame Art too inſtructs us how to prepare Wine from all ſorts of pulpous Fruits: Grapes, all kinds of Cherries, Gooſberries, Berberries, Currants, Elderberries, Pears, Apples, and the various ſorts of Plums, are all, by the management of the ſkilfull Chemiſt, made to produce an agreeable Liquor, which truly deſerves the name of Wine, and is with a little aſſiſtance equally grateful. And all theſe now are conſtantly obſerved to be of the ſame nature and efficacy; for they all agree in this general property, that the firſt Liquid that is ſeparated from them by a gentle heat, is pregnant with Spirits, which will burn in the Fire, and may be diluted with Water; and this Liquor, when it is perfectly rectify'd according to Art, you will always find exactly the ſame, from which-ever of the abovemention'd Fruits it is produced. Nor has happy *Britain* any reaſon to repine, that in her ſoil Grapes won't ripen to that perfection, as to be fit to ſupply her with Wine, ſince Nature has ſo liberally indulg'd her with Apples, which with proper management yield a Wine, that in the fragrance of its ſmell, and gratefulneſs of its taſte, vies with the richeſt of *Italy*, *Spain*, and *France*. Nor is the juice of the Grapes in *Holland* rich enough for this purpoſe; but then, they have a way of preparing the ſame from Currants, Gooſberries, and Elderberries, which is little inferiour to the produce of the hotter Climates. And laſtly, from Herbs themſelves, after being prepared by boiling them with

In making Wine.

a gentle Fire, may be drawn a Spirit, tho' in but a ſmall quantity, which is conſiderably ſtrong. Now after all theſe are ſkilfully made, is it not the Chemiſt that teaches us to preſerve them, and prevent a new fermentation by the aſſiſtance of the fumes of burning Sulphur, and at the ſame time to keep them freſh, and ſecure their flavour? 'Tis from the chemical Art that we learn how to ſoften Wine, when it is too rough by a ſmall mixture of Salt prepared from the burnt *Fæces* of the Wine, and how to recover it, when 'tis grown tart by a proper addition of Crabs-eyes, or Chalk. And it was to the ſagacity of the Chemiſt, that we were beholden for the diſcovery of that abominable practiſe which ſome perſons made uſe of with their ſharp crude Rheniſh Wines, which was a certain management of them with Lead, by which they could give them an agreeable mellowneſs, but which enervated and deſtroy'd the drinkers of it with inſuperable Palſies; for which reaſon it was juſtly branded with a moſt rigorous puniſhment.

In Brewing. *Iſis*, and *Oſiris*, inſtructed the countries that were deſtitute of Wine, by what methods they might prepare Beer from Corn, which was very properly therefore called the Wine of *Ceres*; and hence *Tacitus* tells us, that the ancient *Germans* uſed to make Wine from corrupted Corn. Now this the Art of Chemiſtry lays claim to in a particular manner, they both having their riſe in the ſame part of the world, *viz. Egypt*. And indeed, *Baſil Valentine* has elegantly given us the whole doctrine of the ſecrets of Alchemy, in his deſcription of the Methods of making Beer, which he has examined with all poſſible nicety and accuracy. But there's no need to enlarge upon this head; for as there is very little difference between Wine and Beer, what has been ſaid of the uſefulneſs of the chemical Art in the former, your ingenuity will eaſily apply to the latter.

And thus, Gentlemen, I think I have ſufficiently made appear the abundant ſervices that all the mechanical Arts, or the chief of them at leaſt, receive from Chemiſtry. And hence, I believe, I may ſafely conclude, that if the particular Artiſts in the different branches of Mechanics, had a good knowledge of the chemical Art likewiſe, they would be able to improve their ſeveral profeſſions to very great advantage. There are therefore very many and weighty reaſons, that urge us to apply the Art of Chemiſtry to all other Sciences that are ingaged in the examining and changing of natural Bodies. And this we ſhould do with a reſolution, carefully and faithfully to take notice of every thing that we may be ſo happy to diſcover, which we ſhould afterwards digeſt in order, and publiſh to the world; that thus, by the united labours of us all, human Arts may be improv'd, and carry'd to ſtill greater and greater perfection. What I have been able to contribute to this valuable purpoſe, I have given you; I confeſs, indeed, it is but a little: In this view, however, the pains I have taken, will be of ſome advantage, if it ſerves to incite other perſons of a happier genius, and greater application, to make more uſeful Diſcoveries.

In Alchemy. And now at laſt we are come to lay before you a few ſimple obſervations concerning the excellent uſefulneſs of the chemical Art in Alchemy; where I ſhall candidly repreſent the affair exactly as I have found it. Among all the Writers of Natural Philoſophy, it has not yet been my fortune to meet with any, that have more intimately examined, and evidently explain'd the nature of Bodies, and the effects they are capable of producing, than thoſe that have gone

gone by the name of Alchemiſts. For the confirmation of this, leſt I ſhould be unjuſtly ſuſpected of prejudice, I beg you will read, but with a vaſt deal of attention, the works of the principal, true, profeſſors of the alchemiſtical Art. Give me leave upon this head, to quote *Raymond Lully*, in that Treatiſe of his, which he calls *Experiments.* There you will ſee with what perſpicuity he explains the nature and actions of Animals, Foſſils, and Vegetables, and that purely from ſimple experiments, without any circumlocution, diſguiſe, or fiction; and I am ſatisfied, you will candidly acknowledge, that you can ſcarcely find theſe things treated of in ſuch a manner any where elſe. The obſervations, ſays that Author, that Bodies reſolv'd by our Art, expoſe to the Eyes, and diſcover to the Mind, are of infinitely more force to gain the aſſent, than the utmoſt ſtrength of pure Argument; by theſe we perform what we aſſert, and give Examples of what we inculcate. And it certainly muſt be allowed, that he did as he ſaid: So that in reality, theſe men attempted to found ſuch a Philoſophy, as the great Lord *Verulam* ſo earneſtly wiſh'd for; which ſhould conſiſt in the right comprehending and explaining to others thoſe powers of Bodies, which being in action, would conſtantly produce certain determin'd effects; and hence ſhould lay down no other cauſes of things, than what being at any time ſuppoſed, would certainly and readily effect thoſe very things, thus always performing at pleaſure whatever it aſſerted the truth of. They laugh'd at the ſubtle univerſal cauſes, which the Schoolmen, making an ill uſe of their leiſure, impoſed upon the learned world; for theſe were intirely the effect of pure ſpeculation, and the knowledge of them did not at all qualify the poſſeſſor for any phyſical operations. And hence they moſt carefully inculcate throughout their Philoſophy, that it is abſolutely impoſſible for the utmoſt Art of man to produce any effects in natural Bodies, which ſhall exceed thoſe powers that the divine Being has implanted in them: That ſome of theſe qualities lie open, and manifeſt to every one's obſervation, for the neceſſary uſes of life; whilſt others of them are more abſtruſe and conceal'd, and are only diſcover'd to thoſe perſons, who with diligence and conſtancy wiſely apply themſelves to ſearch out the deeper and more hidden Works of the great Creator: But that both nevertherleſs are to be regarded as equally natural. They aſſert, therefore, that no perſon living, even ſuppoſing him to be poſſeſſed of all the wiſdom of paſt and future ages, can ever, with all his ſkill, either create any one ſingle Being, a grain of Muſtard-ſeed, for inſtance, out of nothing, or produce it from any other kind of matter, that is of a different nature: But that prudent men, however, by receiving and examining created things, as they are offered to their obſervation, may, by the help of proper Experiments, come afterwards to diſcover by what law Nature acts, and what methods ſhe purſues, in forming, producing, and perfecting every particular Being, according to its proper and peculiar Nature. And here they obſerve, that this is found to be the grand principal law, that every thing is generated from ſomething of the ſame kind that firſt exiſted. Thus Plants ſpring from Plants; Animals from Animals; and Foſſils from Foſſils. They further aſſert, that the whole power of Generation conſiſts in one ſeminal principle, which digeſts and changes the crude matter it receives into its own likeneſs, and forms it into a reſemblance of the original: That in order, however, to a fruitful procreation, there is abſolutely required both a Male and Female, without whoſe natural conjunction, no Offspring can ever be produced: That when the prolific Seed is ſafely ſecured in the Matrix or Womb that nature has deſign'd for it, and has there for a convenient time been cheriſh'd, and ſupported with a kindly warmth, and proper nouriſhment, there will then appear a new Being reſembling its father; whereas if Nature is any ways broke in upon, and diſturb'd in her proceedings, her deſigns will prove abortive, and the thing that was intended will not be accompliſhed. Hence they infer, that after creation is once perfectly compleated, there is nothing begotten *de novo*; but that all things ſpring and increaſe according to certain laws, purely from the Seeds of ſomething of the ſame nature that was in being before; that any created thing therefore, by means of its Seed, may be multiplied *in infinitum*, but not without it; and conſequently, that the whole face of the Earth might be covered with one ſort of Plant, as Fennel, for inſtance, if its Seed was continually gathered, ſown, and cultivated, as its particular nature requires. They remark yet again, that there are found in Nature ſome Bodies, and thoſe generally exceeding ſimple ones, that are not obſerv'd to have any ſeminal power in them; and hence, neither increaſe themſelves, or tranſmute any other Bodies into their Nature, but ſerve, either to put every thing in motion, as Fire; to dilute, and be a proper vehicle for nouriſhment, as Water; or to give ſtrength and ſtability to compound Bodies, as Earth, when it is perfectly pure. Now theſe things being found by an infinite number of Experiments to hold good in all other parts of Nature, they at laſt diſcover'd, that even Foſſils were ſubject to the ſame univerſal law. For tho' their natural ſimplicity, and the ſimilarity of their parts are inconſiſtent with the organical, compound, fabric of a Seed; yet they are found to be indued with a certain innate faculty, by which they can attract a proper *Pabulum* for their increaſe, and apply it in ſuch a manner, as to be hence continually propagated. They add farther, that the Spirits called *Rectores* are ſealed up, and do not appear in Metals ſo long as they are dead; but that when they are reſolv'd, open'd, and vivified, they then manifeſt themſelves, and produce very ſudden and wonderful effects; and that even here there is a kind of prolific union; for they tell us, there is an impregnating Male, and a fruitful Female, by whoſe procreating power live Metals do propagate their Species. Nor have they conceal'd from us, by what methods Metals may be made alive, with what degree of Fire they muſt be managed, in what proportion they muſt be mix'd, and with what *Pabulum* they muſt be nouriſhed, in order to make them capable of being multiply'd as long as you pleaſe. And laſtly, they aſſure us, that Metals alone, on account of the extraordinary ſimplicity of their Nature, may be produc'd in the leaſt time imaginable from a mercurial heavy fluid, fix'd by a ſulphureous ſeminal principal, if they can but be intimately mixt by the aſſiſtance of Fire, and join'd together with an indiſſoluble union: That thus Mercury is the Mother of Metals, and the quickening Sun the Father: And hence, that that may be effected upon Metals in the twinkling of an Eye, if they are firſt artfully and properly vivified, which would not have been brought about by a ſubterraneous Fire in the Bowels of the Earth under a long *Series* of years. They confeſs'd, indeed, that in the Vegetable, and Animal Kingdoms, the action of procreation is limited, and determined by nature within its proper time: And that it was impoſſible it ſhould be otherwiſe,

conſidering

considering the exceeding tender nature of the Seed, its compound, intricate, and curious structure, the very various, and numerous parts of which it is composed, and how easily the living spark in the center of the prolific Sulphur, or the little Embryo, might be destroy'd. But at the same time they tell us, that in the pure Metals, Gold, Silver, and their Mother, Mercury, there is such a similarity of parts, that every individual particle is perfectly of the same nature with the whole Mass: That they are observed to be so greatly immutable, that neither the gentlest or strongest Fire is capable of destroying them: That the prolific seminal power resides in Fire, and hence acts with infinite celerity, and in a moment assimilates the mercurial matter that is suitable to it: That upon this principle depends the increase and procreation of pure Metals: And that thus may be prepared the *Philosopher*'s *Stone*, which will convert all other Metals into Gold; on which head, if you desire to know my opinion, I'll give it you freely.

The wise *Socrates* having a Book of *Heraclitus*'s given him to peruse, that was wrote in a very intricate and abstruse manner, he read it over with a great deal of care, and when his opinion was desir'd concerning it, the great man answer'd, that in those places where he understood it, he found it excellently well done, and believed it was the same, where he was not able to comprehend it; but that it required the most subtle penetration to come at the sense of it. In the same manner, where I can discover the meaning of the Alchemists, the truths they deliver appear very evident, and are express'd in the most simple terms, nor are they often mistaken themselves, or do they impose upon others. When I come therefore to passages where the sense is more obscure, why should I pretend to condemn them of being in the wrong, who have shewn themselves vastly my superiours in the Art, and from whom I have got a great deal of information, where they thought it proper to express themselves clearly? For they themselves declare, that when they come to treat of the utmost limits and perfection of the Art, they designedly tell us no more than that the Art is true, in order to excite proper persons to pursue and discover it: That they are obliged in honour, not to publish a secret that might be abused to a great many ill purposes: And that it is enough, if they point out to us the tract that Nature teaches us to follow, and prevent our falling into errors. For this reason therefore, I am rather apt, in these circumstances, to lay the fault on my own ignorance, than to accuse them of vanity. With proper deference, however, I must take the liberty to make the following remark: When I read over the Secrets of those excellent Artists and great Masters of Nature, I am apt to doubt, whether, after they had by pure observation made so many, and such singular discoveries, they did not arrive to such a quickness in perceiving the consequences of things, as led them to relate those things for facts, which they judg'd might possibly be, nay, and certainly would happen, if they had prosecuted the inquiries they had in their view. And indeed, *Alexander Suchthenius*, a considerable Author in Alchemy, who was a scholar of *Paracelsus*, and a zealous defender of his Doctrine, seems to intimate something of this nature; for after having try'd a great many things to no purpose, he tells us, in the end of one of his Treatises of Antimony, that all the Philosophers, of which he there mentions the chief, died before they had brought their speculations to a proper issue. Now supposing this to be true, which I don't pretend to determine, yet every grateful mind will think itself vastly obliged to them for discovering to us those physical truths, which it cost them an infinite deal of pains to come at the knowledge of. And the great Lord *Verulam* very properly compares them to a Father, who when he was dying, made his lazy Sons believe, that in a certain field he had hid a treasure; upon which, as soon as ever he was dead, they went to digging, in hopes of finding the riches, but were baulk'd in their expectations, tho' the service they did the Land abundantly recompenc'd their trouble. These few things concerning the knowledge of the true Alchemists in Natural Philosophy, I have long desired to make known, that they may not be misrepresented, and condemn'd by persons, who are no ways capable of forming a proper judgment of their abilities. The chief performances the Alchemists pretend to are, as follow:

The preparing the *Philosopher's Stone*; a small portion of which being thrown into Metals, whilst they are in fusion, will in a moment transmute the true mercurial part into *obryzum* Gold, purer and finer than was ever dug out of the Mines, or procur'd by any docimastic Art; and at the same time will instantly consume and dissipate every thing contain'd in the Metals, that is not of a metallic mercurial Nature. This, they say, is of the same weight with Gold, brittle like Glass, of a very deep red Colour, and runs in the Fire like Wax.

The making another Stone of the like Nature, call'd the *Lapis Argentificus*, which will in the same manner turn all Metals, except Gold and Silver, into the most perfect Silver.

The carrying the *Philosopher's Stone* to such a degree of perfection, that being cast into melted Gold, it will totally convert the Gold into the *Philosopher's Stone*.

And the exalting this still higher, so as to change pure Mercury intirely into the same Stone.

They say farther, that they have discover'd a Body prepared by Art, which is of such vast efficacy, that if it is mix'd and united with any thing, either in the Animal, Vegetable, or Fossil Kingdom, it will so far improve their natural inherent vertue, as to render them the most perfect in their kind. In the human Body, therefore, it would prove a universal Medicine, so disposing both its Solids and Fluids, that it would become absolutely sound, and would continue so, till it was gently consumed and worn away by the necessary actions of life itself, and then would leave the world easily, and without reluctance. The same thing too it would effect in any living Animal; and if it should insinuate itself into the roots of Vegetables, it would greatly increase both their beauty and fruitfulness. To this noble figment they gave the name of the *Universal Ferment*.

They pretend likewise, to make artificial Gems, that shall perfectly resemble, and be of the same value with natural ones.

And to exalt the baser imperfect Metals into Gold, by carrying on their coction and purification from that step, where Nature was defective and left off. For it is their opinion, that the ultimate design of all Nature's operations in the Mines, is the production of Gold from Mercury by the assistance of Fire, and by refining and filtring it through pure dense Bodies: That if she is hindered in her proceeding, either by the want of Fire, the looseness of the passages

through

through which it runs, or the mixture of any heterogeneous matter with it, there then arises a crude Metal which is not perfectly homogeneous, and hence mutable by the Fire. And thus they say are produced all Metals except Gold, Silver, and Mercury; which, nevertheless, may be still so far perfected by Art, as to be converted into Silver and Gold. This last, however, was not the universal opinion of the Alchemists. And indeed, Lead, Tin, Copper, and Iron, seem as perfect in their kind, as Gold; and are always found to be precisely of the same determinate nature. And, perhaps, the particular nature of Copper may render it as fit, or fitter, both for philosophical purposes, and the common uses of life, than either Silver, or Gold, although it is less simple, and consequently more changeable. Nor in reality is it at all probable, that this Metal should, by any continued subterraneous digestion and separation of its heterogeneous parts, be ever exalted into Gold, or become any thing but the most perfect Copper; which is likewise true of all the rest. I confess indeed, that something of Gold may be obtained from what we call the baser Metals, if they are kept a long time in the Fire; but then it is not certain, whether this is actually produced there by carrying on those Metals to greater perfection; or whether it is only separated from them by the force of the Fire. Nor can I easily conceive how it comes to pass, that lead, which of all solid Bodies, comes nearest in weight to Gold, should be reckoned so much more distant from it in nature than Silver; since all the Adepts assert with one consent, that the Demonstration from weight is of more force than any mathematical one. But I have sufficiently tired both your patience, and my own, upon this subject, and therefore to conclude. Let us never imagine that we are able to determine how far the powers of nature may extend. Those things are looked upon as impossible, that ignorant people are not acquainted with. The ancientest Philosophers gave some hints of an eternal Fire, solid, and durable even under Water; and were ridicul'd for their pains as a parcel of idle men: But since it has been discovered by *Craftius*, improved by *Kunkel*, described by *Boyle*, more clearly explained by *Newentyt*, and most plainly of all treated of by *Hoffman*, the possibility of the thing is actually demonstrated. The artificial Thunder and Lightning of *Roger Bacon* were looked upon for a good while as fiction, and deceit; but they afterwards were made appear by *Schwartz* to have too much truth in them. And the other things that I have mentioned in natural Magic, to persons perfectly unacquainted with Experiments, will seem much more incredible than the transmutation of Lead into Gold with regard to its mercurial part, its original form being first perfectly destroyed. There are inconveniences in being too credulous; and so there are in being too sceptical. It is the business of a wise man to try every thing, and abide by that which he finds to be true; nor ever to prescribe limits to the power of the omnipotent Governour of the universe, or the natural beings which he has created.

Now we are upon this head give me leave, before we proceed, just to mention the *Apparatus*, that the greatest Masters in the Art declare to be absolutely necessary for bringing this grand *Arcanum* to perfection. And first they all agree, that Gold, Mercury, and Fire, are principally requisite. As also Lead, Iron, Antimony, and Nitre, and the nitrous spirits drawn from it. A Cupel. A glass Pestil and Mortar. A Retort, Receiver, and pure Water. A Furnace,

nace, Bellows, filtring Papers, a glaſs Egg, or Matras, and an Athanor. The whole charge of which upon computation never amounts to 20 *l.* Sterling, ſetting aſide the value of the labour.

Of the Inſtruments of Chemiſtry.

Having thus, Gentlemen, explained to you the Bodies about which Chemiſtry is engaged, and the ends that it chiefly propoſes in the changes it produces in them, I ſuppoſe of courſe you will be deſirous to be informed by what methods theſe may be brought about; which I readily comply with. As it is impoſſible now that any Art can produce effects without proper inſtruments; hence theſe, of conſequence, come firſt under our conſideration. A perſon, for inſtance, deſires that I would acquaint him, what it is in Wormwood that gives it its bitter taſte, and that I would ſeparate that part from all the reſt. Now here I muſt know that Water juſt ready to boil will fetch all that is bitter out of the plant, if it is poured on, digeſted, decanted again when it is impregnated, and this is repeated ſo long till the laſt after ſtanding ſome time comes off as inſipid as it was put on. The Plant then will intirely have loſt its bitterneſs, which will all be contained in the Water: And here you ſee evidently, that Fire, and Water, are the Inſtruments made uſe of in this Operation.

For in every Art that inſtructs us in the changing of Bodies, that particular thing is called an Inſtrument, which either has or may have given it a certain peculiar motion, which being applied to the Body to be changed will produce ſuch an alteration in it, as the Art had before determined. And thus in Chemiſtry we have Inſtruments by which we are able to perform the actions we deſire; and theſe we uſually reduce to ſix, as the principal, with thoſe Chemiſts who have cultivated the Art with the greateſt accuracy; and they are as follow. Fire, Water, Air, Earth, the Solvents which the Artiſts call *Menſtruums*, and the common furniture of the Elaboratory; all which the Chemiſt ought well to be acquainted with, if he would rightly underſtand the Operations, which are effected by the help of them. Of theſe therefore I ſhall treat in the order I have mentioned them, beginning firſt with Fire, as there never was, or can be any chemical Operation, in which Fire is not concerned; which is not ſo univerſally true of the reſt.

Of FIRE.

Fire of a wonderful nature.

The power of this is ſo great, its effects ſo extenſive, and the manner of its acting ſo wonderful, that ſome of the wiſeſt nations of old reverenced and worſhipped it, as the ſupreme Deity. Some of the Chemiſts too, after they had diſcovered its ſurprizing vertue, have ſuſpected it to be an uncreated Being. And indeed, the moſt famous of them have acknowledged it as the ſource of all their knowledge; and hence have profeſſed themſelves Philoſophers by Fire, nor thought they could be honoured with a nobler title. Now among all the wonderful properties of Fire, there is none more extraordinary than this, that though it is the principal cauſe of almoſt all the ſenſible effects that continually fall under our obſervation, yet it is itſelf of ſo infinitely a ſubtil nature, that it eludes the moſt ſagacious inquiries, nor ever comes within the reach of our ſenſes: and hence others have been led to be of opinion that it ought to be looked upon as ſpirit, rather than Body. It

It is neceſſary, therefore, if we would keep clear of miſtakes, to act with the utmoſt caution in our ſearches after a thing whoſe nature is ſo hidden and myſterious. And for this reaſon we muſt abſolutely diſengage our ſelves from all mere ſpeculations, nor give into any precarious *hypotheſis*, how plauſibly ſoever contrived, unleſs we would run headlong into confuſion, and uncertainties: For if at ſetting out we lay a wrong foundation, the errors that ariſe hence will diffuſe themſelves through all the branches of natural Philoſophy; ſince in all the productions of natural effects, Fire, as I obſerved before, has always far the greateſt ſhare. To be inquired after with caution.

When we ſet about therefore to inquire what Fire really is, we muſt begin perfectly as though we knew nothing of the matter, and muſt intirely lay aſide every notion that we had formed of it before. And here we muſt follow the analytic method of the Geometricians, who in order to come at the knowledge of any thing, proceed as though they were ignorant of it, and that they may conſtantly keep this in their eye, repreſent it always by ſome ſign that only expreſſes ſomething unknown, and that is then ſought after. Nor do theſe religious Obſervers of truth, in their inquiries after things they are not acquainted with, ever make uſe of any other properties, than what are evidently obſerved in the things themſelves, or have been before clearly demonſtrated. Not from Hypotheſis.

And I will venture to aſſert, that this extraordinary circumſpection is never more neceſſary, than in the ſubject we are at preſent engaged in: For the Elements of Fire pervade and reſide in the moſt ſolid matter of Gold, as well as in the moſt perfect *Torricellian vacuum*, and are equally diſperſed and diſtributed through all Bodies, and every part of ſpace; as will be evidently made appear hereafter. And hence it comes to paſs, that there is nothing in our philoſophical Inquiries more difficult, than truly to diſtinguiſh the particular action of Fire from that of the other cauſes that in every phyſical Operation concur with it; and yet the nature of Fire is ſo vaſtly different from theirs, that they cannot be confounded with one another without the utmoſt impropriety, and danger of miſtakes. One difficulty in this Inquiry.

There is yet another difficulty that puzzles the Philoſophers in their ſearches after Fire as much as the former, and that is, the vaſt ſubtlety of its particles, which in their fineneſs not only exceed every thing yet known, but penetrate into the moſt ſolid, and even the ſmalleſt Corpuſcles that ever fall under our notice. And hence it comes to paſs that we find ſuch very different, and abſurd opinions concerning its nature, even among thoſe Authors, who have ſtudied it with the greateſt diligence, and happieſt ſucceſs. And the errors that have riſen hence, have not only infected Chemiſtry and Philoſophy, but have alſo ſpread themſelves into the medicinal Art, as every Phyſician muſt acknowledge, who has carefully conſidered what has been advanced concerning innate Heat, radical Moiſture, and many other things that depend upon them. Let us therefore in our Inquiries on this ſubject proceed as if we were perfectly unacquainted with it; and let this be the caſe, 'till we are able to come at ſome certainty about it. A ſecond.

It is impoſſible, however, with our utmoſt endeavours, ſo to diſengage our thoughts in this affair, as not to retain at leaſt that idea of Fire, by which every perſon ſays he knows whether it is preſent in any particular place, or is abſent The ſigns of its preſence to be firſt inveſtigated.

absent from it. For it is absolutely necessary that this mark should be perfectly obvious to our senses, and that we should all agree about it; otherwise the word Fire even among persons that talk the same language, would signify nothing at all. And the same Observation equally holds true of every thing else. If a person should say, for instance, that he knows nothing of the nature of Thunder; yet still under this word he conceives this notion of it at least in his mind, that it is something that produces a very extraordinary noise in the Air, and thus understands the same thing by this term as every body else does, nor will easily confound it with any thing else. In like manner, both the learned and the ignorant, if they use the same speech, as soon as ever they hear the word Fire, immediately think of the very same thing. And indeed were not this the case, that word would have no more effect upon the person that heard it, than if it had been spoken to an *Indian*, or an *African*.

The requisites in these signs.

Now this general mark or character must belong so peculiarly to Fire, that it must not be common to any thing else; for otherwise, we shall be constantly at a loss how to distinguish Fire from any other of those things, that this property might equally point out.

Nor is it less necessary that this mark should be an individual one, and absolutely inseparable from Fire, so that wherever Fire actually exists, this should also most certainly and constantly be present with it; for by this means alone we shall be able to come at the knowledge of it, a sign being of no manner of service, if the thing signify'd may nevertheless lie concealed, and not be discovered by it.

And lastly, it is absolutely requisite, that this character should lie open to our senses, and easily affect them; and should plainly point out to us the degrees in which Fire increases, decreases, or continues in any space, or Body. If these three properties, therefore, are found together in any character of Fire, we may venture to make use of this for our purpose.

The use of such a sign.

And then safely relying upon this, we may cautiously proceed to some physical Experiments in order to get a farther insight into the nature of Fire, which though indeed it lies out of the reach of our senses yet, by this sign will certainly discover its being present: Especially, if we set about our Inquiries with prudence and diligence, on purpose to examine into its hidden properties, when we are once undoubtedly sure of its presence. And, then besides, any accidental discoveries that unexpectedly offer themselves to our observation in the prosecution of these Inquiries, will likewise prove of service: For both these will serve to furnish us with arguments, which being properly reduced into order, and rightly improved, will help us by degrees to an insight into the nature of this abstruse, and mysterious Being. And how can we be afraid of falling into mistakes, whilst we pursue this method, which is universally approved by men of the soundest judgment, as the only certain one in searching after natural knowledge?

The difficulty of finding such a sign.

It must be acknowledged, however, that it is exceeding difficult to discover such a mark of Fire as will always demonstrate its presence, let the quantity of it be ever so small; and that for the following reason. Upon examination it evidently appears that there is an incredible quantity of true Fire even in those places, where every body not only judges there is none, but imagines there is really something of a quite different nature. In a hard frost, for instance, it will be demonstrated,

demonstrated, that Fire is actually contained in the very coldest masses of Ice, and may be instantly produced from them with a great deal of violence: And yet at that time it no ways manifests itself to our senses; not one of its actions appears; nor any of the effects that are commonly ascribed to it. I don't pretend, therefore, to lay down any mark, by which a person may be sure of the presence of the very least quantity of Fire; but I'll venture to offer one which will certainly discover it when it is somewhat greater; which will be sufficient for our purpose. And as in Bodies, we have no idea of great, or small, except by comparing the Bodies, either with one another, or with some certain measure: So here, though the absolute quantity of Fire in a given place, cannot by any sign be rightly determined; yet we are able to demonstrate how much there is more, or less of it there, than in any other place assigned. In like manner it is difficult to ascertain the absolute degree of Fire in any particular point of time; and yet the various degrees of it at different times may be easily compared with one another.

Such signs are the sensible effects produced by Fire.

Whilst we are engaged now in pursuit of the marks abovementioned, those effects first offer themselves to our observation, which are produced by the power of Fire alone, and by which, when they are manifest to our senses, we universally infer the presence of Fire. These therefore we may fairly make use of for the present. For if those physical changes which are the sole production of Fire very easily affect our senses, they will serve as a certain indication of Fire; and if these constantly appear wherever Fire is generated, we shall come, in reality, at the very thing we desire. Nor need we here be over sollicitous lest among these effects there should be sometimes intermixed others, that owe their being to some other causes; for when we come to consider them more nicely, we shall easily be able to distinguish those that are proper to Fire, from those that are common to it with other Bodies. Let us therefore at first assume those properties only that are commonly, and universally ascribed to Fire; and afterwards proceed to examine them with care, and accuracy, in order to make a proper discovery of those among them, that we are particularly in search after. Now of these the following are the principal. 1. Heat. 2. Light. 3. Colour. 4. Expansion or Rarefaction, both of Fluids, and Solids. 5. The power of burning, melting, &c.

The examination of these, and first of Heat.

These therefore let us consider in order. Heat then in the first place is ascribed to Fire, and that with the greatest reason, as they are most intimately connected together. And yet if we closely contemplate this very idea of Heat, we shall easily perceive that people mean nothing more by it, than a certain sensation of the mind, excited by the application of Fire to the sensible parts of the Body. But by this perception certainly we understand nothing of the action of Fire, or the alteration that is produced in our organs of sensation by it. And hence Heat, considered only as it exists in the mind, whence alone it receives its name, does not really signify any thing corporeal, but indicates only some affection, or change of our thinking faculty. When any person is hot, he has a clear and distinct idea of what he feels at that time; but yet he will never thence be able to obtain the least knowledge of Fire, or the changes that it then produces in him. Let me ask you, Gentlemen, what it is you feel in yourselves, when you say you are warm; is it not a perception of somewhat agreeable? Now compare this with what the Physicians are of opinion

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happens then in the Body; and what a prodigious difference! They tell us that during that time a moſt ſubtil Fluid is moved in the capillary Nerves after a particular manner: But is it poſſible that ever ſuch a notion as this ſhould enter into any perſon's mind purely from the ſenſation of warmth, ſhould he be affected with it ever ſo often? But conſider again, what is the ſtandard by which every one meaſures his proper degree of Heat? Why, ſo long as a man enjoys perfect health both in body and mind, he will confeſs that the kindly warmth he then feels, excites an agreeable ſenſation in his mind. If this afterwards leſſens by degrees, and at laſt becomes imperceptible, he then ſays he is cold: As on the contrary, if it is increaſed beyond that degree which affected him with pleaſure, he complains of a troubleſome Heat. But there is nothing in all this that will be of any ſervice to us, as a Criterion of Fire. Beſides, as in all other circumſtances, ſo here, the degree of Heat that we are conſtantly accuſtomed to, we are not ſenſible of; and hence we are apt to look upon every degree of it, that is leſs than the natural, or uſual one, as no Heat at all; which leads us continually too into miſtakes: Whereas on the contrary, thoſe perſons that have for a long time been inured to cold, are thence affected in a very different manner from what others are. It is an old Obſervation that ſubterraneous places afford a moſt refreſhing coolneſs to perſons melting with Heat in the ſultry Dog-days; and that on the other hand, when the Body is almoſt frozen with the winter Cold, it will perceive a kindly warmth in the very ſame places. And hence it has been falſly inferred, that theſe places under ground undergo a true *Antiperiſtaſis*, and grow colder in Summer, and warmer in the Winter; whereas we certainly know that cellars conſiderably deep are colder in the former, and warmer in the latter: Indeed if they are ſunk to a very extraordinary depth, the degree of Heat continues always pretty nearly the ſame. From all this we conclude then, that the informations we receive from Heat are very precarious and uncertain. For your farther ſatisfaction, however, I will mention one inſtance more, of great conſequence too in Phyſic, which will ſtill farther confirm my aſſertion, that we can by no means determine with any certainty the quantity of Fire, by that Heat with which our ſenſes are affected. In the ſummer time, when the Heat grows exceſſive, ſuffocating, and intolerable to perſons in health, occaſioned either by the reflexion, or refraction of the Sun from the Clouds, there follows very frequently Thunder and Lightning, with large ſhowers of Rain, and ſometimes of Hail; and this no ſooner happens, but the Air grows chill, and this very troubleſome Heat is ſucceeded by Cold. With this ſudden change we are ready to ſhudder, and feel as though we were pierced through with a Winter's Froſt; and yet I have found by repeated Obſervation, that the Air at that very time, though it ſeems ſo cold, is in reality ſo very warm, that ſhould the ſame come upon us ſuddenly after a very hard froſt, the Heat of it would be greater than we could poſſibly ſupport ourſelves under: For ſhould a room, in the ſharpeſt froſty weather, be heated to the ſame degree, as the Atmoſphere is in the month of *Auguſt* after ſuch Thunder, there is no perſon living who had been abroad a good while in this piercing Cold, that could bear the Heat of this room, but would ſoon faint away. From the whole therefore we conclude, that Heat is a very uncertain meaſure of the quantity of Fire.

Secondly of Light. Again, Light is looked upon by judicious Men as a moſt certain Demonſtration

ſtration of the preſence of Fire. For, ſay they, does not this offspring of Fire evidently point out its parent, and hence imagine, that the ſtronger, and brighter its rays are, the greater quantity of Fire is really contained in it; and that on the contrary this decreaſes in the ſame proportion, as the ſplendour of that noble Being is diminiſhed. This therefore they imagine may be laid down as a mark of Fire. But how little, Gentlemen, are they acquainted with experimental knowledge that are of this opinion? If you make any doubt of this, put a piece of Iron in the Fire, and let it remain there 'till it's almoſt red hot, then carry it into the dark, and it will afford no light at all; and yet if you apply it to the body of an animal, it will burn it to the bone, nay the very bones themſelves, with a hiſſing noiſe, and a very diſagreable ſmell; or if you lay it upon a piece of dry wood, you will produce both ſparks and flame. Here, therefore, there is a vaſt deal of Fire without the leaſt appearance of Light. On the other hand, take a concave *Speculum* made of ſolid Metal, and exactly poliſhed, and in a clear winter night oppoſe it to the Moon when it is at the full and upon the Meridian, then place a piece of white paper in the *Focus*, ſo that it may receive the contracted image of the Moon, and you will have ſo refulgent a Light, that the ſtrongeſt eyes will not be able to bear it; and yet in the center of the *Focus* there will be a very piercing Cold. The ſame Experiment was performed by that famous *Engliſh* Philoſopher Dr. *Robert Hook*, (who ſeemed formed by nature for Experimental Philoſophy) with a double Convex-glaſs, and the image of the Moon received upon a paper in the *Focus* was exceſſive bright; and yet upon putting a very nice Thermometer into the *Focus* there did not appear the leaſt ſign of Heat, or Fire. The ſame thing was afterwards confirmed by *Tſchirnhauſen*'s glaſſes at *Paris*. *Mem. de l'Ac.Roy. des Sc.* 1699. p. 110. And laſtly, in the *Focus* of *Vilett*'s Mirrour directed to the Sun at mid-day, there is not the leaſt appearance of a lucid image, unleſs it falls upon an opake Body, or a perſon ſhould on a ſudden fatally put himſelf directly againſt it; and yet there is in that very place a Fire ſo intenſly hot, that it is able in the leaſt inſtant of time to melt even ſtones themſelves. Now will any one pretend that Light can be a proper meaſure of the quantity of Fire, when we evidently ſee, that there may be the ſtrongeſt Fire without any viſible Light; and on the other hand, the moſt refulgent Light without producing the leaſt degree of Heat?

Upon the head of Colour now, there is little room to ſay any thing: For as this is either Light itſelf, or a various reflexion of Light from opake Bodies, it is evident from what has been demonſtrated of Light's being an inſufficient mark of Fire, that Colours of conſequence muſt be much leſs ſo. And Colours

As theſe, therefore, do not anſwer our purpoſe, we muſt carefully examine the remaining effects of Fire, to ſee if we cannot at laſt diſcover one of them, which will ſerve us as a certain token, and a proper meaſure of the preſence, and quantity, of this moſt active Element. But alas, Gentlemen! the more accurately one contemplates them, the readier one is almoſt to deſpair of gaining one's point, they appear ſo full of contrarieties. If we conſider, for inſtance, its power of attenuating Bodies, why we ſee, on the other hand, that a great many are more cloſely compacted together by it. Some are conſolidated by this Element, whilſt it has a power of diſſolving others. Many it ſeparates into different parts, though at the ſame time it unites, and combines others more And the other effects of Fire.

intimately, than can be effected by any thing elſe; as we ſee plainly in the making of Glaſs, and the mixing of Iron and Gold. But this fruitful argument will carry me to too great a length: In ſhort, therefore, I'll venture to aſſert, that you can ſcarce mention any one effect of Fire, which you may imagine to hold good in all Bodies, but I'll ſhew you a quite contrary one produced in ſome, by the very ſame Fire. You'll be apt therefore to ſay, does then this wonderful cauſe produce no one effect, which is always, and every where the ſame, perfectly inſeparable from it, and conſtantly invariable in every kind of Object? Why, Gentlemen, I believe there is ſuch a one; and by the moſt faithful, and diligent inquiries I have been able to make, I never could diſcover any more.

The rarefaction of Bodies a mark of Fire.

For upon a careful examination of natural Bodies, I don't find any one to which that Being may not be applied, which we generally call common Fire, whether ſolar, artificial, or ſubterraneous: But ever body, without exception, that has been hitherto try'd, upon its being united with this Fire, increaſes in its magnitude, ſwells, and rarefies, without any apparent alteration in its weight. Nor does it at all ſignify whether they are ſolid, or fluid; hard, or ſoft; light, or heavy; for the ſame law holds conſtantly and univerſally true in all.

If you take two Bodies, however, of the ſame bulk and weight, one of which is ſolid, the other fluid, you will always obſerve this difference, that the fluid one will ſuffer a greater expanſion from the ſame Fire, the ſolid one a leſs: At leaſt, I have never found it otherwiſe in thoſe that I have hitherto made trial of. Fluids, therefore, are more proper for the examination of Fire by this effect, than Solids. But again, I have conſtantly found, that thoſe Liquors which are leſs denſe, and light, are always the moſt rarefied by the ſame degree of Heat; and conſequently, the expanſion of the lighter Fluids will moſt ſenſibly affect us, and are therefore the moſt ſuitable to indicate to us the very minuteſt augmentations of the ſmalleſt Fire. The truth of this I confirm by the following Experiment: You perceive, that this Glaſs in my Hand, which conſiſts of a ſpherical Body, and a narrow cylindrical Neck, is fill'd with fair Water as high as this mark which you obſerve on the Neck; as ſoon now as I dip the bulb of the Glaſs into the warm Water that is contain'd in this open veſſel, you ſee immediately that the Water in the Neck riſes above the firſt mark, and aſcends continually, ſo long as it acquires a ſtill greater and greater degree of Heat. Again, if I take it out of this Water, and put it into that other which is ſomewhat hotter, you perceive that it riſes ſtill higher in the Neck of the Vial. And laſtly, as I move it nearer and nearer to the Fire, you diſcern that it is more and more expanded; and that it deſcends again by degrees, as ſoon as ever I remove it farther from it. Now does it not hence very plainly appear, that the Water is expanded by the Fire, ſo as to take up a greater ſpace when it is heated, than it did when it was cold, and that, without any ſenſible increaſe of its weight? And is it not as evident, that this ſolid glaſs Veſſel is not equally dilated with the Water; ſince, tho' this is heated to the ſame degree, and indeed ſooner than the Water, yet the Bulb is not now able to contain it as it did before, and therefore ſome of it riſes into the Neck? Again, pleaſe to turn your Eyes this way, and here you'll ſee how much quicker Alcohol of Wine riſes in this Glaſs, when it is immerged in the ſame hot Water, and how ſwiftly it mounts to the very top of the Neck, ſo that it is ready to run out at the Mouth. Hence then, with me you will readily infer, that Alcohol, which is lighter than Water, is ſooner, and more rarefied by the ſame degree of Heat. Theſe Experiments therefore, tho' they may ſeem plain and trifling, evidently confirm the truth of what I aſſerted. And I wiſh that thoſe Gentlemen who have had a thorough knowledge of Hydroſtatics, had given us the comparative weights of all the Fluids we are hitherto acquainted with: Then, poſſibly, I might have been able to lay down this as a general Rule, which the conſideration of many of them ſuggeſts, *viz.* that the ſpaces of expanſion from the ſame degree of Fire, are to one another, as the rarities of the expanded Bodies, or in a reciprocal proportion of their denſities. Theſe that follow are found, by Experiment, to ſucceed one another nearly in the order they are mentioned:

The lighteſt of all Fluids is the *Vacuum* of *Torricellius.*
Then *Boyle*'s.
Air.
Alcohol.
Pure diſtill'd *Petroleum*, *Boyl. Mech. Qual.* 88.
Spirit of Turpentine.
Water.
Vinegar.
Aqua Fortis.
Spirit of Nitre.
Oil of Vitriol.
Mercury.

See the great *Boyle*, in his *Medicin. Hydroſt.*

If ſeems, therefore, as if the eaſy expanſion of the ligheſt Fluids, might ſerve as a certain mark of the preſence, increaſe, or decreaſe of Fire: For this no ways depending upon our ſenſes, which we find in theſe inquiries to be ſo uncertain a guide, will not eaſily lead us into miſtakes. Beſides, this will determine to the greateſt exactneſs its very ſmalleſt increments, or decrements, which cannot be ſo nicely adjuſted by any other method that I am acquainted with. And there is yet this further advantage in it, that it may moſt expeditiouſly be called into uſe in any place whatever that you have a mind to, even in the inſide of Bodies, as well as without them; for it is always and every where equally ready for ſervice. And laſtly, it has this excellency in it, that this expanſion of Bodies by Fire, if it is effected in a Glaſs hermetically ſealed, cannot be produc'd by any other phyſical cauſe hitherto known. We have now therefore at length diſcover'd that property of Fire which we were in ſearch after; which may, and ought to be regarded as a true, certain, individual, and proper mark of Fire. This then alone is what we ſhall make uſe of as we proceed in the inveſtigation of its Nature; and we ſhall take it for granted, that in every *Phænomenon* where we ſee this rarefaction excited, there is there a proportionable degree of Fire as the cauſe of it; by which means we ſhall have an opportunity of examining it in almoſt every circumſtance, and hence may fairly reaſon about its hidden Nature, which will diſcover itſelf to us in every Experiment of this kind. Now in the proſecution of theſe inquiries, we ſhall begin with the moſt plain Experiments, and proceed in order to

thoſe

thoſe that are more uncommon; and thus lead you by degrees from the ſimpler, to the more abſtruſe properties of this Element.

EXPERIMENT I.

Iron is inlarg'd by Heat in all its dimenſions.

Fire expands the hardeſt Bodies in all their dimenſions ſo long as it is contained in them.

Which I thus demonſtrate. You ſee theſe two iron cylindrical Rods, which are exactly three feet long, and pretty nearly of the ſame thickneſs, as you perceive by their juſt paſſing through this iron Ring.

One of theſe I'll put into the tower of this Athanor, in which there is a Fire; and when it has been there a ſufficient time to heat it, I'll take it out again. You ſee now that it is almoſt red hot, and that when I apply it to the other Rod that is cold, it exceeds it in length very conſiderably ſince it was put into the Fire.

Decreaſes again as it grows cool.

You obſerve farther, very evidently, that as it cools, it grows every moment ſhorter and ſhorter: And now it is quite cold, it is of the ſame length with the other; its length decreaſing in proportion as the cold returns, and the Fire leaves it.

I have now again made the end of the ſame Rod red hot, and endeavour, as you ſee, to thruſt it through this Ring, but am not able: For you are witneſſes, that it is a good deal thicker now than it was when it was cold. But have a little patience till it is quite cold again; and now you ſee it will go through the Ring: So that tho' this would not admit it when it was hot, yet it lets it eaſily paſs through now it is cold.

A method by which this increaſe may be meaſured. Pl. I. Fig. 2.

If any perſon now has a mind to meaſure exactly the difference there is betwеen the length of a piece of Iron, or any other ſolid Body, when it comes red out of the Fire, and when it is cool'd to any certain degree determined by the Thermometer, he may do it in the following manner: Let AB and CD be two parallel braſs Plates, contriv'd ſo to move upon the ſide ones, that their paralleliſm may be always preſerv'd; and let the ſide ones be divided into very ſmall equal parts. Take then the Body you deſign to make your Experiment upon, and fit it exactly, when it is cold, betwixt AB and CD, cloſe to the Plate AC. Then put it in the Fire, and when it is red hot, as nimbly as poſſible place it pretty near the ſame AC, and remove AB from CD, till they can contain the heated Body betwixt them; which muſt be done expeditiouſly, that A C may not be too much heated. You will then have the difference betwixt the Rod when it is cold, and after it is heated: But you muſt take care that the Rod be made ſharp at both ends, as you ſee in the figure E F, that it may heat the Plates as little as may be. The ſame thing may likewiſe be determined in the manner following: Let AB repreſent a ſtreight braſs Ruler, the longer the better, at whoſe extremity B, let there be another pretty long one fixt perpendicularly, and minutely divided into equal parts, and let the braſs Hypothenuſe AD be made moveable at A, upon the plane ABC: Then if the heated Rod is placed upon AB, it will elevate the Ruler AD, and by the motion of this upon BC, you will have the difference you wanted, which will be the more remarkable, the longer you make AB, and BC.

Fig. 3.

This expanſion happens in all Bodies.

1. Now this expanſion of ſolid Bodies by Fire, is ſo univerſal, that I have never

never obſerved it to fail in any one that I have had as yet an opportunity of making trial of: Which is a remark of conſiderable conſequence in our preſent inquiry.

Take care, however, you don't here fall into an error, by imagining this expanſion to be equally great in all kinds of Bodies: For by every Experiment that I have hitherto made, it appears that heavier Bodies ſuffer a leſs, and lighter a greater dilatation from the ſame degree of Heat; ſo that this rule ſeems to hold true of all in general. But let it ſuffice that I have hinted theſe things to you; you yourſelves will eaſily carry on theſe obſervations, by the help of the ſecond inſtrument, and examine, whether, univerſally, the dilatations of ſolids by the ſame degree of Fire, are in a reciprocal proportion of their reſpective denſities? I did deſign to have purſued this inquiry farther myſelf; but the multitude of my affairs, and the little time I had to ſpare, would not permit it: Thoſe things, however, which I have ſeen and perform'd, perſuade me to believe, that the rarer Solids are always more dilated, and the denſer leſs, by the ſame Heat. But is different in Bodies of different denſities.

But there are ſtill other cauſes that produce ſome variety in the degrees of this expanſion of Bodies, beſides the difference of their weights; which I came to the knowledge of in the following manner. I deſired that induſtrious and incomparable Artiſt, *Daniel Gabriel Fahrenheit*, to make me a couple of Thermometers, one with the denſeſt of all Fluids, Mercury, the other with the rareſt, Alchol, which ſhould be ſo nicely adjuſted, that the aſcents of the included Liquor in the ſame degree of Heat, ſhould be always exactly equal in both, as might appear by a ſcale fix'd on the ſide. This, after a good deal of intreaty, he endeavoured to do; but tho' he had made his calculations with the greateſt accuracy, yet upon examination I found they did not perfectly agree. I acquainted this honeſt Gentleman, therefore, with my diſappointment, and he candidly confeſs'd that there was a defect, and acknowledg'd frankly that he did not then know the occaſion of it. However, not being ſatisfied himſelf, he ſet about more diligently to inquire into the cauſe of this difference; and upon a nicer examination he diſcover'd, that the various ſorts of Glaſs made in *Bohemia*, *England*, and *Holland*, were not expanded in the ſame manner by the ſame degree of Heat; but that one ſort of it was affected ſooner, and with more eaſe, another with more difficulty, and in a longer time. And hence he found out, that his method of making theſe inſtruments would ſucceed, if they were both form'd of the ſame ſort of Glaſs; but would be defective, if one was made of *Bohemian*, and the other of *Dutch*: For it appeared, that that Glaſs which requires a ſtronger Fire to melt it will be leſs expanded, whilſt that which runs eaſily in the Fire will be more dilated, if they are both expoſed to the ſame degree of Heat. How infinitely careful therefore ought we to be in our ſearches after natural knowledge, if we would come at the truth? How frequently ſhall we fall into miſtakes, if we are over haſty in laying down general rules? How vaſtly preferable is that Science, which is form'd with patience and deliberation upon cautious Experiments, to that which is the effect only of raſh and precipitate ratiocination? And varies too from other cauſes.

2. This expanſion always increaſes in proportion, as a greater quantity of Fire is admitted into the expanded Body; ſo that this Rod, when it is perfectly white with Heat, is longer than it is when it is not red, tho' it ſhould ſtill continue exceeding hot; and it is ſhorteſt of all, when it has laid a good The greater the Heat is, the greater the Expanſion.

 while

while in the most intense cold. Here, therefore, I would again recommend to you, the making some Experiments upon Iron, (which of all Metals will bear the strongest Fire without being fused) in order to discover the difference of its length, when it is just upon melting, and when it is perfectly cold in the coldest season: For then you will have the action of this expansive power in its greatest latitude.

When Solids are put in fusion by Fire, their expansion ceases.

When once Iron is put in fusion, and becomes a fluid Mass, it seems afterwards to continue of the same bulk, tho' the action of the Fire upon it is increased by the assistance of Bellows: And then possibly, if it is not capable of receiving any more Fire, nor consequently, of being farther expanded by the force of any common one: For Metals, when they once are melted, do not seem, as far as one can judge, to admit any more Fire, except it is collected by Bellows, a Mirrour, or Burning-glass, and by this means directed to some particular part of them.

All the parts of Bodies are put in agitation by Fire.

3. Hence we evidently perceive, that Fire, as it increases from the greatest degree of known Cold, to the most intense Heat, must necessarily dilate all the parts of the hardest Bodies to which it is applied, and remove them from their mutual contact. It appears farther too, that this extension, and the rarity of the Body consequent upon it, is successively augmented, 'till the whole Mass, supposing it fusible, becomes fluid in the Fire. And hence it follows, that all the constituent parts of Bodies, during the application of these different degrees of Heat, are continually expanded from the centre of their substance, as well as the whole Body itself.

Even in the very hardest.

Thus then we see, that the particles of Fire which are distributed through the corporeal Mass, act with an equal force upon all its *moleculæ*, or corpuscles; nor is there any Body so hard, or rigid, that it will not submit to the power of this Element, and may be so chang'd through its whole substance by the very gentlest action of it, that there sha'n't any one part of it remain unaltered.

4. Now what is the expansion of Bodies, but a dilatation of them into larger spaces than they took up before? Hence therefore we infer, that their component parts must be constantly in motion during this extension. Nor does it less evidently appear, that Fire moves all the particles of the hardest Mass, both external and internal, towards every point of its surface, and always so much the more, the fiercer it is; till at last, having reduced them into a state of fluidity, it then violently agitates, mixes, and drives them one among another.

Does Fire melt Bodies into their very Elements?

Does Fire then so attenuate and divide such a Body, that those corpuscles which are thus fluid, are in reality the very Elements of the Bodies, so long as they continue in this state? And is this the reason, that the particles of Metals, when in fusion, are so intimately mingled one among another, that it is impossible to reduce them to the same degree of fineness by any other method? Why certainly, the docimastic Art, which is the truest of all Arts, informs us, that if one grain of Gold is mix'd with a hundred thousand grains of the purest Silver whilst they are fused, so that they may be perfectly melted together, then the Gold will be so dispersed among the particles of Silver, that if you afterwards take the least bit of this compound, you will find the proportion of the Gold to the Silver, as 1, to 100,000: Nor indeed, has there ever been discover'd any limits to this division and distribution of the Gold among the Silver. If

you

you accurately examine, then, the effect of this Experiment, you must readily allow, that the Fire, whilst it gradually acted upon the Gold from its greatest degree of cold, so agitated its elementary Particles, that they continually cohered less and less, till at length their cohesion being perfectly destroy'd, they were separated, and run from one another. And here, Fire, so long as it exerts this force upon them, is the only cause that these Particles, tho' they touch one another, do not coalesce; for that being removed, they are again presently united into one solid Mass.

The parts of melted Metals attract one another.

I confess, indeed, that the parts of pure Metals, when they are put in fusion, retain a tendency towards a union: For I always observe, that Gold, Silver, and other melted Metals, immediately collect themselves into a globular figure, perfectly in the same manner as Mercury would form itself into a sphere, if the weight of its parts did not prevent it. This property, however, cannot exert itself with any effect, so long as the violence of the Fire is continued; which is pretty extraordinary.

Fusion alone perfectly unites the parts of Metals when they are separated asunder.

Again, it is impossible to unite two pieces of Gold together in such a manner, that they shall regain the tenacity that's peculiar to this Metal, unless you first divide them into their ultimate parts, by reducing them to a fluid state by Fire; but then, as soon as ever they are cold, they immediately recover their former ductility: And what we have asserted of Metals, holds true likewise in other simple Bodies; as we see in fix'd Salts, Glass, and many others. Lastly, it appears from what has been said, that it is not only possible, but really true in fact, that the most fix'd and solid Body, may be so continually agitated in its constituent Elements, that there sha'n't be any one Particle of the whole Mass, tho' ever so small, that will be absolutely at rest. All which observations follow so evidently, from the consideration of the aforemention'd Experiment, that nothing can possibly be clearer. Does therefore the influence of Fire reach even to the most intimate nature of Bodies? Surprizing Power!

5. Why therefore should that *Phænomenon*, which is often observ'd to happen, any longer appear so wonderful, *viz.* that houses built in the strongest manner, frequently tumble down in very hot clear weather, and for the most part in the middle of the day, when there is no wind at all to affect them?

The same Bodies not equally great in all parts of the world.

6. From this property of Fire we learn yet farther, that Bodies removed into the torrid Zones, grow bigger in all their dimensions, than they were in a colder climate: That hence they will become comparatively lighter, as they contain the same quantity of matter under a larger surface: That their percussions, of consequence, will be more feeble: That *Galileo*'s pendulums, therefore, that are made in the frigid Zones, if they are remov'd into the torrid ones, will increase in their length, of course, and will take up a longer time in performing their oscillations; on which account clocks the best carried thither, will be found to vary from the truth. The same things in proportion hold true likewise in the same climate, according to the various vicissitudes of Heat in the different seasons of the year.

The laxity of Bodies, what.

7. That very ancient observation therefore is most certainly just, that Bodies are principally relax'd and weaken'd by Fire: For as these two words denote that condition of the Solids by which they are disposed to have their parts more easily separated, it evidently appears from what has been said of

Fire, that this is the very thing it is effecting from the first instant of its acting upon them, and that through every degree of its increase it brings about this dissolution more and more, till at length the most solid parts retain their firmness no longer, but dissolve, and melt away. And this is confirmed by the universal testimony of all Historians, who inform us, that the inhabitants of *Asia*, and *Africa*, who are exposed to the scorching heat of the Sun, have always been of a softer and weaker make, and less fit for hard labour, than those of colder climates. And in like manner we see, that in the most ardent Fevers, our Bodies are quite dissolv'd, and enervated. I confess, indeed, that at that time too they are parch'd up with the heat, and by this means grow dry and more rigid: But then this is not to be attributed to the Fire, as it is dispersed among the Solids, but only as it dissipates the most watery part of the Fluids; and in this sense alone is it true, that Fire ever gives strength to Bodies when once they are debilitated.

EXPERIMENT II.

Cold reduces all Bodies into a less space,

Cold, by which we universally mean the absence of Fire, contracts the hardest Bodies in all their dimensions, so long as it remains in them. This I demonstrated to you so plainly in the latter part of the former Experiment, that it would be paying a very indifferent compliment to your understanding, should I attempt the proof of it again. You'll give me leave, however, to point out to you the consequences that evidently follow from it; of which let this be the first.

Of what kind soever.

1. All solid Bodies are equally affected by this action of Cold; nor was there ever observ'd any one, tho' ever so firm, and closely compacted, but might be still farther condensed by it; even Diamonds themselves, the hardest of all Bodies, not excepted.

This contraction increases in proportion to the cold.

2. This contraction of Bodies is always increased, in proportion as the cold is augmented; and the former expansion, which they had in a lesser degree of cold, is diminish'd; which ought to be consider'd.

And lessens the cavities of Bodies.

And, which is pretty remarkable, this reduction of Bodies into smaller spaces, happens even in hollow spheres, and orbicular rings, and is directed towards the center of the Body, or Surface. For when this Iron ring is cold, it will not admit this Iron cylinder, tho' it will receive it within its cavity after it is heated. This glass sphere, with this very narrow cylindrical neck to it, is fill'd as you perceive with a colour'd Liquor, as high as this mark which you see on the Cylinder: I dip this now into a Fluid, that is a good deal colder than the Sphere, and what is the consequence? Why you observe, that the Liquor in an instant rises very discernibly higher than it was before, tho' afterwards, indeed, it sinks down again. And the reason of this is plain; for the external cold being immediately apply'd to the Surface of the immersed Sphere, must of course affect that, before it can reach to the included Fluid; and hence, that being contracted into a narrower space, must necessarily expel some of that Liquor into the neck, which before it was capable of containing: But afterwards, when the cold has intimately penetrated into the Liquor itself, that is condensed as well as the Glass, and so must of consequence descend again. From this Experiment then we learn very clearly, that this power of contraction exerts itself, if I may so express myself, upon the very substance

of

of Bodies. In other glaſs veſſels made hot, and then expoſed to the cold, this coarctation is much more evident.

3. Again, it appears, that this contraction of Bodies into leſſer ſpaces, proceeds always in proportion to the cold itſelf; whence it plainly follows, that ſince they ſtill contain the ſame quantity of matter in a leſſer bulk, it muſt increaſe their comparative, or ſpecific gravity: Nor is it leſs evident, that every Solid is then actually leaſt, when it is affected by the intenſeſt cold. As there is, however, no aſſignable Body in which there is abſolute Cold, or no degree of Fire, hence, it is impoſſible to reduce any Body, an ounce of Gold for inſtance, to its leaſt poſſible ſize; tho' the proportion of this condenſation from different degrees of cold may be nevertheleſs diſcover'd. Hence the ſpecific gravity of Bodies uncertain.

4. From the ſole abſence of Fire, therefore, there raiſes in every ſolid corporeal Maſs a very ſurprizing motion, both in its internal and external parts, by which all its Elements conſtantly tend towards its center, and by this means become more intimately united with one another. If then we conſider cold as a mere privation of Fire, it follows, that this power, by which the Elements of Solids contract themſelves into a ſmaller ſpace, muſt be look'd upon as ſomething implanted in matter itſelf, whilſt the force by which they are expanded, muſt be regarded as the action of Fire; which, conſequently, being external, and accidental, cannot exert itſelf upon Bodies, without offering them ſome degree of violence. Hence, therefore, all Solids would naturally endeavour to form themſelves into little compact Maſſes, and when they were reduced to the ſmalleſt ones poſſible, would enjoy a moſt fix'd perfect quiet: Whilſt on the contrary, they would be ſo conſtantly agitated by the action of Fire, that their parts could never poſſibly come to a ſtate of reſt. The laſt effect of cold, therefore, upon the Particles of Bodies, would be their moſt intimate union, and abſolute reſt: That of Fire, their diſſolution, and perpetual agitation. The ſubſtance of Body is condenſed by cold. Hence a cold is proper to Body.

Does Fire and Cold, therefore, alone, affect the very ſubſtance of Bodies, whilſt every thing elſe reaches only their conſtituent parts? Does perfect reſt, in any part of ſpace, produce the greateſt degree of Cold? And ſhould any place be perfectly free from Fire, ſo as not to poſſeſs the very leaſt degree of it, would there of conſequence neceſſarily follow abſolute reſt? Heat and Cold, the principal agents upon Matter.

5. Hence it appears farther, that Pendulums growing ſhorter about the Poles of the Earth, will perform a greater number of vibrations within any given time; and their appended weights being condenſed, will ſuffer a leſs reſiſtance from the Air. And hence too does it not ſeem probable, that the Cold towards the Pole, and the Heat about the Equator, are one cauſe of the ſpheroidal figure of the Earth? The figure of the Earth from Heat and Cold.

6. Again, Cold condenſes all ſolid Maſſes, by reducing that very part of them, which we call Body, into a leſſer ſpace than it took up before; and hence their whole matter being more cloſely united, there almoſt always ariſes a ſtronger coheſion of the Maſs in general; which is what we call ſtrength, and firmneſs. From the ſame cauſe too, the particular Particles of which the Body is compos'd, are more ſtrongly compacted together, nor ſuffer themſelves to be ſo eaſily ſeparated aſunder, as they were in their former ſtate; which therefore is a ſecond cauſe of their ſtability. And laſtly, as far as one can judge, the very conſtituent Elements of Bodies are render'd more denſe by Cold, as well as the whole Maſs; and this gives them the greateſt degree Denſity from Cold.

of ſtrength, and was what we juſt now called acting upon their very ſubſtance. But, Gentlemen, what notion can the moſt ſubtle penetration form of ultimate Body? For my own part, I confeſs, all that I can conceive here is this, that any ſingle Body, ſuppoſing it ſimple, is compoſed of leſſer Bodies perfectly like the greater, and theſe again in the ſame manner of ſmaller, and ſo on beyond any limits that the mind is capable of fixing: That there is a certain principle implanted in ſome corpuſcles by the great Creator, by which they are united and form'd into little Maſſes, which it is not poſſible for any natural, or artificial Power, to ſeparate aſunder; and which of conſequence remain always the ſame, notwithſtanding all the violence that can be exerted upon them: And laſtly, that theſe may be concreted with one another, and by their reciprocal attraction, produce ſo firm a union, as will be very ſeldom deſtroy'd, and then only by ſome few particular cauſes, which will be able to effect nothing more upon them, than barely dividing them aſunder, and reducing them again to their original ſtate; for then they will be perfectly immutable as they were before. Theſe few ſimple things, are all, that upon the moſt intent inquiry into the powers and operations of Nature, I have been able to come to the knowledge of. Hence we underſtand what were the Atoms of *Democritus*, the *Monads* of ſome Philoſophers, the *Hylarchic* Principles of others, and the laſt Principles of Bodies of almoſt all Philoſophers in general. Are thoſe Particles therefore ſo ſolid, that they won't admit even Fire itſelf within them? And hence are they neither dilatable by any natural power, or reducible into a leſſer ſpace? And of conſequence, does condenſation and rarefaction affect only the corpuſcles which are compounded of theſe Elements, and not the very Elements themſelves? Be this as it will, this is certain, that both the Philoſophers and Phyſicians have conſtantly obſerved, that all Solids in the Animal, Vegetable, and Foſſil Kingdom, are ſtrengthen'd by cold, and the condenſation that ariſes from it.

A Duumvirate and viciſſitude of Heat and Cold.

7. The alternate viciſſitudes of Heat and Cold ſeem to produce a continual motion and agitation in all the Bodies in the univerſe, and in all their Particles, as often as they ſucceed one another, inaſmuch as the actions of each of them muſt neceſſarily bring about the effects already mention'd.

Always and every where alternate.

8. Now theſe ſeldom continue to act long upon Bodies in the ſame degree, but are perpetually changing, and when one begins to grow exceſſive, it is generally ſoon temper'd by the ſucceſſion of the other, whoſe effects are quite contrary to the former. For if we diligently examine into the order of Nature, we ſhall find nothing more cautiouſly provided againſt, than that the ſame degree of Cold or Heat ſhould reign for any conſiderable time. Is not the Earth, for inſtance, diſpoſed in ſuch a manner, with regard to the Sun, that at one time it may receive its rays in a more oblique direction, at others in a more perpendicular one, nor ſhould ever remain for the leaſt ſpace of time in the ſame aſpect? by which means, this perpetual change of Heat in the different ſeaſons of the year, brings about very different effects. Nor is there a leſs variation produc'd in Heat and Cold by the alternate ſucceſſion of day and night; for hence it comes to paſs, that they ſeldom continue in the ſame degree, for ſo ſmall a time as the ſpace of an hour: Nor are the Meteors we obſerve in the Air, a leſs evident proof of this mutability. The Sun again, has no ſooner parch'd up the Earth with its ſcorching Heat, and fill'd the Atmo-

ſphere

ſphere with vapours and exhalations, but there very ſoon follow Clouds, Thunder, Lightning, Hail, and Rain, ſo that inſtead of that exceſſive Heat, there preſently ariſes a very conſiderable Cold. From theſe conſiderations then, I can't but infer, that in every ſolid Body that exiſts in our World, there is a conſtant periſtaltic or oſcillatory motion of all the particles that enter into its compoſition.

9. It appears evident, now, that this reciprocal ſucceſſion of Heat and Cold induces very different and more powerful alterations in Bodies, than either of them would do were they continued any conſiderable time in the ſame degree. By the ſame Heat, for inſtance, acting upon them a long while, Plants and Animals are rendered dry, and the remainder becomes more durable; and a conſtant Froſt effects the ſame: Whereas if theſe very frequently ſucceed one another, there follows an intimate ſolution of bodies, which are hereby diſpoſed to become volatil, and are in a great meaſure diſſipated into the Air. But there would be no end, ſhould I only hint at the effects that are hence produced. Of great uſe to the world.

10. For this reaſon the wiſe Author of Nature ſeems to have ordained that ſuch a viciſſitude of things ſhould be fixed, and unalterable; that thus the whole univerſe might remain in a perpetual motion, not only in the larger Bodies that compoſe it, but alſo in their moſt intimate and ultimate particles, that by this means the production, increaſe, ſtate, decreaſe, and diſſolution of every thing might be brought about by the ſame law. Putting every Body into motion even to its moſt intimate parts.

11. But who, now, will pretend to determine the ultimate limits of Cold? Or where is that ſo intenſe, that it cannot be increaſed? There, you'll be apt to ſay, where there is no Fire. True; but it is impoſſible for us to find any ſuch place; nor can the ſubtleſt Artiſt with all his ſkill ever perfectly extract Fire out of any Body, or any part of ſpace. Upon this head, therefore, we need not trouble ourſelves with any farther Inquiries. May the ultimate degree of Heat, therefore, be more eaſily diſcovered? Nothing leſs; for we are here as much at a loſs to find out the greateſt quantity of Fire that may be contained in any given ſpace, as we were before to aſſign any place that is abſolutely free from it. The violence of that Fire which we ſee collected in the *Focus* of a large concave Mirrour, or a convex Burning-glaſs is apt to ſtrike us with aſtoniſhment: But who knows how prodigiouſly this power might be increaſed, if the concave ſurface of the *Speculum* was vaſtly greater, and of a conoidal, or parabolical figure? Or if it could be made of a ſubſtance perfectly ſolid without the leaſt Pore in it? Or laſtly could it be formed of ſome matter of ſuch a nature, that it would reflect the rays exactly in the ſame manner as they fell upon it? The limits of Cold not to be determined.

12. 'Tis ſufficient, however, for our purpoſe, if we can determine the different degrees which happen commonly here upon our Earth. And it is very eaſy now to inform ourſelves, what alterations happen in the increaſe or decreaſe of Heat, and when it continues the ſame, by what has been already delivered: For here (as our ſureſt guide) we have principally to regard the dilatation or contraction of Bodies, which by proper inſtruments may be readily aſcertained without difficulty. The degrees of it may be compared together.

13. In the mean while it muſt be confeſſed, that it is both an ingenious and difficult work to determine the quantity of Fire in any given place, ſo as to be able to expreſs the proportion of it in numbers to any other known Fire. And exactly enough be expreſſed by numbers.

It is eaſy enough, it's true, to perceive whether it is increaſed, or not; but to diſcover the degree of this augmentation, is vaſtly more difficult. It will appear, however, preſently, that even this, hard as it is, is not impoſſible, but may be attained to by human induſtry. All theſe things now, ſeem ſo evidently to flow from our firſt and ſecond Obſervation concerning the nature and preſence of Fire, that I think they may be fairly taken for granted, nor will they be of ſmall ſervice to us in our chemical Inquiries.

EXPERIMENT III.

Common Air, is every way expanded by the leaſt increaſe of Fire in its whole bulk, and in all its parts.

This the Philoſophers were long ago acquainted with; tho' the illuſtrious *Boyle* principally ſet about the proof of it: Upon this head therefore we need not detain you.

The Air-Thermometer of *Drebbelius.* The truth of this was ſufficiently demonſtrated formerly by the Thermometer invented by *Cornelius Drebbelius* of *Alcmar*; for this purely by the aſſiſtance of rarefied, or condenſed Air, very evidently repels liquors from it, or attracts them to it. You ſee, for inſtance, by only breathing upon this Sphere, I make the coloured fluid in the neck to fall lower: But as ſoon as I leave off it begins again to aſcend: And upon the approach of a warm hand towards it, you perceive the ſame effect is inſtantly produced. Now theſe Improved. Inſtruments may be rendered ſo ſenſible of the very leaſt degree of Heat, that by the help of them you may plainly diſcern the perpetual Syſtole, and Diaſtole of the Air, which is never obſerved to be at reſt. The conſtruction is as follows. Let your veſſel that is to contain the Air be made of thin and very clear glaſs, and formed of two Segments of a Sphere joined together, and Plat. II. Fig. II. ſo contrived that the two great oppoſite Segments AB, CD, may be pretty near one another: And here the larger the veſſel is, and the leſs ſpherical the Figure, if the Air can but be eaſily contained in it, and freely paſs in and out, the fitter it will be to demonſtrate theſe minute differences. To this veſſel then let there be connected a ſlender pipe EF, open at F, and as narrow as it can be made, without hindering the free paſſage of the Air with all its force. If this Inſtrument, now, being full of common Air, as it will be of courſe if it is expoſed to it, has its lower orifice F immerſed in a veſſel filled with water deeply tinged; and you then gently heat the glaſs ABCD, you will preſently obſerve bubbles of Air paſs out of EF, by the mouth F, which will continue to do ſo, as long as you keep the Fire near the glaſs. When, therefore, you have forced out a ſufficient quantity of Air, which muſt be but a few little bubbles, remove the Heat, and the coloured liquor will immediately aſcend into the neck; and if you have taken care that too much Air was not expelled, it will get no higher than about the middle of the pipe EF; and then you will have the pleaſure of obſerving the perpertual riſings and fallings of the liquor in the neck, at the ſmalleſt changes of Heat, and Cold. And this will be always the more evident the thinner the glaſs is, the larger the veſſel ABCD is in reſpect of the Cavity of the pipe EF, and the nearer the Segments AB, CD, are made to approach to one another; as is eaſily demonſtrated by Hydraulics. You readily apprehend, now, why I prefer the Segments AB, CD to a Sphere in this Inſtrument, and why I would have

them

them but at a ſmall diſtance: For you ſee plainly that by this means the ſurface of the included Air being much increaſed, either Heat, or Cold will be more readily communicated quite through it. But that the truth of this may appear evidently to you all, ſee here I take this chemical glaſs with a large belly, and very ſlender neck; which being now full of the common Air, we breath at this time, I thus invert, and immerge into this Water. You obſerve now, that as I bring the Fire near the glaſs, the included Air runs out of the neck in bubbles through the Water. You conceive therefore, that there is leſs Air at preſent in the veſſel than there was before, and that in proportion to the quantity of bubbles that were forced out. I'll now remove the Fire: and you ſee how inſtantly the Water aſcends into the neck; and perceive farther, that as I bring the Fire nearer, and remove it by turns, how the Water alternately riſes, and falls, ſo that it ſcarcely remains a moment at reſt.

COROL. I.

This expanſion of Air by Fire extends to a prodigious ſpace, nor can eaſily be determined by any Experiments. For a proof of this, heat a hollow ſpherical glaſs in a glaſs-houſe furnace till it is juſt ready to melt, then hermetically ſeal it there, and afterwards carefully cool it by degrees, and you will find that even then it is not perfectly void of Air: For if you ſink it under Water, and there break off the end of the neck, the Water indeed will ruſh in with great violence, but ſtill there will always remain a ſpace at top full of Air, which is able to ſuſtain the whole weight of the Atmoſphere.

Fire in reality expands Air.

Hence, therefore, we evidently learn, that though the intenſe Fire of the furnace rarefied the Air to a prodigious degree, yet it was not able totally to expel it. It is probable indeed, that a greater degree of Heat would ſtill have rendered it more rare; but it is equally probable that it can never be expanded *in infinitum*, and that therefore, there will always remain ſome Air in the very ſtrongeſt Fire. From ſome Obſervations made on this head the famous *Des Amontons* has ingeniouſly inferred that the ſpace into which Air is dilated by the degree of Heat neceſſary to make Water boil, is a third part greater than that which it took up before. I am aware of a plauſible objection, that may be made to the inference drawn from the laſt Experiment, and that is, that the Air which thus collects itſelf at the upper part of the glaſs, when it is immerſed in the Water, does in reality proceed from the Water, whilſt it is forced into the neck by the preſſure of the Atmoſphere: For as this repletion is ſucceſſive, the firſt portion of Water that enters, is in reality, in a more perfect *vacuum* than that of *Boyle*; and conſequently the Air which is mixed with that Water, will endeavour to diſengage itſelf, will ruſh into this *vacuum*, collect itſelf there, and thus hinder the perfect repletion of the veſſel. To this I anſwer, I will allow you indeed that ſome Air may have come into the glaſs, in the manner you mention, but then it muſt be with this limitation; that all the Air that thus extricates itſelf out of the Water into the empty glaſs, will be always again abſorbed by that Water from whence it came, and then the whole cavity will be perfectly filled with Water; for this the accurate *Mariot* has happily diſcovered, and I ſhall evidently make appear when I come to treat profeſſedly of Air: Since therefore (in this caſe) the Air will not be abſorbed, and the Sphere be filled, it is plain that the ſpace that will not admit the Water, does really

But does not totally expel it.

contain a portion of true Air, which the force of the Fire dilated indeed, but was not able perfectly to expel; which was what I asserted.

COROL. 2.

The difference betwixt the expansion of Air, and that of Iron.

If we consider now the dilatation which was before demonstrated in Iron, how very small is that, even in a Fire so strong as to heat it red hot? How great on the other hand do we observe the expansion of Air from a small degree of Heat? We found indeed that Iron is capable of being presently extended by a very gentle Fire; but then, this was not to be discovered without the assistance of an Instrument; whereas the difference of the rarefaction of Air by the same Fire, is vastly remarkable. No Body that we are acquainted with is more easily affected by Fire than Air; nor any one put into fusion with more difficulty than Iron, or which is the same thing, distended to its greatest dimensions.

COROL. 3.

The expansion of Air by the least degree of Heat, discernible.

Hence we may have the pleasure of determining the least increase of the Heat of Air almost to any given measure, that can here be of service: For we have nothing to do, but to make the spherical Segments in the Instrument above described very large in proportion to the capacity of the pipe, and to make this very long; for then, the least difference of Heat will be very sensibly discerned in the pipe.

COROL. 4.

The greatest natural Heat in the Air.

But whereas the greatest natural Heat of the Air, even in the most sultry Dog-days, is rarely observed to come up to the 90th degree in † *Fahrenheit's* Thermometer, hence we know exactly the limits of that Heat, which it will be found hardly ever to exceed. All its natural variation therefore in this respect will consist in its decrease below this degree. Hence therefore the use of the *Drebbelian* Thermometer is very easy, and very serviceable. But then you must take care to have always a Barometer near it, in order to measure the different weights of the Atmosphere at the same time; for that must likewise enter into the consideration. By this means, then, and with very little trouble, you will be able to observe the smallest increases of the least degree of Heat.

† See Plate V. and VI.

COROL. 5.

Air is never at rest.

If we consider, therefore, the very easy dilatability, and contractility of Air by the very least augmentations, or diminutions of Fire, and at the same time remember that these are in a constant vicissitude; does it not evidently appear that this Air can never be at rest, but must suffer a perpetual agitation in all its parts, by which even its very ultimate particles must be kept in a constant oscillation? And this will hold as true in what we call the open Air, which is only kept within its bounds by the weight of the incumbent Atmosphere, as it does in that Air which is perfectly confined in a close vessel.

EXPERIMENT IV.

Air, by the least decrease of Heat, is every way contracted, both in its whole bulk, and in all its parts.

This was evident in all the instances we gave under the third Experiment; for this contraction was always obſerv'd to follow, in proportion as the Fire was removed.

Corol. 1.

The ſpaces, into which Air is thus reduced, grow conſtantly leſs and leſs, ſo long as the Heat decreaſes; and conſequently, there is no ſuch thing as determining the leaſt poſſible ſpace that any quantity of Air may be contracted into, as it is impoſſible to free it abſolutely from Fire; as has been already taken notice of. In the glaſs Thermometers of *Drebbelius*, expoſed to a ſucceſſively increaſing Cold, this obſervation appears very evident.

Corol. 2.

The greateſt contraction that is obſerved in any other Body from the moſt intenſe cold, is leſs than the condenſation that the Air ſuffers from the very leaſt decreaſe of Heat or Fire, that our ſenſes are capable of diſcerning by any other method. And hence for this reaſon, likewiſe, the Air is the fitteſt of any thing to diſcover to us the quantity of Fire.

Corol. 3.

Again, any diminution of Heat or Fire, or the leaſt augmentation of Cold, may be rendered viſible, and adjuſted to any aſſigned meaſure: For this is the converſe only of the third Corollary of the third Experiment.

Corol. 4.

The uſe therefore of this Air-Thermometer, will be ſo much the more excellent, and eaſy, as the greateſt degree of artificial Cold, and the intenſeſt natural Cold of the Winter Seaſon, have been very nicely determined by Obſervation. An Inquiry into the greateſt degree of Cold.

In the moſt ſevere Cold in the year 1709, the liquor in *Fahrenheit*'s Thermometer was obſerved, in *Iceland*, as low as the firſt number; and I myſelf ſaw it one morning this year in our Univerſity garden almoſt down to number 5. Firſt natural,

As for the contrivances that have hitherto been invented to excite artificial Cold, no body has yet been able by the help of them to produce a freezing Cold in Summer, till there firſt appeared a conglaciation of Water, either in form of Snow, Ice, Hail, or Hoar-froſt: For though ſome perſons have come pretty near it; yet it would never ſucceed, 'till the ſeaſon was grown conſiderably Cold, and inclining towards the freezing point, and thus rendered the Water cold, and fit for the purpoſe. There have indeed been a great many, and very laborious Experiments made uſe of, in order to produce the greateſt poſſible artificial Cold. And it has long ago appeared by chemical Obſervations, that Salts, the very inſtant they are diſſolved in Water, will excite a greater degree of Cold, than was in either of them before the mixture. Now the principal of theſe for this purpoſe, is the common pureſt *Sal-Ammoniac*; with which I made the following Experiment. I took four ounces of this Salt, and reduced it to a fine dry powder, and let it ſtand all night in a clean dry glaſs ſtopped very cloſe with a cork. In this condition I put the glaſs with the included Salt, which was ſo ſecured that no moiſture could poſſibly come at it, into ſome fair Then artificial.

Water that had ſtood a whole night expoſed to the open Air; and by this means I brought the Salt, Water, and Glaſs exactly to the ſame degree of Cold. In the morning, then, I placed one of *Fahrenheit*'s Thermometers in this Water, till the Cold of it had fixed the included liquor at the degree 53 above O; and then at once I threw the four ounces of the *Sal-Ammoniac*, into twelve ounces of this Water contained in a cylindrical glaſs, and with a ſtick I briſkly ſtirred them about, and mixed them together; upon which the liquor in the Thermometer immediately fell from the firſt degree 53, to the degree 25; the ſame in the Air open ſtanding at the ſame time at 51. Hence, therefore, it evidently appears, that *Sal-Ammoniac* mixt with Water in a ſubtriple proportion, will generate 28 degrees of Cold in this Thermometer,

Artificial Cold for producing of Ice.

And of conſequence, a Cold that will produce Ice may always be excited by Art, when the Heat of the Air don't make the Thermometer riſe above the degree 60. For it is obſerved, that as ſoon as ever the temper of the external Air reduces the liquor in the Thermometer to the degree 32, then Water, too being equally cold begins to form itſelf into Ice. The colder therefore the Air grows from the degree 60 towards the degree 32, the more will the artificial Cold produced by this method exceed that which is neceſſary to turn Water into Ice.

And a greater degree.

When the Coldneſs of Water therefore is about the degree 32, this mixture will excite a Cold, which will ſink the Thermometer almoſt as low as the degree 4. But now if we take ſome Water in a large veſſel, and by this ſolution make it 28 degrees colder than it was before; and then place another ſmaller glaſs full of Water in this cold *Lixivium*, and by this means give this ſecond Water as great a degree of Cold, as this *Lixivium*, which will remain cold a good while, can communicate to it; we may then, by mixing freſh *Sal-Ammoniac* with the Water in this ſecond glaſs, whilſt it ſtands in the firſt *Lixivium*, quickly produce even in the hotteſt weather a greater degree of Cold than was ever obſerved in our Country. And yet again, if we take the Ice that we may procure by this contrivance, and mix that with new cold *Sal-Ammoniac*, the Cold thus generated will be ſtill more intenſe: So that by this method, we may, in the middle of Summer, preſently excite a ſharper Cold than that of the ſevereſt Winter.

The freezing point not eaſily obſervable.

Give me leave, however, to mention one caution, that may here be of ſervice to prevent your falling into miſtakes, which is, that it is not ſo eaſy to determine that temper of the Air, which is juſt neceſſary to the production of Ice, as one may at firſt imagine. For Heat, and Cold, when they are once communicated to Bodies; remain in them a conſiderable while before they leave them: And the denſer they are, the longer will they retain the Heat impreſſed upon them; as will be demonſtrated in its proper place. And hence it comes to paſs, that though the Air is cold enough to reduce the liquor in the Thermometer to the degree 32, yet there will not immediately be Ice upon the Water; for this being more than 800 times denſer than common Air, will continue warm from the former Heat a conſiderable time after the Air has been affected with a new degree of Cold. If any perſon, therefore, deſires nicely to inform himſelf in what temperature of the Air Water will begin to freeze, let him make uſe of the following method. Firſt ſuſpend your Thermometer in the free open Air; for I have obſerved, that if you hang it againſt a wall, or any other Body, the Warmth that is in them will have ſome effect upon it

When.

When you have in this manner exactly discovered the Heat of the Atmosphere by your Thermometer, expose a small quantity of Water to the Air in such a manner that the surface of it that is contiguous with the Air may be as large as possible; which is best effected by dipping a fine clean cloth in fair Water, and then hanging it open in the Air, and keeping it there some time. By this means, that upon the first freezing Cold, the cloth will grow stiff, and thus shew that the Water at that time begins to be hardened into Ice. And by this method, I have observed that Water will begin to freeze, if it is as Cold as the Air is when the Thermometer is almost at the degree 33; though it will not do so, if it is kept something warmer than the Air, by any Body that is near it, or by the largeness of its own bulk.

And hence it comes to pass that Hoar-Frost, which is nothing but a moisture congealed on the broad surfaces of thin Bodies, as Grass, Leaves, and the fine asperities of the ground, appears a good while before we see any Ice. And in the same manner as Winter comes on, this white Frost appears on bridges that are suspended in the Air, before there is the least sign of Ice in the Streets, or on the Water. But who don't plainly see that this is occasioned by the arch's not being contiguous to any thing else, and of consequence being every way exposed to the Cold of the ambient Air? And for the same reason it thaws there as suddenly. Whereas Bodies that are thicker, retain their former Heat longer; for as they can only receive the impression of the Cold by their surface that is in contact with the Air, they hence must propagate it gradually through their substance towards their Center of gravity; and by this means they successively acquire a greater and greater degree of Cold, till they have been so long exposed to the Air as to be equally affected by it quite through. And here, how much time is necessary for this purpose it is not easy to determine. *Hoar-Frost a mark of it.*

From what has been said, therefore, upon this head it appears, that the limits of the most intense natural Cold that has been observed, have been found to descend to O in the Thermometer; whereas Art, by dissolving Salts in the coldest Water, could never reach below the degree 4, or 3.

The indefatigable industry, however, of the ingenious *Fahrenheit* has discovered somewhat yet farther in this affair, which before seemed quite incredible, and which I think well worth relating in the same manner as it was communicated to me by the Author himself, to whom all lovers of natural knowledge will be ready to make proper acknowlegements for this surprizing Experiment. *Production of a surprizing Cold.*

The severity of the Winter of this year 1729, gave him an opportunity of making some Experiments for the production of artificial Cold; and among the rest, it fortunately came into his mind to try what would be the effect of pouring Spirit of Nitre upon Ice, the Spirit being so strong, that its weight, to that of pure Water, was as 1409 to 1000, when the Heat of both was 48 degrees. He took, therefore, some Ice, and pounding it very small, poured upon it two ounces of this Spirit of Nitre; by which means there was instantly produced such a Cold, that the Thermometer being presently immersed in this mixture, the liquor subsided more than 4 degrees below O. This unexpected and very surprizing event raised the curiosity of this excellent Artist, who could not rest till he had made some farther discoveries. He contrived, therefore, a Thermometer with Quicksilver sensible of the very least alteration of Heat, which he very nicely divided into parts that might be easily discerned, *The great industry of M. Fahrenheit.*

and constructed in such a manner, that O in the cylindrical neck should be 76 degrees above the bulb of the glass. The Spirit of Nitre, then, abovementioned being reduced to the same Coldness as the Air which was at that time 16 degrees, he poured seven ounces of it upon some Ice finely pounded; and the Thermometer immediately fell 30 degrees, viz. from 16 degrees above O, to 14 degrees below it. The Mercury in the Thermometer being then at rest, he poured off the fluid part, and to the remainder of the Ice which was not dissolved, and was now so very cold, he put fresh Spirit of Nitre; upon which the Thermometer sunk to 29 degrees below O. He had then no more Spirit by him, and therefore could not at that time prosecute this experiment any farther.

He poured, therefore, Spirit of Sea Salt that was 17 degrees cold upon some Ice beaten very small; and the Thermometer sunk in an instant to the degree 8 below O. Then decanting the liquor, he mixed fresh Spirit with the remainder of the Ice that was reduced to this degree of Cold; and the Mercury subsided to the degree 14 $\frac{1}{2}$ below O. Being pleased, therefore, with the agreable success of these Experiments, the curious Author was resolved to carry them still farther, and therefore provided some of the same Spirit of Nitre. But the temper of the Air being then so altered that it thawed, he was forced to contrive a method to preserve an artificial Cold after he had produced it; which he did in the following manner. He got three vessels made of very thin plates of Iron, of a cylindrical figure, and almost 6 $\frac{1}{2}$ inches wide. In these he placed three cylindrical glasses of 3 $\frac{1}{2}$ inches diameter; so that the distance betwixt these and the sides of iron vessels was inch and a $\frac{1}{2}$; nor did the bottoms of the glasses come nearer the bottoms of the other vessels than by the same distance. These spaces, then, between the two vessels he exactly filled up with cotton, that the Cold might be retained the longer, nor might be too soon affected by the Warmth of the Air, when once it was produced. These three vessels, then, being thus prepared, the glasses were filled with pounded Ice, and in them were placed three glass Tubes of $\frac{3}{4}$ of an Inch diameter, filled with Spirit of Nitre, which was at that time 32 degrees warm; and the Water that ran from the beaten Ice was carefully poured off. This being done, some Spirit was put upon the Ice, and when the Thermometer applied to it would fall no lower, the fluid part was poured off from the remaining refrigerated Ice, and at the same time the Spirit of Nitre, that was reduced to the same degree of Cold in the other glasses by the affusion of this Spirit, was poured upon the Ice. After this, then, had been repeated in the same manner four times, the spirit of Nitre made use of being thus kept exceeding cold, and the liquor being carefully poured off from the Ice after every affusion of the Spirit, he observed that the Thermometer at last subsided to 40 degrees below O. And then, the very Spirit of Nitre being acted upon by so great a Cold, shot into fine sharp Chrystals about $\frac{1}{2}$ an Inch long, and being frozen as it were itself, required shaking with some force to get it out of the Tube. As soon, however, as this inspissated Spirit came to touch the Ice, they were both presently dissolved, and at the same instant the Thermometer sunk from the degree 37 below 40. By mixing pot ashes with the pounded Ice he was able to produce a Cold 8 degrees below O.

Now what person living could ever have had the least suspicion of such a *Phænomenon* as this? The greatest natural Cold has never been observed to sink

ſink the Thermometer below O; and then, all Animals, and Vegetables, that were expoſed to it, died immediately: Art has increaſed it yet 40 degrees more: But if to 32 degrees, which is the point of freezing, you add 40 degrees, the Heat of the Air will be then ſo great, that we could not bear it long without the alternate interpoſition of ſome refreſhment from a greater degree of Cold. Hence we ſee evidently, which one could ſcarcely have believed, that Cold, which is able to turn Water into Ice, may ſtill have its power increaſed by 72 degrees. Now what would be the conſequence, ſhould Nature ever generate ſuch a temperature as this? We find, that ſuch ſtrong Spirit of Nitre as was made uſe of in this Experiment would be congealed. We ſee Mercury is ſo condenſed in it, that it takes up a ſpace almoſt $\frac{1}{269}$th leſs than it did before. We obſerve that this wonderful Body, in ſo vaſt a degree of Cold, and with this increaſed denſity, remains equally fluid, mobile, and expanſible, as it was before. We know farther, that the ſubſtance of Mercury, from the degree 600, in which it begins to boil, to this degree 40 below O, will be contracted $\frac{640}{10782}$ parts of its whole bulk; and conſequently may be rendered $\frac{1}{17}$th ſpecifically heavier, or lighter, by the Cold, and Heat, that we are at preſent acquainted with. Now theſe things we are abſolutely ſure of from Experiment; and hence we ſee that Mercury, as it is gradually condenſed by Cold, approaches nearer and nearer to the weight of Gold. But who will pretend to determine, what farther degrees of Cold may be ſtill produced, either by the powers of Nature, or Art, that lie hitherto undiſcover'd? Who can deſcribe the alterations that both Solids and Fluids would undergo, were they expoſed to this degree of Cold? If we have a deſire of promoting natural knowledge, let us prepare ſuch a Cold as this, and then try what effect it will have upon the Bodies that we are acquainted with. By this means certainly we might come at an infinite number of uſeful diſcoveries, of which at preſent we muſt be ſilent. In the mean while, however, we ought to pay a due honour to the worthy Inventor of this Method, who has thus ſet us an Example, pointed out the way to us, and furniſh'd us with proper helps for carrying on theſe inquiries to greater perfection.

The weight of Mercury incredibly altered by Cold.

Corol. 5.

And laſtly, the converſe of the fifth Corollary of the third Experiment, appears very evident, *viz.* that the Air is ſcarce a moment at reſt, neither that which is open, nor that which is confin'd in any veſſel whatever.

Experiment V.

Pure Alcohol of Wine is expanded every way in its whole bulk by a ſmall increaſe of Fire.

For inſtance: Obſerve this glaſs veſſel, which contains 1933 parts of this Alcohol. You ſee it terminates in this narrow Cylinder, which has been made with a great deal of care, that it might be every where equally wide. This whole Cylinder now contains 96 of thoſe parts, of which the lower Bulb contains 1933, and is graduated with numbers correſponding to thoſe parts. In the ſevere Cold of 1709, in one of the coldeſt parts of the world, the Alcohol was reduced to number 1: And yet, if the warmth of a Man in health is applied to the Glaſs, the Spirit will be expanded to the number 96, and fill the Cylinder ſo high.

Corol.

COROL. 1.

In this inſtrument therefore, the Liquor, conſidered in the ſtate in which it was in the greateſt obſerv'd natural Cold, may be dilated by the vital Heat of a healthy perſon to $\frac{1}{20}$th part of its bulk. It is neceſſary, however, to take notice, that we here ſuppoſe the capacity of the Thermometer to continue the ſame, whereas, in reality, it will be increaſed, as appears by the ſecond Corollary of the ſecond Experiment.

COROL. 2.

The difficulty of determining the rarefaction of Fluids.

If we could exactly diſcover therefore the proportion of the capacity of this inſtrument in the moſt intenſe Cold, to the ſame when affected by this vital Warmth; we could then alſo abſolutely determine the increaſe of the bulk of this Fluid by the greateſt degree of Heat contained betwixt theſe two limits: For then the difference of theſe two capacities will help us readily to meaſure this dilatation.

COROL. 3.

Another cauſe of the figure of the Earth.

Shou'd the moſt pure Alcohol, therefore, about the Poles of the Earth be compared with the ſame betwixt the Tropics, what a conſiderable difference would there be in its hydroſtatical weight in theſe two places? For it is plain, that all theſe Liquors are heavieſt about the Poles, and lighteſt near the Equator. Is this therefore another phyſical cauſe of the compreſs'd ſpheroidal figure of the Earth; ſince a ſmaller bulk in one place, is equal in weight to a larger in the other, and they both tend with an equal force towards their common center of gravity?

COROL. 4.

Hence the Areometers are not perfectly exact.

From theſe obſervations we learn, that the ſame veſſels fill'd with ſuch a ſort of Liquor, will not be ſo full by a good deal in the cold of winter, as they are in ſummer; for the firmer parts of the ſolid veſſels are not ſo much dilated with the ſame degree of Heat as the contained Fluids are. And indeed, the Chemiſts have very often experienc'd the truth of this to their diſadvantage, when they have in froſty weather fill'd their glaſſes quite full of valuable Liquors; for when they have afterwards been affected by the Heat of the Summer, they have penetrated through the ſtoppers, forced them out, and often burſt the glaſſes themſelves. Being now therefore made wiſer by theſe inconveniencies, they always leave an $\frac{1}{18}$th part empty, when they fill them in the Winter; or elſe, warm both the Liquors and Veſſels to as great a degree of Heat, as one may reaſonably expect in the midſt of Summer.

COROL. 5.

The vaſt rarefaction of Alcohol.

If Alcohol is made ſo hot as juſt to begin to boil, it is then obſerv'd to riſe to number 174 in the Cylinder; and therefore is then increaſed almoſt $\frac{1}{11}$th of its dimenſions: Nay, in reality, it is at that time more dilated, as appears by what has been remark'd under the firſt Corollary of this Experiment. And here, by the way, give me leave to take notice, how much difference there is in buying Alcohol by meaſure in the depth of a hard Winter, and in the ſultry

Dog-days, which is certainly very conſiderable. If we conſider now that Alcohol in the moſt intenſe cold ſubſides 40 degrees below 0, and when it begins to boil, riſes to 174 degrees above 0; it appears, that there may be a difference in its dimenſions of 214 parts in 1933; and conſequently, that it may be contracted or expanded to $\frac{1}{9}$ of its whole bulk.

Corol. 6.

If you urge Alcohol ſtill farther, ſo as to make it boil, there preſently ariſes a vapour from the upper part of it, which expands itſelf in the ſuperiour *vacuum*, and grows denſer and denſer every moment, whence the dilatation of it cannot be conveniently meaſur'd any farther. And as ſoon as the Thermometer is open'd at top, the rareſy'd vapour immediately flies off, nor can it be determin'd how much more it may be afterwards expanded. Ebullition puts a ſtop to the meaſure of its expanſion.

Corol. 7.

Alcohol, therefore, can ſcarcely ever be perfectly at reſt: For if it is confin'd in a veſſel, and has either a *Torricellian vacuum*, or Air above it, it is evident, that it will be continually dilated, and reſolv'd into vapours; or contracted, and ſo condenſed into Alcohol again; unleſs, by chance, the degree of Heat, or Cold, ſhould conſtantly remain the ſame: Or on the other hand, if it is expoſed to the open Air, it cannot be at quiet; but, as we took notice in the Air, will ſuffer a perpetual ſyſtole and diaſtole, ſo long as there is a ſucceſſion of greater and leſs degrees of Heat in the Atmoſphere; which is obſerv'd to happen continually, almoſt without intermiſſion. But then, however, this agitation will be moſt remarkable, when either Heat or Cold grows exceſſive; which ſtate ſeldom continues any conſiderable time. Laſtly, hence the Phyſicians underſtand what certain and frequent oſcillations muſt happen in the human Body from the Particles of Alcohol, when they are mixt with our juices; as they will be at one time compreſſed and heated by the action of the Arteries, at another, freed from this preſſure, and of conſequence, cool'd, in the Veins. Alcohol impatient of reſt.

Experiment VI.

The moſt limpid, light, ætherial Oil of Turpentine, is every way expanded in its whole bulk, by a ſmall increaſe of Fire.

This you'll ſee evidently in this ſpherical Glaſs, with this long narrow cylindrical Neck. You obſerve, that the Bulb of this is fill'd with Oil juſt to the beginning of the Cylinder. I dip this into Water, that is exactly as cold as the Oil, and you ſee it continues preciſely in the ſame place. I'll now put this veſſel of Water with the glaſs of Oil in it upon the Fire in this Chafing-diſh: And now how evidently do you perceive, that as the Water, and conſequently the Oil in the Glaſs grows gradually hotter and hotter, the Oil riſes in the Neck, and ſcarcely remains one moment in the ſame Altitude? I have now kept the Water, as you ſee, upon the Fire till it boils; and now the Oil, you obſerve, is at reſt in the Glaſs, neither aſcends nor deſcends, nor would do ſo, tho' it ſhould continue a good while in the boiling Water: Nay, I'll put more Fire about the veſſel, and make the Water boil more violently; and yet you obſerve the Oil keeps exactly at the ſame height: Nor will this mercurial Ebullition gives Liquors their greateſt Heat.

rial Thermometer riſe any higher, when once the Water comes to boil. For this beautiful diſcovery, the Philoſophers are obliged to that very ingenious Gentleman, *Monſieur des Amontons*; the truth of which you have now evidently ſeen in Water, and it is continually found by Experiment, to hold good in almoſt every kind of Liquor. And here, the candour, which I feel within my Breaſt at preſent, and which I hope I ſhall always have the pleaſure of, obliges me to acknowledge in this publick manner, that nothing has been of greater ſervice to me in diſcovering the uſefulneſs of Fire in the deepeſt chemical inquiries, or better help'd me to come at the knowledge of the properties of this Element, than this valuable Experiment of this noble Author. But I refer you to the fountain, the *Mem. de l' Acad. Roy. des Sci.* where you may have the pleaſure of ſeeing what he himſelf has ſaid upon this ſubject. There you will find that famous Gentleman has actually demonſtrated, that when Water once comes to boil, tho' you urge it with ever ſo ſtrong a Fire, you cannot make it afterwards grow any hotter. This valuable diſcovery, however, may be ſtill farther improv'd, by a very curious obſervation of the induſtrious *Fahrenheit*; for he has found, that the Heat of the ſame boiling Water will be conſtantly greater, when the weight of the incumbent Atmoſphere preſſes heavier upon its ſurface, and leſs, when the preſſure of that is lighter. If we would therefore at any time nicely determine the degree of Heat in boiling Water, we muſt have a Barometer by us, to obſerve at the ſame time the weight of the Air; or elſe we ſhall not be able to aſcertain it exactly. In the mean time, however, 'tis abſolutely certain, that ſo long as the preſſure of the Atmoſphere continues the ſame, boiling Water will not grow hotter by any increaſe of Fire whatever: And with this limitation, the rule of *Monſieur des Amontons*, will always be found to hold true. When the difference now of the weights of the Atmoſphere is 3 inches, then the difference of the Heat of boiling Water under theſe two preſſures, is found to be about 8 or 9 degrees. Hence this Author evidently infers, that the more cloſely the parts of Water are compreſſed together by the increaſe of the incumbent Weights, the more Fire will be required to make them recede from one another; in which conſiſts ebullition. And hence he makes this elegant deduction, that the Thermometer, by being immerſed in boiling Water, will, by the degree of Heat it expreſſes, diſcover at that time the weight of the Atmoſphere; and of conſequence would accurately enough determine it at Sea, where the Barometers are not ſteady, if every degree of increaſe was made viſible in the Thermometer, which may be accompliſh'd with a great deal of eaſe. And hence, laſtly, he obſerves, that our Atmoſphere is ſo much the more heated by the Solar rays, as it is more compreſs'd, that is, the nearer it approaches to the ſurface of the Earth; and the leſs, the lighter the preſſure is, *viz.* in the regions above us. And this is plainly confirm'd by obſervation; for the tops of the higheſt mountains that are neareſt expoſed to the heat of the Sun, and never obſcured with clouds, are found to be ſo extremely cold, that the Snow lies there perpetually without being melted. Have you a mind to be witneſſes to the truth of this yourſelves? Under a Receiver in *Boyle*'s Air-Pump, place a glaſs veſſel full of Water, heated to 96 degrees, and then gradually draw out the Air, and you will evidently perceive an ebullition excited in the Water, as the preſſure of the Atmoſphere is leſſened, which will intirely diſappear again upon the letting in of the Air. Hence, there-

And the compreſſion of Liquors.

therefore, by a Barometer fix'd in the Receiver, you may be able to determine what degree of Heat is neceſſary to make Water begin to boil under any given Weights of the Atmoſphere; and by this means we may come at an infinite number of beautiful diſcoveries that we are at preſent unacquainted with. There is one thing more upon this head, that I think well worth mentioning, before I quit it, and that is this; Put ſome Water into *Papin*'s Digeſter, and with the included Air ſtop it in ſuch a manner that nothing can poſſibly come out, and afterwards make it Oil. The Water then will be expanded $\frac{1}{85}$, and the Air $\frac{1}{3}$; and conſequently, the Water will be as much compreſſed, as if its preſſure was increaſed by 10 inches of a common Atmoſphere; and by this means Water acquires 30 degrees of Heat extraordinary purely by being made to boil in this Machine, for I here take no notice of the force it gains by the motion and attrition of the particles of Water and Air againſt the veſſel, and among one another. What wonder therefore is it at all, that by this Machine are produced ſuch prodigious effects? If you have a mind now to examine by a ballance the proportion of the expanded Oil in this Experiment, to the ſame in its natural ſtate, you may compute it in the following manner: The Oil fill'd the Bulb of the Glaſs juſt to the beginning of the Neck, when the Water, Glaſs, Oil, and Air, had 52 degrees of Heat in *Fahrenheit*'s Thermometer. When the Water boil'd, and the Oil would aſcend no higher, the Thermometer was riſen to degree 212, and the Oil was as high in the Neck as the mark which you ſee I have fix'd on it. If I now weigh the Glaſs fill'd to this mark with Oil that is 52 degrees hot, and then empty it as low as the bottom of the Neck, and weigh it again, I find pretty nearly the expanſion of the Oil; which upon examination, appears to be a very conſiderable part of its bulk. I muſt caution you, however, that I have no regard here to the increaſe of the capacity of the Glaſs in this degree of Heat: But I have taken notice of this before, and therefore ſhan't mention it any more for the future. See *Exper*. V. *Cor*. 2.

And you need not wonder here, Gentlemen, that I determine the limits of the dilatation of Oil of Turpentine by boiling Water, which I did not do in the former Experiment. The reaſon is evident. Alcohol boils with a much leſs heat than Water; and as ſoon as ever it boils, its expanſion cannot be meaſured any farther. *Exper*. V. *Corol*. 5. Whereas in Oil of Turpentine, which is much lighter than Water, an ebullition cannot be excited by the greateſt Heat of boiling Water, but its ſurface will always remain at reſt in this degree, in which therefore we may meaſure its dilatation.

Before I quit this Experiment, give me leave to take notice of a pretty remarkable *Phænomenon* that preſents itſelf to our obſervation in this ebullition of Liquors. Alcohol, which is lighter, boils ſooner than Water, in a *Ratio* which we ſhall afterwards aſſign; and yet Water, which is heavier, boils a conſiderable deal ſooner than Oil of Turpentine. Is the cauſe of this the affinity there is betwixt Fire and inflammable Oils? Or is the ſpecific Gravity of the boiling Liquid of conſequence here? Or laſtly, is it owing to a greater or leſs tenacity of the parts among one another? You will ſee by and by, what a vaſt deal of pains I have taken to reſolve theſe Queries: And I think it will be evident, that they ought all to be conſider'd, as well as the different preſſures of the Atmoſphere, which are likewiſe concerned in it. See the incomparable *Newton* in his *Opticks*.

Some ſurprizing Phænomena in the ebullition of Liquors.

EXPERIMENT VII.

The rarity of boiling Water.

Pure Rain-water, gradually heated by a gentle Fire, is every way expanded in its whole bulk, by a very ſmall augmentation of Heat.

This you ſee evidently in this Glaſs, where its dilatation is $\frac{1}{85}$ of its whole dimenſions: For from the degree of Heat 56, it always riſes to the degree 214, in which it begins to boil; and then it remains at reſt, and has acquired the dilatation mentioned.

EXPERIMENT VIII.

The rarity of Mercury in boiling Water.

Mercury, by the application of Heat, is eaſily rarefied.

The truth of this is plainly demonſtrated by this elegant Thermometer, which was made at my requeſt, by that very ingenious Artiſt *Daniel Gabriel Fahrenheit* The inferiour Cylinder of this Thermometer contains 11124 parts of Mercury, which in the greateſt Cold obſerv'd in *Iceland*, reach'd to the mark 0, from whence upwards we compute the increaſing degrees of Heat. If I immerge this in the Water in this veſſel, and gradually heat the Water, you ſee the Mercury continually aſcends till the Water boils; and then you obſerve it remains perfectly quiet at one number, *viz.* 212, and ſomething more. Setting aſide, therefore, the dilatation of the Glaſs, the Mercury at preſent takes up 11336 little ſpaces, of which in the greateſt Cold it took up but 11124; and conſequently, in this degree of Heat, is expanded $\frac{1}{52\frac{25}{53}}$ of its whole bulk.

COROL. 1.

The rarity of other boiling Liquors.

In the ſame manner the ſtrongeſt *Lixiviums* of Sea-Salt, Nitre, and fix'd alcaline Salts, are dilated by Heat; and in ſhort, all Liquids that have hitherto been examined: So that Air, Alcohol, Oils, Water, ſaline Spirits, *Lixiviums* of Salts, Oil of Vitriol, and Mercury, are all affected by the very ſame law.

COROL. 2.

The cauſe that dilates all theſe Bodies paſſes through glaſs, and all other veſſels, into the Liquors themſelves.

COROL. 3.

And this ſame cauſe proceeds from what we univerſally call Heat, or Fire.

SCHOLIUM.

For the future, therefore, by Fire I ſhall always mean that Being, however otherwiſe unknown, which is endued with this property, that it penetrates all Bodies, both ſolid and fluid, and by this very action, extends them into larger ſpaces: For as on the one hand I am not acquainted with any Body in the whole compaſs of Nature that has theſe qualities, except what by every one is called Fire; ſo on the other, there never is Fire really preſent in any Body, but theſe two effects are immediately produced; and in proportion as this is increaſed, the extenſion of Bodies is likewiſe augmented. Now ſuch a character as this is ſufficient in Phyſics for determining and diſtinguiſhing particular natural Bodies: Nor indeed are there any other that will anſwer the ſame purpoſe, whatever your idle Philoſophers may boaſt of their ſubtle ſpeculations. It is our buſineſs therefore to obſerve with the greateſt care, thoſe properties that we are able to diſcover in Fire under this notion; and of theſe the firſt ſeems to be this, that it exiſts in every point of time, and every part of ſpace; the truth of which I ſhall demonſtrate by the following Experiments.

Experiment IX.

Take a thick cold plate of Iron, and in the ſharpeſt weather, and coldeſt place, lay this upon another of the ſame kind, and equally cold, and let this, by the help of a weight, be preſs'd hard upon the under one; then, let it be briſkly rubb'd upon it backwards and forwards, and it will begin to grow warm, then hot, and in a ſhort time will acquire ſuch a degree of Heat, as to emit ſparks of Fire, and at laſt the whole Maſs will be as red hot, as if it came out of a large common Fire. The firſt manner of producing Fire.

Corol. 1.

This production of Fire may be effected at any time whatſoever: Nor does it at all ſignify, whether the ſeaſon is hot, or cold: Nay, in reality, the more compact the Bodies are render'd by Cold, you will, *cæteris paribus*, have the ſtrongeſt Heat.

Corol. 2.

Nor is there any place hitherto known, where the ſame Experiment will not hold true. On the tops of the higheſt mountains, in the deepeſt ſubterraneous caverns, in the warmeſt parts of the world, and moſt frozen climates, the effect will conſtantly prove the ſame. I confeſs, indeed, that the Heat will be ſooner and more ſtrongly excited in dry places, than it will in moiſt ones; but ſtill, it may be always produc'd in this manner. And the ſame thing is obſerv'd to happen in every kind of ſolid Bodies whatever.

Corol. 3.

Nay even in *vacuo* Bodies grow hot by mutual attrition; as evidently appears by the accurate obſervations of the ingenious *Haukeſby*, which have ſince been happily improv'd by my good Friend and Collegue the famous *James-Williams' Graveſand*, a Gentleman ſo form'd by Nature, and finiſh'd by Art for theſe abſtruſe inquiries, that by his diſcoveries, the boundaries of natural knowledge are daily inlarged.

Corol. 4.

But there is nothing more remarkable in the Fire produc'd in the manner abovemention'd, than that it penetrates into all Bodies, the denſeſt not excepted, heats, expands, burns, and melts them; and that it ſhines, grows exceſſive bright, and in ſhort, has perfectly the very ſame effects that we conſtantly obſerve in true Fire. And we ſee here it is thus generated without any *Pabulum*, or any Fire that exiſted before by which it might be raiſed, which is commonly the caſe, Fire generally being lighted by Fire, and one Flame excited by another. Hence then, I think, we may fairly conclude, that this Being ought to be look'd upon as true Fire.

COROL. 5.

The first cause of this.

In the mean time we learn by general obſervation, that the harder and more rigid the Bodies are that are agitated one againſt another, the more intenſe will the Fire be that is produced by their mutual attrition. Hence the very ſame Body, when it is rigider, or ſofter, acquires in this reſpect a very different degree of Heat. Iron, if it is taken out of the Fire when it is juſt ready to melt, and in the heat of ſummer ſuffer'd to cool very leiſurely in the Air, will remain very ſoft and flexible; whereas, if you inſtantly throw it into cold Water, the Particles, that were before put in motion, and render'd flexible by the Fire, being now compacted together, and driven into cloſer union by this ſudden contraction, the Iron becomes exceeding hard, rigid, and very elaſtic: But every body knows how much fitter Iron is for ſtriking a light when it is harden'd by Cold, than when it is ſofter. If the vaſt hard *Axis* of a Wind-mill lies upon a rigid block, and the ſails are whirled rapidly about by a ſtrong Wind, Fire and Flame break out immediately; but if you take care to put Lead between them, there is not much danger of ſo great a degree of Heat. If you ſtrike a Flint againſt a very hard piece of Steel, how certain are you of procuring Sparks from it? which would not be the caſe, ſhould you ſtrike it againſt a bit of ſoft Iron. And hence it comes to paſs, that if you interpoſe any ſoft Body betwixt two hard ones, you can ſcarcely excite Fire by the ſtrongeſt attrition, till this is conſumed, and the Bodies come to rub one againſt another, and then you have Fire preſently. If you take, for inſtance, two Plates of Iron, and oil them very well, you cannot by rubbing them together, make them conceive any very great degree of Heat; but when the ſurfaces of the Iron come to touch one another, they will ſoon grow exceſſively hot by the ſame agitation.

If Bodies, therefore, are alike in every thing elſe, the denſer the matter is of which they conſiſt, the fitter will they be for this production of Fire; which rule holds univerſally true: I ſay, if they are alike in all other reſpects; for Lead which is denſer, but at the ſame time ſofter, will not by attrition yield ſo much Fire as Iron, which is lighter, but vaſtly harder: But if they are both equally rigid, then the heavieſt is always moſt efficacious. Hence it appears, how that exceeding hard, and ponderous Wood, the *Sideroxylon* of the *Indians*, not only furniſhes them with weapons, but by being rubb'd ſwiftly together, ſerves to kindle their fires whenever they want them.

The harder, then, and more denſe the Bodies are, that are agitated one againſt another, the ſooner will Fire be produc'd from them. Hence the colliſion of Steel and Flint excites Fire in the leaſt inſtant of time; which is much longer generating from Bodies that are lighter, and not ſo hard.

COROL. 6.

A ſecond cauſe.

The principal phyſical power, however, that produces Fire by this attrition, conſiſts in the Bodies being preſs'd very hard together, whilſt they are rubb'd one againſt another. If you lay, for inſtance, one Iron Plate upon another, ſo that it may preſs the under one only by its own weight, and then with a certain reciprocal motion, agitate the upper one over the inferiour, you will be able to excite but a ſmall degree of Heat. Lay a ten pound weight now upon

the

the upper plate, and then move it with the ſame velocity as before, and a greater Heat will immediately be generated. And thus if you proceed you'll be ſurprized to find how the increments of Heat conſtantly correſpond to the augmentations of the weights, if the agitations are performed with the ſame velocity. So that at laſt, if the preſſure is increaſed to a very great degree, the ſtrongeſt Fire may be produced in an inſtant. And the ſame alſo holds true in the Elements of Fluids themſelves compreſſed together, as has already ſufficiently appeared.

COROL. 7.

And, laſtly, we obſerve, that the ſwifter the motion is of theſe hard Bodies one againſt another, the Fire excited by this attrition will *cæteris paribus* be ſo much the ſtronger, and the ſooner produced; ſo that a ſlow motion ſcarcely generates any Heat, though a briſk one will raiſe a great quantity of Fire immediately. Hold a rope, for inſtance, very tight, and draw it gently through your hands, and you'll perceive no Warmth at all; but let it run through your hands with a rapid motion, and it will ſoon conceive Heat, and burn them: Preſs a ſteel blade hard againſt a threſhold, or a grindſtone, and it will ſcarcely grow warm if you move it but ſlowly; and yet if the reciprocal agitations are ſwift, you may ſoon produce a great degree of Heat: So that by holding a knife very hard againſt a grindſtone whilſt it is very rapidly turned round you may make it almoſt red hot, whilſt the ſtone itſelf is hardly warm, becauſe no part of the ſtone remains long in contact with the blade, but inſtantly moves from under it. Hence, therefore, the production of Fire may be increaſed in proportion to the augmentation of this celerity, and that without limits. A third cauſe.

COROL. 8.

It follows, therefore, evidently from what has been ſaid, that when the three cauſes juſt mentioned unite their power, there then may be the ſtrongeſt Fire excited in an inſtant from the coldeſt Bodies. If two large, thick, circular plates of very hard Iron ſhould be compreſſed together by a force of ten thouſand pounds weight, and then be very rapidly agitated one againſt another, there would be the moſt violent Fire produced immediately in both the plates. This is evident in Windmills, where if the *Axis*, and block it lies upon are dry, and the wind is very ſtrong, the attrition quickly generates both Fire, and Flame; though there, the motion is but ſlow, on account of the ſmaller Diameter of the *Axis*. Filings of Iron as they fly off burn the Workman's hands, and the raſpings of Wood doe the ſame. In the deep parts, therefore, of the Earth towards the Center, where Bodies are vaſtly compreſſed by the incumbent weight, and conſequently rendered exceeding denſe, does the attrition excited there produce a very great degree of the ſtrongeſt Fire? and conſequently does the Heat there gradually increaſe more and more? See *Boyle* of *Coſm. Qual.* This is certain from what has been demonſtrated, that it is impoſſible to determine the ultimate, or intenſeſt degree of Heat, that may be generated by attrition: For though it were poſſible to diſcover what kind of Bodies were actually harder and more denſe than all others; yet we could never poſſibly aſſign the greateſt weight by which they might be preſſed together, or the ſwifteſt degree of motion with which they might be agitated. There never, therefore, can exiſt ſo great a degree of Heat, but that a greater may be ſtill produced.

This threefold cauſe united.

The power of Fire excited by attrition not to be determined.

EXPERIMENT

EEPERIMENT X.

Fluids interposed between Bodies retard this production of Fire.

If in the former Experiment any Fluid had been interposed between the Surfaces of the two Bodies thus densed, and pressed together, and had been continually supplied whilst they were in motion, they would scarcely have conceived any Heat; or at least nothing in comparison of what would have been produced by the same causes had that been away; the truth of which is confirmed by universal Observation. If I rub, for instance, the dry blade of this knife hard upon this dry whetstone, it presently grows hot, makes a noise, and often, as you see, emits sparks; whereas if I put a drop or two of Water, Oil, or Spirit between, the same cause, as you observe, repeated, does not produce the same effect. Every body knows that the Axletrees of Wheels hardly ever grow hot if they are well guarded with grease; but if they and the Boxes are dry, they presently skreak, smoke, grow hot, and very often take fire: And for want of being secured in this manner whole Windmils have been frequently burnt down. But this never appears more evident than in the polishing of Glass: Neither the *Lens*, or the plate it is polished on, becomes hot till the interposed oily or watery liquor is consumed, and they both grow dry, but then, a very great Heat is excited immediately.

COROL. 1.

Soft rare fluid Bodies unfit to excite Fire by attrition.

The softer, therefore, the more yielding, less elastic, and rarer any Bodies are, the less fit they are for producing Fire by attrition. And hence, as Fluids for the most part are possessed of these qualities, they are observed of all Bodies the least capable of exciting Heat in this manner; for they easily yield to any impression, and by this means slip out of the way, and elude the force of it. And this is found to hold true in the whole compass of nature.

COROL. 2.

And bodies that lie loose upon one another.

And again, the less the force is by which any Bodies are pressed together, the less Heat will be generated by their rubbing one against another. This too is confirmed by every kind of Experiment without exception.

COROL. 3.

And Bodies that are at rest.

And lastly, if Bodies are moved softly one upon another, tho' they have all the other properties requisite to the production of Fire by friction, yet they will not generate any considerable Warmth; and if they are quite at rest, they will be reduced to the common temper of the ambient Air. This we see in vast heaps of Iron, where, though the Body is so hard, and that which lies at bottom is pressed down with such a prodigious incumbent weight, yet it conceives no more Heat than the very soft, rare, light Air, that surrounds it.

COROL. 4.

The absence of natural Fire thus discovered.

From what has been observed, then, it seems to follow, that Fire least of all discovers itself by its effects in those parts of space where, first, there is either no body at all, or exceeding rare ones, whose parts are so loosely connected together that they scarcely cohere with one another; Secondly, where there is no cause to compress these Bodies together in these spaces; and thirdly, where there

there is no power to put them in motion ſo long as they continue there. With us, the *Torricellian Vacuum* is ſuch a ſpace as this: For if you take a glaſs Tube 40 inches long and cloſed at one end, and fill this quite full of the pureſt, drieſt Mercury made very hot, and then in an erect poſition properly immerge the open orifice in ſome more of the ſame Mercury, ſo that there ſhall be nothing but pure Mercury in the glaſs; there the Mercury will deſcend, and leave an empty ſpace in the upper part of the Tube, in which, there does not appear the leaſt ſign of any heavy reſiſting Body; nay, if you compreſs the Mercury in the under veſſel, that in the Tube will aſcend and fill it perfectly full. Here, therefore, ſeems to be a ſpace, where there is not the leaſt attrition of any Bodies; and conſequently, here will be the very ſmalleſt degree of Fire, ſo far as it depends upon this attrition. And yet, if you agitate this baroſcopical Tube in the dark, a light will be hereby excited, which you will perceive in this *vacuum*, as that excellent Mathematician the great *Bernoulli* has ſo elegantly deſcribed, and explained. Hence every one will be ready to infer that, even there, there muſt be Bodies alſo. And indeed, that Being which thus penetrates the Glaſs, the Mercury, and the Air, muſt be uniformly diſtributed through that ſpace; but it does not, however, any ways appear, that this, be it what it will, exhibits the leaſt mark of any degree of Heat generated in this manner. Hence, perhaps, the light, that is thus excited by this concuſſion, is of the ſame nature with that which we treated of in our Hiſtory of Light as a property of Fire. And, hence, we are led to imagine, that Light, and may be Fire itſelf, conſidered without the concurring action of any ſolid Bodies, paſſes freely through all parts of ſpace, without diſcovering any effects of Fire that we are hitherto acquainted with. This, at leaſt, is evident beyond all diſpute, that as we aſcend from the common ſurface of the Earth, and get to the tops of high mountains, where there are no Meteors to obſtruct and diſturb the equal action of the Sun, and where, therefore, its rays ſtrike the Bodies oppoſed to them in the moſt direct manner, and with their utmoſt force, I ſay, there, we are not affected with Heat, but on the contrary always find a greater degree of Cold. And at length, when we are got ſo far from the Earth, and ſo near the Sun, that there are ſcarce any viſible exhalations, or vapours obſerved to riſe ſo high, then, Water, when any does reach thither, is congealed into Snow, and lies at the tops of theſe mountains all the Summer. So that it hence ſeems probable, that in thoſe parts of ſpace where there is no hard reſiſting corporeal ſubſtance to withſtand the action of Fire, nor any thing which is capable of exciting attrition, there, Fire, though it is actually preſent, appears moſt quiet, and acts with the leaſt efficacy: And ſince the altitude of the higheſt mountain is ſcarce equal to $\frac{1}{859}$th of the Semi-diameter of the Earth, and yet there is ſo great an increaſe of Cold there, in this little receſs from the Center of the Earth, this ſmall approach to the Meridian Sun, and under this great preſſure of the Atmoſphere, what muſt we think would be the caſe, could theſe obſervations have been made a thouſand times higher? Why, certainly, as far as we are able to gueſs by that poor little that we know of Nature, all motion ſeems gradually to decreaſe as you aſcend higher and higher from the Earth, till at laſt, the uppermoſt regions appear to enjoy the moſt calm, and undiſturbed reſt. And this ſeems confirmed by this Obſervation, that the ſame ſort

Pure ſimple Fire.

Scarcely diſcernable.

ſort of trees, ſprung from the ſame ſeeds, on the ſame mountain, and in the ſame ſituation with reſpect to the Sun, are always the largeſt at the foot of the mountain, and grow by degrees weaker and drier, the more you aſcend. And this opinion will give us ſome light into the abſtruſe writings of the ancient Alchemiſts, where they tell, that in pure Fire there is the moſt perfect ſilence, and abſolute reſt, and that God reſides in it; that from hence, however, are ſent forth miniſtring Fires to quicken and move Bodies that would otherwiſe die through inactivity, and to diſpoſe them to execute the pleaſure, and appointment of the omnipotent Creator of all things. And, indeed, in this, they did but follow the opinions of the moſt ancient *Hebrews*, and the Sacred Writers. *Exod.* iii. 2, 3, 4. xix. 16, 18. xxiv. 17. *Lev.* x. 2. *Pſalm* civ. 2, 4. Ep. to *Heb.* i. 7. xii. 29.

Of the pure Fire of the Alchemiſts.

And *Hebrews.*

COROL. 5.

An exceeding great and ſudden Heat excited by the attrition of Metal againſt the lighteſt Fluid.

Laſtly, it appears evident from modern Experiments, that a ſurprizing Heat and Fire may be inſtantly produced in the coldeſt, hardeſt, and heavieſt Bodies, purely by their attrition with the lighteſt, ſofteſt, cold Fluids, if the motion is exceeding violent.

If a large ball of ſolid Iron is fired from one of the biggeſt ſort of cannons in the Winter, it will run through the cold Air 600 feet in a ſecond, and conſequently will meet with a vaſtly greater reſiſtance from the Air, than from the moſt rapid wind; for when that moves only 22 $\frac{1}{4}$ feet in the ſame time it condenſes the Air ſo violently, that it bears down every thing before it, tears up the trees, and breaks them to pieces, nor are houſes, or towers able to withſtand its fury, *Maraiotte* pag. 140. Hence it appears, what a very great attrition it muſt ſuffer purely from this cauſe; and yet this muſt be ſtill increaſed conſidering that no part of its ſurface moves in a ſtrait direction; for as the ball in its paſſage turns round upon its *Axis*, every point is continually deſcribing a Cycloid. Now this ball, when it has run through its way with this rapidity, and comes to fall, is found to be perfectly hot; although through its whole paſſage it has conſtantly been expoſed to freſh cold Air, and conſequently has loſt every moment ſomething of the Heat it had conceived. Some perſons may be apt here to object; that the Heat of the ball may be owing to the flame of the Gunpowder with which it is fired; but that can't poſſibly be, as it remains in it ſo infinitely ſhort a time; certainly, ſcarce $\frac{1}{1080000}$ of an hour. Now who can believe that in ſo ſmall a point of time this flame can communicate ſo great a degree of Heat to ſo ſolid a Body? But this may eaſily be accounted for, from that vaſt attrition that muſt ariſe betwixt the Air and the ball whilſt it moves with this prodigious celerity, and acts, and is reacted upon by the Air with 27 $\frac{3}{11}$ times more force than that of the ſtrongeſt wind that was ever yet obſerved.

The Doctrine drawn from theſe premiſes.

Since, therefore, it appears by every kind of Experiment, that Fire by the friction of any Bodies together may be quickly produced where it did not appear before, and that, at all times, in every degree of Cold, and in every place where trial has been hitherto made, ſuppoſing the three phyſical conditions which we mentioned before; I ſay, theſe things conſidered, I think we may thence fairly make a great many deductions, which will be of ſervice to us in diſcovering the nature of this Element: Some of which by your leave I will here mention.

In

In the firſt place, then, by what we already know of Fire, it appears, that it muſt be always preſent in every part of ſpace, though we are not at all times able to diſcover it, if we ſearch for it only in the common methods: For the moſt accurate Thermometer evidently ſhews us, that there is always, and every where actually exiſting, a Heat greater than the intenſeſt degree of Cold that we formerly deſcribed, though people are very apt wrongly to imagine, that there then remains no Fire at all in that place where the Thermometer is fallen as low as o. Fire always preſent in every place,

Nor does Fire thus exiſt only in every part of ſpace, but it is likewiſe equally diffuſed through every Body, the moſt ſolid, as well as the rareſt: For if in the hotteſt day of Summer, or the coldeſt of Winter, you apply the moſt ſenſible Thermometer to a glaſs in which there is a *Torricellian Vacuum*, where one might poſſibly ſuſpect there was nothing but mere Fire, and at the ſame time apply the ſame inſtrument to Gold, which is the ſolideſt Body that we are acquainted with; you will find the degree of Heat and Cold perfectly alike in both, if they have both remained long enough in an Air that has in the mean time neither grown hotter or colder. Theſe things ſeem ſtrange, it's true, nor have I met with any Body that at the firſt propoſing them, could readily come into them; but yet this juſt, and indeed, infallible method of making the Experiment, moſt evidently confirms the truth of them. In cold froſty weather I examined in this manner the *Torricellian Vacuum*, that of *Boyle*, Air, pure Alcohol, expreſs'd Oils, diſtill'd Oils, Water, *Lixiviums* of various Salts, Spirits drawn from Salts by Diſtillation, Mercury, Feathers, Filings of Metals, Sand, and Lime, after they had been expoſed to the cold Air, and found the degrees of Heat and Cold perfectly alike in all, without the leaſt difference. This ſeems a ſurprizing paradox; but it is, nevertheleſs, abſolutely true. And in every Body.

I have not, therefore, hitherto been able to diſcover, that in all nature there is any part of ſpace, in which there is not Fire. Nor yet, has it ever appeared to me after the moſt laborious Inquiries, that there is any kind of Body, that has a power implanted in it by the Divine Being, by which it is able to attract this Fire thus equally diffuſed, and ſo unite it to itſelf, as to make the exceſs diſcernible to our ſenſes. On the contrary, all the Obſervations that I have had an opportunity of making ſeem to evince, that where there is neither any degree of attrition, nor motion from the mixture of various Bodies together, there, Fire is moſt equally diſtributed through every part of ſpace: Nor does it in the leaſt ſignify whether theſe ſpaces are empty, or full, or with what kind of Bodies they are filled. I am ſenſible that every body will be here apt to cry out, that theſe are all Chimeras of my own brain, and that I aſſert things that are abſolutely falſe, and contrary to common ſenſe, which plainly teaches us that Iron in the Winter is colder than Feathers, and Mercury than Alcohol. But, Gentlemen, I have already given you a caution, that I am not here treating of Fire as it manifeſts itſelf to our ſenſes by Heat, or Cold, but purely with regard to its property of rarefying Bodies, which after a good deal of diligent inquiry we have found to be its peculiar character. How it comes to paſs that Alcohol in Winter appears warmer than Mercury, or raſped Ice, we ſhall endeavour to explain, when we have treated of the ſolidity, or rarity of Bodies with regard to Heat or Cold; nor can we do it now without breaking in upon the order of our ſubject. The quantity of Fire as the ſpaces it is diffuſed through.

 The

Seldom discovered as it exists in this manner.

The ſecond thing I lay down in our doctrine of Fire is this, that this Fire, which is thus equally, and for the moſt part quietly diffuſſed through every part of ſpace, is ſcarely ever taken notice of: For thoſe things which conſtantly remain perfectly the ſame, nor diſcover themſelves by any alteration, are commonly no more regarded than if they did not exiſt at all. If, for inſtance, there ſhould at any time be ſuch a degree of Fire, as ſhould not produce the leaſt change in either Fluids, or Solids, then no body would think at all of Fire, Heat, or Cold: But as ſoon as ever there was a ſmall increaſe of Heat, ſo that Wax ſhould become a little ſofter than it was before, then every one would immediately ſuſpect that there was a new production of Heat, and Fire ſuppoſing them to know before that Wax would be reduced from its ſolid form to a fluid one by the application of Fire. And from this prejudice it happens that people generally think, that Fire is really generated by Art, or chance, whenever its effects are ſo remarkable as to render it more apparent than it was before.

And yet in this condition is always in motion.

In the third place, from what has been ſaid it ſeems evidently to follow, that this Fire that is thus diffuſed through all ſpace and every Body, is continually both moved itſelf, and puts other things in motion, although you ſuppoſe it ever ſo ſmall. For what perſon living can aſſign the ultimate point of abſolute Cold, or which perhaps is the ſame thing, the perfect reſt of Fire? But the very leaſt degree of Fire, Heat, or this rarefying power, immediately begins to expand every kind of Body, to remove their parts from their ſpontaneous coheſion, and, ſo long as it remains in them, to keep their Elements from their proper and natural union; which evidently demonſtrates that a real motion is there excited. And hence it ſeems exceeding probable, that this Fire is contained *in vacuo*, and in the vacuities that are diſperſed through the moſt ſolid Bodies, as in a kind of veſſel, where it is frequently agitated, and always in action; and that hence it is of neceſſity continually producing certain Operations, the effect of all which principally tends to remove the Elements of Bodies from one another, that ſo the Fire may expand itſelf more equally.

And repelled.

In the mean time, however, it is not leſs certain, that the Elements of corporeal matter conſtantly endeavour to unite themſelves together more and more, to leſſen the vacuities between their impenetrable particles, and conſequently by the exceſs of their power to expel the Fire that is there continually endeavouring to dilate itſelf. Here, therefore, will be a conſtant action and reaction, between the Fire contained in theſe Pores, and the conſtituent Elements of the Bodies; the former tending always to ſeparate theſe Elements from one another; the latter from a natural propenſity perpetually attracting one another into the ſtrongeſt union. On this account, therefore, the whole Syſtem of natural Bodies which the Almighty Creator has formed and diſpoſed in infinite ſpace, may be divided into Fire, which has a power of expanding every thing elſe, and the remaining Bodies which have a vertue implanted in them, whereby they conſtantly reſiſt this ſeparation of their Elements. And thus theſe two principles, the one of expanſion, the other of attraction or aſſociation, exert themſelves through the whole compaſs of nature, and are the cauſe of a vaſt number of corporeal effects. The energy, however, of theſe principles we cannot at preſent rightly underſtand from the ideas we have hitherto been able to form of them: This is the ſole prerogative of that infinite Being, whose supreme Wisdom, at one view, perfectly takes in these and all other things, which his Almighty Power has created in such a manner as is not possible for mortal minds to comprehend.

The more intently, now, I examine this mysterious subject, the more plainly I am convinced, that Fire is not able to insinuate itself, into what we call the ultimate impenetrable Elements of Body, but that it is repelled thence whenever it exerts itself upon them, and always the more so, the greater the force is by which it endeavours to penetrate them: that some degree of attrition therefore may, nay, and must arise betwixt Fire and other Bodies: And that Fire itself does in reality never reside in the proper substance of Bodies, but only in the vacuities that will be left betwixt their Elements, let the Bodies be ever so solid. And certainly, the ἀντιτυπία of *Democritus*, or impenetrability as it is called by others, seems so proper to Fire, and every other Body, that it appears by every kind of Experiment to be perfectly inseparable from them.

Never penetrates the substance of Bodies.

As a fourth position in this doctrine we observe, that whilst this Fire thus residing within the Pores of Bodies, is not acted upon or moved by any other cause, so long it does not discover itself by any effect; for since it can go out of these passages again with the same ease with which it enters into them, it will not much vary its action upon the Body that contains it, as it seems to exist, and act every where in an equal quantity. That you may more clearly understand what it is I would here inculcate, observe the degree of Heat that this Thermometer, which is extremely sensible of Warmth and Cold, indicates at this time. I'll place this, now, against the mouth of this great Bellows, and you perceive what a prodigious wind comes directly upon the Thermometer. Don't you all expect now, that the force of this wind will produce a considerable degree of Cold; and that hence there will be a variation in this infallible Instrument? And yet you observe it remains perfectly at the same height. Here, then, we see evidently, that there was no degree, either of Heat, or Cold, generated by this means, which our senses were capable of discerning: For Fire, by reason of its exceeding rarity, is almost as easily conveyed through Air, when it is in motion, as when it is at rest. Indeed, was this Air agitated with an extraordinary violence, such a one as this Bellows is not capable of, in that case, by the attrition arising hence, might be excited a greater degree of Heat, as has already appeared; but then, this would be owing intirely to attrition. And hence perhaps it comes to pass, that the greatest storms, a few cases excepted, do generally *cæteris paribus* rather raise than sink the Thermometer. This, at least, I have long ago observed, that we have generally a very warm Air at the same time we have the highest winds, and the sharpest Frosts when every thing is perfectly calm. But you'll be apt to say, why then does the wind, and indeed the Air itself, appear so cold to our Bodies, especially when they are heated, so that every one very justly ascribes to them a power of cooling? And do we not find by undeniable Experience, that in a cold high wind, the Cold is vastly more injurious to us *cæteris paribus* than at other times, so that no person is able to bear it, but would soon have his limbs destroyed by a Gangrene? In answer to this, I acknowlegde the truth of these facts, but at the same time assert, that the cause of them is very different from what people generally imagine. To account for

Wind don't produce Cold,

But rather Heat.

And yet it cools the Human Body.

 this,

this, then, we must observe, that no body is able to endure an Air that is heated to 90 degrees, but it soon becomes fatal to all sorts of Animals that we are acquainted with; whereas the vital Warmth of the Human Body, as *Fahrenheit* has observed, will raise the Thermometer to the degree 92, and that of children often to 94. Hence, therefore, we are always warmer than the ambient Air; and of consequence the garments that encompass our Bodies have a greater degree of Heat in them than if they were every way exposed to the open Air. Again, this natural Warmth heats the Air that is contiguous to our Bodies; and therefore, if it is not disturbed by any wind, but remains quiet about us, this Atmosphere of our Bodies will be warmer than the Atmosphere of the common Air, and consequently we shall feel it warm, as it really is. When this warm Air then, that every way surrounds us, is dispersed by the wind, and a colder Air is applied to us in its room, there immediately is excited a real Cold both in our Lungs, and on the surface of our Bodies, that are exposed to it: And besides, the Heat that is communicated by us to our clothes is at the same time blown away, and fresh Cold is continually received by them, and thus applied to our Bodies: So that, in reality, we are nearly in the same circumstances as if a man should perpetually shift his clothes, and put on fresh ones that were just come out of the Air. It appears, therefore, from these considerations, that though wind does not actually generate any degree of Cold, yet it is capable of cooling the Human Body by thus carrying off the warm Air with which it is encompassed, and bringing fresh colder Air in its room. But as this Observation may be of exceeding service in Medicine, give me leave to illustrate it yet farther by an Example. Let us suppose then by exercise, disease, or some other cause, the heat of any person in his clothes, and in a serene Air to be 100 degrees; and that of the common Air at the same time to be moderate, *viz.* about 48. Now you easily conceive that the clothes that are about his Body, will in a little time be pretty near as warm as his Body; and that the Air which remains quiet about his clothes, and his head, will be considerably warmer than the degree 48; for I have often observed, that the Thermometer has been raised at the distance of 4 feet purely by the Warmth that has exhaled from a man that was hot, and fallen again when the person removed farther from it. Suppose, therefore, the person's clothes, and the surrounding Air, to be heated to the degree 60: His Body then will be perfectly encompassed with this temperature, his vessels, and humours relaxed suitably to this degree of Heat, and his exteriour Nerves will be just affected with a sense of the same. Let him be exposed, now, to a wind that moves 6 feet in the second of an hour; and then all this heat of the ambient Air, and his clothes, will be removed in that time, and a Warmth of only 48 degrees will be applied to his Body on every side, and consequently his external parts will be 12 degrees colder than they were before: And since we suppose this wind to continue constantly the same, his Body must in a little time grow cold in its inmost parts; as the constant application of this external Cold must every moment necessarily destroy as much of that Heat, which is generated by the vital actions. Thus, therefore, we have an evident solution of this *Phænomenon*, which otherwise, indeed, appears a paradox.

Not a Thermometer.

For if now, instead of a human Body, you place a Thermometer in this Wind, the Heat of the Liquor in the Thermometer, and that of the ambient

Air, will be exactly the ſame; and hence, whether the Air that encompaſſes this Inſtrument remains perfectly at reſt, or is conſtantly changed, the Liquor will ſtill continue exactly at the ſame height; and conſequently, the greateſt Wind will not produce the leaſt degree of Cold in the Thermometer; unleſs there is at the ſame time ſome alteration in the temperature of the Air in the place the Wind blows from. Now, from what has been remark'd, you, Gentlemen, who conſider the human Body in a medicinal view, will eaſily underſtand, how nothing produces ſeverer diſeaſes, or is more quickly fatal to the healthieſt, nay and the ſtouteſt Bodies, than expoſing them to the Wind, when they have been heated with motion, and are ready to diſſolve with Sweat; eſpecially, if they are grown hot by a violent exerciſe in a cold Wind, and then remain quiet. Hence often ariſe Aſthma's, that are never got rid of, *Angina's*, Pleuriſies, Peripneumonies, Gout, and Rheumatiſm. A plain proof of this, likewiſe, we ſee too plainly in thoſe perſons who unhappily labour under an exceeding weak and tender habit of Body: How prodigiouſly do theſe ſuffer from the ſlighteſt Wind, or leaſt breath of Air, if it comes only through a crack of a window, and is but little colder than the temperature of the chamber in which they live; eſpecially, if that has been always kept pretty nearly the ſame by the help of a Thermometer, than which I know nothing more injurious to a good conſtitution.

The uſe of it in Phyſic.

In the fourth place then, from what has been now ſaid, and which we ſhall not repeat for the future, we may reaſon ſomething of the nature and action of Fire: For if two denſe, hard, and very elaſtic Bodies are rubb'd one againſt another with a great force, and a briſk reciprocal motion, then all the parts of theſe Bodies will every moment be cloſely compreſs'd; and as they are rigid, they will ſtrongly reſiſt this preſſure, whence will ariſe an exceeding ſwift, and very powerful contraction and expanſion, or a kind of quick vibration, ſuch as we obſerve in Chords when they are very tenſe. How great theſe vibrations are, we ſee evidently in an elaſtic metal Bell, if it receives but one ſtroke upon it. Does not the whole Body of this, vaſtly large, as it is ſometimes, expand and contract itſelf through all its ſubſtances in an infinite number of *Ellipſes*, and that, for a very conſiderable time? And when the attrition that we juſt now deſcribed is excited, with what force, violence, and celerity, are the elements of the Body compreſſed, agitated, and relaxed, to their very inmoſt Particles? What a *ſtridor* is produc'd from this attrition, ſo acute, that the Ear is not able to bear it; a certain demonſtration of the greatneſs of the vibration? We conceive, therefore, that whilſt the Body ſuffers this agitation, compreſſion, and relaxation, there muſt be an exceeding rapid motion in all its Particles, as all Chords perform their vibrations ſo much the quicker, the more elaſtic, and ſhorter they are, and the harder they are ſtrained: But thoſe three circumſtances concur here all together. Now as this is beyond all diſpute confirmed by Experiments, ſo I think it is not leſs evident, that the Fire, which in the mean time reſides in the pores of theſe Bodies, and exerts there a power of expanding them in all their dimenſions, and is likewiſe repelled by the contractile, reſiſting force of the expanded Body; I ſay, that this Fire muſt now, by the action of this attrition, be neceſſarily every moment moſt violently compreſs'd and relax'd in theſe vacuities. Hence, as from that property of expanding every thing which we took notice of before, Fire ſeems of all Bodies

The action of Fire excited by attrition.

to

to be the moſt elaſtic, it appears that its proper force and motion muſt thus be prodigiouſly increaſed. For this reaſon, therefore, we conceive, that both in the Bodies thus agitated, and in the Fire contained within their Pores, there will be excited a motion exceeding great, and that will continue a conſiderable time. But farther, this cannot happen, but the ſurrounding Fire from both theſe cauſes muſt be agitated likewiſe, and that, ſo much the more violently, the nearer it is; for it has already appeared, that Fire is equally diffuſ'd through quieſcent Bodies, and Space, which is neither capable of motion or change, and perhaps acts equally too. The ambient Fire, therefore, muſt likewiſe follow the concuſſions of that intercepted in the *Meatus's* of the Bodies thus rubb'd together; and of conſequence, muſt be driven backward and forward. And this vibration ſeems to continue as long as that which is produc'd in the Bodies by this attrition, or till the oſcillations of the Fire itſelf are reduc'd to reſt, or a motion equal to that of the Fire in the Spaces or Bodies round about it. But ſince the ſame cauſes that agitate theſe Bodies muſt add a new motion to the Fire alſo, beſides what it had before in common with all other, hence its force muſt be likewiſe increaſed: And as the expanſion of Bodies is the proper effect of this force, it will of conſequence preſently diſcover itſelf by this effect. Thus far, therefore, we may comprehend the power of Fire, conſider'd purely as excited by attrition: And the ſolution of a great many *Phænomena* we meet with here, will be hence eaſily underſtood.

By which ſome *Phænomena* are underſtood.

1. Why do elaſtic Bodies chiefly generate Fire by attrition? Becauſe they alone oſcillate in their Elements. 2. Why do the moſt elaſtic Bodies produce moſt Fire, as we ſee in the hardeſt Steel briſkly ſtruck againſt a rigid Flint? Becauſe the vibrations here are the ſwifteſt and greateſt. 3. Why do the ſofteſt non-elaſtic Bodies generate the leaſt Fire? Becauſe they have no ſpring in them, nor reſtore themſelves again, nor oſcillate backwards and forwards. 4. Why then will Lead rubb'd forcibly againſt Lead produce a very great degree of Heat? Becauſe the ultimate Elements of Bodies are expanſile and contractile by Fire, and from their own nature, tho' the larger Bodies that are compoſed of theſe Elements, have a coheſion of parts that is leſs reſiſting, and will eaſier give way. Hence it appears, that the elaſticity of theſe Elements, which is common to all Bodies, and may be changed by Heat and Cold, is different from that by which Bodies reſiſt an impulſe, and reſtore themſelves to the ſame form they had before the ſtroke. 5. Do not Fluids, therefore, generate Heat by attrition? Moſt certainly, if they are elaſtic; but with difficulty, if they are not. Hence Water will not eaſily grow warm by attrition. Nevertheleſs, if non-elaſtic Fluids are forc'd through very narrow canals with a vaſt *impetus*, they will conceive Heat by this attrition; becauſe the ultimate Elements of theſe ſeem likewiſe to be ſomewhat elaſtic: But if the Pipes are elaſtic through which the Fluid is impell'd, then a ſtill greater degree of Heat may be excited. Hence, our elaſtic Blood being violently propell'd through elaſtic Arteries, is hot whilſt it circulates in a healthy Body: But when the Blood by any means becomes of a more watery diſpoſition, and conſequently leſs elaſtic, the Heat that is produced by its circulation will not be ſo great: Which is likewiſe the caſe, if the ſpring of the Arteries becomes weaker. 6. Why does the interpoſition of a Fluid, when Bodies are rubb'd together, hinder, or diminiſh, the production of Heat? Becauſe the force impreſſed is

eluded by the ſlipperineſs of the Fluid. 7. Does therefore an elaſtic quality in Bodies increaſe the action of Fire upon them? Vaſtly; as appears from what has been juſt obſerved. 8. If the power of gravity determin'd Bodies leſs towards one another, what would be the conſequence with reſpect to Fire? Then, we ſhould ſcarcely perceive any of its effects: This we experience in the deepeſt pits, and on the tops of the higheſt mountains. 9. How does it happen then in very deep places, where the Air is always at reſt? Why there, at the ſame depth, there will always be the ſame degree of Heat and Cold, tho' it will be different, at different depths, according to the various nature of the Earth that in thoſe particular places ſurrounds and warms it: The truth of this is confirm'd by ſome elegant obſervation made in the Well of the Obſervatory at *Paris.* 10. Why does the percuſſion of Steel againſt a Flint, yield the largeſt and moſt vivid Sparks in the coldeſt weather? But there would be no end, ſhould I mention every thing that is conſtantly occurring, whilſt one's thoughts are engag'd on this ſubject. In ſhort, therefore, Gravity, Elaſticity, and Fire, ſeem to be the three principal of the univerſal or common cauſes of the actions of natural Bodies; and when to theſe, likewiſe, is added attrition, a great many *Phænomena* that are common to them all, may be eaſily underſtood.

The *Ratio* of Fire, and where it is greateſt and leaſt.

From what has been premiſed, we infer, Fifthly, that if the denſeſt, and moſt elaſtic Bodies of all, lying in the deepeſt parts of the Earth, and vaſtly preſs'd together by the weight of the incumbent ones, ſhould be agitated one againſt another with the utmoſt degree of celerity, there would by this means be generated the moſt violent Fire. And hence it ſeems exceeding probable, that at the center of the Earth the Heat is moſt intenſe; and that it decreaſes gradually as you remove farther from it, till it becomes leaſt of all at the boundaries of the two Planets. Let us ſuppoſe the Earth and Moon to be Bodies of the ſame nature; then in the center of the Earth and Moon will be the greateſt degree of Heat, which will leſſen by degrees, till you come to that part of ſpace between theſe ſpheriodal Orbs, which terminates the action of both their powers. It appears, therefore, abſolutely impoſſible, that any Birds can fly from us to the Moon, or from thence to us, as ſome Philoſophers have aſſerted; or that they can exiſt in the profound Abyſs. And what we have ſaid of the Earth and Moon, will hold equally true in all the reſt of the Planets. And hence it ſeems likely, that heavy Bodies are diſpoſed only about the Planets, and perhaps about the Suns or fixt Stars, and thence by degrees grow ſo rare and light, that at laſt the reſiſtance they yield becomes inconſiderable, if any at all: That the quantity of Fire there, however, is equally great: That this Element, therefore, may poſſibly not be affected by the power of Gravity, but be abſolutely indetermined to any part of Space: That hence, of itſelf, it may have no other power than that of an equable expanſion every way, without any particular direction to one place more than another: And that on this account, it may ſcarcely produce any effects in thoſe ſuperiour regions, as there is no agitation of denſe, elaſtic Bodies one againſt another, to cauſe there any attrition. And as the motion and tracts of the Comets are not yet accurately determin'd, does not the path of theſe wonderful Bodies lie through theſe Spaces between the Planets, and Suns, where they meet with ſcarcely any reſiſtance?

Birds can't bear the temperature of the higheſt part of the Atmoſphere.

Some other circumstances increasing the Heat raised by attrition.

It appears, farther, in the Sixth place, that those Bodies which have such large Pores interspersed through them, that Air, Water, Spirits, and Oils, may easily enter into them, and be expell'd again, are the least fit to generate Heat by attrition: Whereas those on the other hand, whose substance is so closely condensed, that their vacuities will admit nothing but pure simple Fire, must, if they are thus agitated, give a great degree of motion to the Fire contained within them. If we suppose, then, the Surfaces of two Bodies in contact to answer one another so nicely, that nothing but mere Fire shall be able to insinuate itself between them, when they are thus fitted together and put in motion; then, if they are rapidly mov'd one upon another, the Fire, which can alone interpose itself, will be agitated too: And from this cause again, the Heat will be augmented. And farther, if the agitation of these Bodies is so excessively rapid, that neither Air, nor any thing else can keep up with it, except the Fire that is dispersed through the Air, and other places; then, it seems exceeding probable, that this Fire will rush into these Spaces that are thus alternately empty, and fill'd again with this prodigious celerity; and thus more Fire will be collected in that Space which is nearest the Surface of these Bodies, than was there before; which will therefore be another cause of the production of Fire by attrition. And lastly, if the Elements of any hard Bodies are connected together by the firmest cohesion, and at the same time the Fibres and *Strata* form'd of them are exceeding short, and very tremulous; then, their vibrations will cause in Fire a very swift and strong agitation, and they will be able by a brisk attrition, to produce a vast degree of Heat in a very short time. The motion, therefore, that Fire acquires by these means, must certainly be prodigiously great.

Why does Fire quit a rarer Body sooner than a dense one.

It remains, now, carefully to inquire in the Seventh place, whether there is really observ'd in Bodies, any power by which they are able to attract Fire, so that the more solid substance they contain, the more Fire will of consequence be united with them? In quiescent Bodies, that this is not the case, is past dispute; for by Experiment, it constantly appears, that there is neither more nor less Heat or Fire in the *vacuum* of *Torricellius*, than there is in Gold, when they have both continued a good while in a place of the same temperature. But by the attrition we have spoken of so often, do Bodies acquire a kind of magnetic virtue, by which they are then capable of attracting Fire, and retaining it a considerable time when it is once united with them? I have taken a great deal of pains to answer this question; and this at least, I have evidently observ'd, that the rarer a Body is, the sooner it will be heated by the same degree of Fire; and that when once a Body is heated, the denser it is, the longer it will be before it is cold; and the rarer it is, the sooner. Hence, then, it seems to follow, that there is, in reality, in the solid Mass of Bodies, something like an attractive power, with regard to Fire; especially, as the same observation holds equally true in elastic Bodies, and those that are not so. In *Tschirnhausen*'s *Focus*, the Fire is vastly intense; and yet, if with an Umbrella you cover that side of the Glass which is towards the Sun, the Heat will at once vanish from that place in the Air, where the moment before it was so excessive: Whereas, if a piece of Metal had been heated by the same Fire, it would have retain'd its Heat for a long time. If one vessel full of Air, and another of Water, had been exposed to the same Heat, the Air, may be, in this

Heat,

Heat, would be a thousand times rarer than the Water heated to the same degree; but then the Water would retain the Heat so much longer, as it was longer in acquiring it, so that possibly the Air would grow cool a thousand times sooner. From these observations, however, I think we can fairly conclude no more than this, that the denser the Bodies are that are exposed to Fire, the greater difficulty it has to penetrate into them, and to disengage itself from them again; for this is all that experience certainly demonstrates: Nor does it appear with sufficient evidence, that this *Phænomenon* is really the effect of any other cause. Indeed, if one might be indulg'd a conjecture on this head, one would be apt to surmise, that when Fire enters into denser Bodies, it causes a concussion in their very Element, and puts them into vibrations, which are larger if they are less dense, and of longer continuance, if they are more so; and that these, as long as they are in action, agitate the Fire that is contained within them, in the same manner as it happens to elastic Bodies by attrition: Upon the most careful examination, however, of this matter, I have not been able hitherto to discover by observation any such thing as a magnetic power in Bodies with regard to Fire.

Heat excited by percussion alone.

In the Eighth place, I observe farther, that the hardest, and most solid Bodies being penetrated by a very small degree of Fire, and heated through all the Particles of their whole Mass, are mov'd and agitated to their very inmost substance; as appear'd plainly under our first Experiment. When, therefore, the same Bodies are heated perfectly through by attrition, they will be constantly agitated in the same manner. And hence again, these *Stamina* being thus all tremulous together, we conceive that they must produce a friction among themselves so long as this motion continues; and consequently, must be agitated in the same manner as if this attrition was external. On this account, therefore, they must move the Fire contain'd within them, and attract, collect, and retain it a good while within their solid Mass. And then again, these filaments of the Bodies are reacted upon by the Fire, and thus too, suffers an attrition from it. From all these causes then, Heat will be sometime retained in Bodies when once it is communicated to them. And indeed, that great Philosopher *Robert Boyle*, long ago made it appear by Experiment, that a solid piece of the coldest Iron, laid upon a cold Anvil, and briskly hammer'd with cold Hammers, would, purely from this compressive force, and its own recoiling elasticity, grow so hot, as to kindle Sulphur that was thrown upon it: And again, that an iron Nail driven up to the head in a piece of hard Wood, would, by being struck upon with a cold Hammer, immediately grow exceeding hot, when once it could enter no farther, tho' the Hammer itself would continue cold. And he farther demonstrated the same thing in filing of Iron, where the Iron will acquire Heat, tho' there appears none at all in the File. See those valuable Treatises of his, *Of the Mechanical Production of Heat and Cold.*

Purely by the vibrations of elastic Bodies.

From these observations, therefore, we see in the Ninth place, that there may, by this means, be a great deal of Fire produced, where we are certain nothing more happens than the elastic Iron's being compress'd by other elastic Iron, and its restoring itself again between every stroke of the Hammer: And yet there will be here so great a collection of Fire, that Sulphur being sprinkled upon the Iron, will be kindled into a Flame.

From a simple stroke.

Tenthly, then, we conceive, that when once ſuch an elaſtic Body is thus heated by percuſſion, it will for ſome time retain this oſcillation in its compreſſed and recoiling Particles, and by this means continue the motion of Fire: As we ſee a Chord, when once ſtruck, will tremble a good while; and a Bell, from one ſingle ſtroke, will continue its ſonorous undulations a great deal longer.

Fire is not actually generated by this means,

In the Eleventh place, it ſeems of conſequence to examine whether this Fire that we have thus mention'd, as produc'd by attrition and percuſſion, is really generated *de novo* by theſe vibrations of the Particles, and did not exiſt before: And again, whether the parts thus vibrating do ſo wear away their own ſubſtance, that the Particles of the Body itſelf, thus abraded and agitated, become real Fire; and conſequently, whether other Bodies may thus by attrition, percuſſion, and vibration, be actually chang'd into true Fire, and thus Fire be created of what was not Fire before? For my own part, I confeſs, this, to me, ſeems impoſſible. For I have demonſtrated, that Fire exiſts in all places. I have made it appear, that it is equally diffuſed through every part of Space. I have prov'd, that it may be produc'd by the attrition of any Body whatſoever. And it is evident, that when it is once excited, let the manner of its production be what it will, it is always abſolutely the ſame, and diſcovers immediately that property, which is peculiar to Fire and inſeparable from it, and belongs to no other Body in nature beſides. It is not at all probable, therefore, that Fire is continually generated *de novo*: But it ſeems likely, that when it is once created, it then continues always to exiſt, and that in the ſame quantity; tho' in all the actions abovemention'd, it undergoes ſuch changes, in reſpect of its motion, reſt, collection, diſperſion, and direction, that it ſometimes diſcovers itſelf to our ſenſes, whilſt at others it lies concealed beyond their penetration. And if a perſon carefully conſiders the things I have already offer'd concerning the marks and production of Fire, both as they ſtand ſeparately, and as they give light into one another, I can't but believe, he will find they plainly confirm my opinion, and ſhew the fallacy of the other: For who does not ſee, that by the attrition and percuſſion of a hard elaſtic Body, Fire may be put in a greater motion, than it was in before? And who will deny, that this will likewiſe agitate other Bodies in a greater degree, when it is thus put into a ſwifter agitation itſelf? Who don't eaſily perceive, that Fire alone is able to keep up with the exceeding rapid motions of the moſt ſolid Bodies, and of conſequence, muſt be there collected? And who doubts, but that in all theſe caſes, ſo much Fire is really brought hither from the neighbouring places in particular, as now exiſts in this place more than did before? For the motion of Fire from one place to another, don't ſeem at all more difficult than that of any other Fluid. But as ſoon as ever it is collected from a larger Space, and more cloſely reduc'd into a leſs, it muſt of conſequence appear to our ſenſe, as tho' it was really created a-new, both on account of its quantity, and of its effects.

But is put in motion and collected, and ſo diſcovers itſelf.

The concluſion.

In the Twelfth, and laſt place, give me leave to mention what I have taken notice of already, *viz.* that in every part of the known world, where there is the greateſt degree of Cold that either Nature or Art produces, Fire does actually exiſt, and that in a very great quantity: For either by attrition, or percuſſion, the ſtrongeſt Fire may be excited there in the leaſt inſtant of time. This we ſee evidently by ſtriking a Flint againſt a piece of Steel; and this the

Thermo-

Thermometer infallibly demonſtrates, which we know certainly never ſuffers the leaſt variation, when it is apply'd to Spaces, or Bodies of the ſame temperature. I think, therefore, Gentlemen, I have now, by Experiments, and the Corollaries drawn from them, pretty intelligibly explain'd to you the firſt phyſical manner, by which that Being may always and every where be certainly excited, which has a power of penetrating, and expanding or rarefying every thing we are acquainted with, Space only excepted: But this we plainly made appear before to be univerſally called Fire. We now, therefore, begin to get a little light into its hidden and myſterious Nature, and conſequently, have ſome encouragement to proſecute our inquiries.

Experiment XI.

If Fire, explain'd as above, and now known by its power of rarefying, putting in motion, and inſinuating itſelf into every kind of natural Bodies, is collected in any Space, or Body, ſo that it becomes perceptible to our ſenſes, it then immediately begins to move itſelf by this power, and expands itſelf every way from the center of this Space, or Body.

That you may the better conceive what I mean, and at the ſame time ſee the proof of it, let this leaden Bullet be immerſed in boiling Water, and after it has remain'd there till it has acquired the ſame Heat with the Water, be pulled out again by this Thread by which it is ſuſpended. It then throws out the ſame degree of Heat from every point of it, with regard to our ſenſes, has exactly the ſame effect upon the Thermometer plac'd at the ſame diſtance on any ſide of it, and by every circumſtance indicates an equable diſperſion of this Heat or Fire. Again, obſerve this red hot Iron juſt taken out of the Fire, does not the Fire look equally lucid and bright, and exhibit the ſame Colour in every part of it? And it warms us all equally, that are at the ſame diſtance all around it. It has evidently, likewiſe, the very ſame power of fuſion, exſiccation, and burning, on every part of it. And which is the ſtrongeſt proof of what I aſſerted, all Thermometers, let them be immerſed in what Liquors they will, if they are plac'd at the ſame diſtance, will immediately diſcover the ſame temperature, by either expanſion or contraction: And indeed, this is evidently confirm'd through the whole compaſs of Nature.

Corol. I.

It appears, therefore, that this is the property of Fire, that its parts, whilſt they expand or move themſelves, tend equally towards every part of Space, and conſequently, are not determined to one point more than another. This, I confeſs, ſeems ſomewhat ſurprizing, and not eaſily intelligible; and indeed, this idea differs very little from the idea of reſt. I'll endeavour, therefore, by a ſimple Example, to explain what I mean, a little more clearly. Suppoſe a hollow Sphere perfectly empty, and then conceive another Sphere a hundred times leſs to be plac'd in the center of it, and its parts to have ſuch a power, that by equably receding from one another, they may perfectly fill up the larger Sphere: By this means then, you will have a true motion in all the parts, and yet the whole Maſs thus mov'd, will be perfectly indifferent, and indetermined to any particular ſide. We conceive, therefore, from the

The proper *niſus* or tendency of Fire.

 foregoing

foregoing Experiment, that the Fire that resides in our Air always expands itself, and is compress'd by the same law, if no other cause intervenes.

CoROL. 2.

The computation of this Fire, with regard to its force and quantity. Pl. III. Fig. 1.

If you'll give me leave now to call the circumstance of Fire, describ'd in the preceding Corollary, its State of Stagnation; then the force of stagnating Fire will be as the Spaces in which it is contain'd; and consequently, the communication of this force from it, will be as those Spaces. Suppose the Globe A full of Air, hotter than the other surrounding Air contain'd in the larger concentric Sphere B; then the quantity of Fire, and its active force upon any part of the circumscrib'd Sphere, will be to the whole, as the Space on which you suppose it to act, is to the whole Space circumscrib'd: But this, in any case, the Geometrician may easily compute; and therefore, with regard to this property of Fire, the case is very evident.

CoROL. 3.

By an Example. Fig. 2.

For the easier conceiving of this, let us suppose the geometrical Globe A full of Fire, and in contact with another equal one B. From the center of the first C, draw the Tangents CD, and CE, to the Globe B. Then it is plain, that none of the Fire in the Globe A can, upon our supposition, come at the Globe B, except through the Sector CFG. Now the proportion of this to the whole Globe may be geometrically found *quam proxime*, as also the magnitude of the Cone CDE, and the spherical Segment DIE; and consequently, the quantity of Fire communicated to this Segment. These demonstrations we may be easily furnish'd with from the Geometricians: It is sufficient to our present purpose, just to have mentioned them.

CoROL. 4.

An exact determination of it. Fig. 3.

These things being understood, let us now suppose some physical cause to arise, which has a power of impelling all the Fire contained in this Sphere in parallel lines, and so of determining it towards one particular part. We then immediately conceive, that its whole efficacy will be directed that way, so that it will pass through the Cylinder EFGI, and all of it fall upon the Sphere KGBI; and consequently, will exert its whole force upon that Sphere. The effect of it, therefore, in this direction, will be to the former, as the whole is to that part, and as this parallel direction is to the diverging one; from the combination of both which causes, its force will be very considerably increased. But the quantity of Fire being doubled, its efficacy will be vastly augmented: For in 32 degrees of Heat, Water will freeze; in double the number, *viz.* 64, the Air grows very hot; in 92 degrees, which is tripple the first, the Heat will exceed that of the Blood of a person in health, and an Air so hot would be fatal, perhaps, to every kind of Animal; in 192, which is 6 times the first, the Heat will come near to that of boiling Water, and would be able to dissolve and destroy all the parts of every Animal whatsoever. Since now the *Area* of a great Circle of this Sphere is to the whole Surface of the same, as 1 is to 4; hence the Fire in the Basis of the Cylinder abovementioned, will be 4 times more condensed than it was in the Surface of the Sphere before; and therefore, its force thus united, will be so much augmented. If we could nicely

nicely, therefore, discover how the expansive power of Fire is increased in proportion to the smallness of the spaces into which it is condensed, then we should be able to finish the computation: For if this was as the *Areæ* themselves, then its force would be four times greater on account of the quantity, and four times on account of the expansion, and consequently, sixteen times more violent from both causes together. We must endeavour, therefore, to determine if possible, by Experiment, this expansive power of Fire in respect of its density; for it is probable, that this is exceeding great; and consequently, that this direction of it in parallel Lines is of prodigious efficacy.

Experiment XII.

Now, if we turn our eyes every way to discover a cause that is able thus to determine the action of Fire into a Parallelism in our Air, the Sun certainly seems principally to offer itself as a being endued with a power sufficient for producing this effect. For that vast Globe, which the learned discover to be 13431 times greater than the Earth, and almost 12543 diameters of the Earth distant from it, as it appears by every kind of argument to diffuse its Light and Heat in right Lines, must in respect of its vast distance be considered as acting upon us in parallel Lines. It is not necessary here to cite those Arguments from Optics, Catoptrics, and Deioptrics, which no doubt you are acquainted with, by which the Rays of Light that flow from the Sun are demonstrated to proceed in right Lines, if they meet with nothing to interrupt them; and that then they are directed again in the same manner from that point of the obstacle upon which they fall. Give me leave, however, to mention one Experiment that occurs to me, which I think is an absolute proof that all the Rays, that either proceed from, or are determined by the Sun, affect the most strait direction; and that is this. Suppose it to be twelve a clock in a cold Winter's night, the Moon to be at the change, and the Heavens to be perfectly serene. Let any one then look up to the Sky, and he will see nothing lucid in that immense space, besides the Stars. Of the Heat, and Light of the Sun, there will nothing at all appear in the whole Hemisphere, except that inconsiderable quantity which the Planets borrow from that Luminary, and reflect to the Earth: And yet we are certain, that the Rays of the Sun at that very time, strongly enlighten all this Hemisphere, except that small Cone, whose Base is a great Circle of Earth, and its *Axis* 114 Diameters of the same; which small portion is all, of that vast space, that is included within the shade of the Earth, and consequently is not illumined by the Light of the Sun. It appears evident, therefore, beyond all dispute, that let a place be ever so brightly enlightened by the solar Rays, yet the Light will not be discerned by a person situated in such a position, that a right Line cannot be drawn from the Body of the Sun to his eye; except these direct Rays should first fall upon a Body by which they might be reflected to it. And the same thing is, nearer at hand, perceived in a chamber so nicely shut up that the least discernible Light cannot enter. For if you then make a very small hole towards the Sun, and by this means let its Rays into the room, you will in this place have only one lucid Cone, whose *Apex* in the hole, and its base projected *in infinitum*. Now if you take any Body perfectly black, and oppose it to the Base of the Cone, there will, then, no Light at all appear in the room,

The Sun determines Fire into a Parallelism.

room, except to an eye placed within the illumin'd Cone; for if it is placed on one ſide it will be nothing at all, though at the ſame time the Cone is exceeding lucid. I confeſs, indeed, if we look at it ſideways we may diſcern a kind of weak Light in the Cone; but then you will eaſily ſee, that this muſt proceed from the duſt that flies about in the Air, and ſo reflects the Rays of the Sun that fall upon them; which was it away there would not appear the leaſt Light at all. And this is evidently obſerved to be true, when by chance, for this has been the caſe, theſe particles are ſo diſpoſed that they will not repel the Rays of Light. By this argument, then, we are induced to believe, that the Sun has a power of making the particles of Fire, deflect from their natural tendency, which is from the Center to the Circumference, and determining of them in parallel Lines.

If we conſider, again, that all objects which are viſible by the means of Light, though obſcure of themſelves, immediately begin to ſhine, or appear, as ſoon as ever the Rays proceeding from the Sun fall upon them in a right direction, and grow inviſible again the inſtant that this is prevented, then the ſame thing will be ſtill farther confirmed. And again, if we rightly conceive, that the ſolar Rays falling upon a perfectly plain *Speculum*, and reflected thence by certain laws, only illuminate that part towards which the reflexion happens, this doctrine will be more fully eſtabliſhed. But this Catoptrics certainly and evidently evinces; and moreover teaches us, that one Ray of Light, proceeding from the Sun in a right Line, and falling upon a pure *Speculum*, will be thence reflected to ſuch another Glaſs in a right line, and repelled again by this in the ſame manner, and ſo on, and that this ſingle Ray, after ſo many reflexions, will ſtill retain its lucid property, though it will never be ſeen but in a right Line drawn from the lucid point of the laſt reflecting *Speculum* to the eye. Since, therefore, this happens in the whole image of the Sun, as well as in one ſingle point, it is evident that that power of the Sun by which it determines Fire in parallel right Lines muſt always exert itſelf ſo long as this emanation and reflexion continue. But as ſoon as ever this luminous Body withdraws itſelf, this rectilineal direction immediately ceaſes, and Fire is then again left to its proper tendency, and enjoys its own natural expanſive power. For this reaſon, therefore, the Sun ought to be looked upon as the director of Fire.

But, again, if we conſider, that the vaſt Body of the Sun on account of its prodigious diſtance appears only a lucid Orb, whoſe Diameter takes up but $\frac{61}{43200}$ or $\frac{1}{708\frac{12}{61}}$, or $30'.\ 30''$ of a great viſible Circle of the Heavens, we ſhall eaſily ſee, that the Rays projected thence in reſpect of that little ſpace which falls under our Obſervation, may be fairly regarded as parallel. And laſtly, as a farther confirmation of this Doctrine, let us obſerve that in Optics, Catoptrics, and Dioptrics, we always ſuppoſe the Rays to come from the Sun in a parallel direction, in computing their refractions, reflexions, and the directions they move in; and yet, we can hence very accurately determine the true points of their *Foci*, reflexions, and directions, ſo that the *Phænomena* we obſerve in them, very nicely correſpond with the demonſtration.

From all theſe Obſervations, therefore, thus ſuccinctly collected, it appears very evident, that the Sun is ſuch a cauſe as will inſtantly determine the matter of Light reſiding in our Air into a Paralleliſm, as often as it can exert its power upon it without any impediment.

But it has been always obſerved, that theſe lucid parallel Rays of the Sun produce Heat in the Bodies to which they are thus directed. And, hence, what has been juſt now demonſtrated of Light, will appear as evidently true of Heat. And ſince we here ſpeak of that Heat which is diſcovered by the Thermometer, we infer farther, that the ſame things will hold good of true Fire likewiſe, as we have hitherto explained it. We have now, therefore, found out the true reaſon why the Sun can very conſiderably increaſe the power of Fire, diſcoverable by its expanſion, purely by this parallel determination, without any addition of new matter, without any ſupply of Fire from the body of the Sun itſelf, or any production of Fire from ſomething that was not Fire before. And this, if I am not miſtaken, is a diſcovery of the utmoſt conſequence in a chemical Treatiſe of Fire.

Perhaps you may aſk, now, why don't a lighted Candle then, ſince it emits its Rays of Light in a right direction, warm the place too that it illuminates? To this I anſwer, becauſe this little radiant Cone does not act in a Paralleliſm, but diffuſes its Rays in a kind of Sphere, and hence does not propel the Fire in the room to one part more than another, but every way equally. But even in this caſe, if you approach ſo near to the candle, that, on account of the ſmall diſtance, the Rays may be conſidered as almoſt parallel, you will then immediately be ſenſible of Heat.

Thus, then, I think this difficulty intirely vaniſhes; eſpecially if you conſider at the ſame time, what I have obſerved already concerning the wonderful diverſity of Light, and Heat.

COROL. I.

When this Paralleliſm ceaſes, Heat ceaſes likewiſe.

Whenever, therefore, this rectilineal impulſe of the ſolar Rays, which thus give Fire its parallel direction, is by any means impeded, this Paralleliſm immediately ceaſes too, and that very moment the parts of Fire are equally expanded towards every ſide: Hence it eaſily appears, that this Paralleliſm was the only cauſe of all its former power. For let *Vilett*'s *Speculum* be directed to the Sun at noon in a perfect clear day, and an iron rod be placed in its violent *Focus*, and be actually melted down; and then, whilſt it acts with this vaſt power, let ſuch an opake Body be interpoſed between the *Focus*, and the Sun, as will ſhadow the whole *Area* of the Glaſs, and that intenſe *Focus* will inſtantaneouſly be deſtroyed, though the Air between the *Umbrella* and *Speculum* remains equally warm, that is, contains as much Fire as it did before, the Sun continues to ſhine equally bright, and nothing more happens than this parallel direction being prevented. Nor was there, as perſons may imagine, more Fire between the *Focus*, and the *Speculum*, whilſt the Rays of the Sun fell directly upon it: For in fact, one does not diſcover there any greater Heat, except what proceeds from the reflexion. There is a prodigious difference, therefore, betwixt that Heat which Fire yields from the attrition of Bodies, and that which is produced in the Air by this ſolar Paralleliſm: For the former continues a good while; the latter vaniſhes immediately. If a ſolid Body, however, is heated by the Sun, it will by reaſon of its ſolidity retain the Heat a conſiderable time.

The

The proper manner of building Green-houses.

The truth of what I have asserted, some Gardiners have experienced much to their prejudice, in their Greenhouses where they preserve their Plants in the winter season: For if the windows of these, by which they let in the Warmth of the winter Sun betwixt the hours of ten, and two, are so disposed that the Rays cannot reach to the ceiling, but tending downwards leave a space between the ceiling, and that part which is shone upon, that does not receive any of the solar Rays; then *cæteris paribus* there will be always in that place the greatest Cold. And, hence, there will be a cold moisture continually collected there, which falling upon the Plants frequently destroys those that are of a more tender nature. These Winter-houses, therefore, being built full South, should be furnished with windows (which, if possible, should reach quite down to the pavement, and be very clear) erected at an Angle of 34 degrees 30′ from a perpendicular; and the ceiling should be built slooping in such a manner as to make an Angle of 20 degrees 30′ with a Line drawn horizontically from the top of the windows towards the opposite wall; in those countries, I mean, where the elevation of the Pole is 52 $\frac{1}{2}$ degrees. The reason of this construction may be easily come at by the help of Astronomy, and the doctrine of Dialing: Brevity obliges us here to omit it.

COROL. 2.

The proportion this Fire bears to the former produced by attrition.

The greatest Heat that the Sun ever naturally produces in our Air, and the Bodies heated by it by means of this Parallelism, is considerably less than that which is generated in a healthy man by the vital actions. For this frequently raises the Thermometer to the degree 92; that hardly ever to 84, and then never continues long in that degree, but quickly abates. It is necessary, however, to caution you, that I here speak only of that Heat which is observed in open places purely from the direct Rays of the Sun, without their being any ways reflected, or collected: For clouds, by reflexion, and aqueous Globules formed in the Air, by refraction, may very much increase the action of this Fire. But, however, even in this case, Fire never was known to be raised to such a degree by means of this Parallelism, or these natural reflexions, or refractions, as to be able to set Fire to Alcohol, Oil, Sulphur, or Gunpowder; unless, perhaps, Lightning may be an instance of it, of which, hereafter. And these Observations hold true of the natural Heat under the Equator itself, and every part of the Torrid Zone. Hence, therefore, it appears, that the greatest power of the Sun is not capable of heating any Bodies we are acquainted with to such a degree as to kindle them into flames, and consume them, and thus to produce spontaneous Fires, except, by means of Lightning alone. And it is farther evident, that the most scorching Sun cannot excite so much Fire in the hottest parts of the World, as may be quickly generated by a moderate attrition of very cold Bodies in the coldest: For if Iron is rubbed against Iron, it will soon grow so hot as to be able to set fire to Sulphur, or Gunpowder that is thrown upon it; and yet, even then, the Iron does not begin to emit any Light. Hence, again, we perceive it is not at all strange, that some Bodies are very lucid, though they give very little Heat; nor is it, we see plainly, a necessary consequence, that a Body is very hot, because it gives a great deal of Light: For the Light of the Sun, when it is upon the *Meridian* in a clear Winter's day affects the eyes so strongly, that it renders them quite blind for a considerable a confiderable time; and yet its Heat, at that very time, is fo weak, that it is not able to melt a thin piece of Ice fufpended in the open Air, and directly expofed to it, as I myfelf have obferved this Winter. The image of the Sun reflected from polifhed Gold, Silver, Brafs, Iron, Tin, or Glafs, is intolerable to our eyes by reafon of its exceffive brightnefs; and yet it does not excite the leaft degree of Heat, that we can perceive, either by our fenfes, or the Thermometer. And hence, again, I infer, that there is a vaft deal of difference betwixt the nature of Light, and Heat; Luftre, and Fire.

Corol. 3.

The Supreme Being, therefore, has wifely provided that the Bodies of Animals, and Vegetables, even the tender ones, fhould not be deftroyed by the direct force of the Sun. Direct I fay, left any one fhould imagine that I defign to include that too, which proceeds from the reflexion, and collection of its Rays, which may thus be prodigioufly increafed; for by this means it fometimes becomes fo intenfe, that it renders places uninhabitable: Of this the Ifland *Ormus* has long been an inftance, where the high mountains of white Salt, in a certain pofition to the Sun, by their whitenefs fo reflect, and unite its Rays, that at that time no body is able to live there. The fame exceffive degree of Heat, however, does not continue a great while, but is in a fhort time tempered by a fucceeding Cold. Scarcely deftroys Bodies.

Corol. 4.

If the Sun fhould ever irradiate the Atmofphere of our Earth, at a time, when all the Corpufcles that float about in it, were difpofed to an equable tranfmiffion of its Rays, it would then drive all the Fire in the Atmofphere into parallel Lines, except that portion that was included within the conical fhade of the Earth. But there are a great many different reafons that makes it incredible that this fhould ever be the cafe, and, therefore, it appears exceeding probable, that very extraordinary reflexions, refractions, collections, and difperfions of the folar Rays perpertually happen there. And hence, the force and action of the Sun, both upon our Atmofphere, and Earth, will every where be found furprizingly different: But, in thofe places, that lie beyond the limits of our Atmofphere, the Fire thus directed by the Sun, feems to be always as the fpaces themfelves, if they are not at too great a diftance from one another. Is not the fame in different places;

Corol. 5.

Hence it feems exceeding likely, that the fame degree of Fire is fcarcely ever obferved in different places: For whether you confider the various afpects of the Sun with regard to the Earth; or the different nature, and motion of the Bodies that float about in the Atmofphere; or the different properties of the very fame, at different heights; and many more fuch like circumftances: you will find that nothing feems more cautioufly provided againft, than that there fhould be the fame force, and effect of Fire in different places. The efficacy, now, of thefe caufes will be manifeft by the following Experiments. On various accounts;

EXPERIMENT XIII.

Chiefly from the various Colours of Bodies.

If this Fire, thus determined by the Sun, falls upon Bodies that are exceeding black, its Heat will be retained there a conſiderable time. On this account, therefore, ſuch Bodies grow ſooner hot, and acquire a greater degree of Heat from the ſame Fire, grow dry in a ſhorter time when they have been wetted with Water, and burn much more readily than any other. We need go no farther for the proof of theſe aſſertions, than daily Obſervation. Take a piece of cloth died a very deep black; another piece of the ſame cloth, but white; a third, ſcarlet; and others of different Colours; and hang them up in the Air, and Sun, and you'll find that the black will grow warmeſt, and much ſooner than any of the reſt. And of the others of different dies, thoſe always acquire Heat ſloweſt, whoſe Colours are moſt vivid, and affect the eyes moſt ſtrongly: for the white, and ſcarlet are longeſt growing warm; and the reſt ſo much ſooner as their Colours are leſs bright, as we ſee evidently in the weaker Green. And this, thoſe people that live in the hotteſt countries are well acquainted with; for they find, that if their outward garment is white, it beſt ſecures them from the Heat of the ſcorching Sun, whereas if it is black, it ſuffocates the Heat, and makes it more troubleſome. And it is a common Obſervation of the manufacturers of Woollen-cloth, that if a parcel of wet cloths are hung up at the ſame time, and are equally expoſed to the Sun, the black will preſently grow warm, reak, and dry; the white will retain its wet a long time; and the others will dry ſo much ſlower, as their Colour is brigher. Hence, again, white garments, when they are expoſed to Heat retain their dampneſs much longer than others, and thus too keep the Body cool.

It has, yet farther, been obſerved that black Bodies take fire, flame, and burn, much eaſier with the ſame Fire than Bodies of any other Colour. Shavings, for inſtance, of very white wood will ſcarcely receive a ſpark ſtruck upon them, ſo as to keep it in; but if you burn them to a black coal, the powder of this will eaſily ſupport it, and be ſoon kindled all over by one ſingle one. In the ſame manner a ſpark won't keep a-light any conſiderable time in a piece of very clean white linnen; whereas, if it falls upon the ſame when it is reduced to tinder, which is a ſort of exceeding thin black coal, it will ſpread itſelf all over it. Nor would even Gunpowder itſelf, ſo ſoon take fire, where it not for its blackneſs; as we ſee evidently in the powder of very white Nitre rubbed with Sulphur. The Gardeners too have long obſerved to their diſadvantage, that white Earth will hardly grow hot, except juſt on the ſurface; whilſt the black conceives ſo great a heat, as to burn the very roots of their Plants. The Chemiſts, likewiſe, long ago informed us, that black Bodies committed to digeſtion, or reduced to it by Art, grow warm with the ſame Fire eaſier than others; different degrees of Heat being required in the head of a Crow, the neck of a Swan, and the tail of a Peacock. And laſtly, the Philoſophers have confirmed the ſame by ocular demonſtration. If you hold a piece of very white paper in the *Focus* of a burning Glaſs, it will be a conſiderable time before it grows hot, and much longer before it takes fire; and when it is juſt going to kindle, it firſt loſes its whiteneſs, grows brown, then black, and afterwards flames in an inſtant. See upon this head the remarkable Obſervations in the *Memoirs* of the *Acad. del Cimento.* 266, 267.

Hence, then, we get ſome light into a good many *Phænomena* of Meteors: for every one knows that there never happens more terrible Thunder and Lightning, than when the face of the Heavens is firſt obſcured with the blackeſt Clouds, and thickeſt darkneſs; whence too, there often ſuddenly follow prodigious Whirlwinds, occaſioned by the rarefaction of the Air from this Heat thus inſtantly generated, and retained in it.

EEPERIMENT XIV.

Black Bodies do not reflect igneous Light, or Light that gives Heat, though it is impreſſed upon them by the Sun ever ſo ſtrongly. This we ſaw evidently by covering a *Speculum*, which burnt very powerfully, with the thin ſmoke only of a Candle; for when by this means it was grown black all over, and then directed towards the Sun, an eye placed in the *Focus* perceived neither Light, nor Heat; nor did there appear by any Experiment the leaſt ſign of Fire there, though as ſoon as ever the ſoot was wiped clean off, and it was reſtored to its former brightneſs, it immediately, upon being expoſed to the Sun, regained both its ſhining, and burning faculty. For this reaſon, eyes that are inflamed are not injured by black Bodies; and when they are affected with a painful Ophthalmy no colour gives them more eaſe, than darkneſs does, which is a perfect privation of all. Even *Tſchirnheuſen*'s glaſſes themſelves, if they are thus blacked with the ſmoke of a candle, do not produce the leaſt Light, or Heat in their *Focus*, though they are directed towards the hotteſt Sun. Black Bodies ſcarcely reflect the Light they receive.

From theſe Obſervations, therefore, it evidently appears, how little a matter is often neceſſary in the Air, to ſuffocate, and deſtroy the moſt powerful effects of Fire, that depend upon the action of the Sun; and how very different a Heat may be ſuddenly excited in different places from the ſame cauſe. And, here certainly, there is nothing more ſurprizing, than that this ſhould be effected by a black cruſt, ſo exceeding thin that the external ſurface only ſeems to be concerned in it, without any thickneſs to aſſiſt it.

But, now on the other hand, Bodies that are exceeding white, reflect this igneous Light almoſt with the ſame power as they receive it. This is very evident in white Metals, as in the moſt ſolid pure Silver, if it is formed into a plain *Speculum*: For that will return the image of the Sun very nearly as vividly as it falls upon it, and for a time hurts and blinds the eyes; and when they are inflamed, and painful it is perfectly intolerable. Look through a plain clear glaſs towards the Sun, and it ſeems to tranſmit the Rays, almoſt, without any alteration: Let then your eye be placed directly betwixt the glaſs, and the Sun, and then look in the glaſs, and you'll ſcarcely perceive any thing; but if the back part of the glaſs is covered over with a very white compoſition of Mercury, and Tin mixed in a certain proportion, the reflexion of the image of the Sun from the *Speculum* will be ſo ſtrong that the eye will not be able to bear its brightneſs. White Bodies reflect it very powerfully.

In like manner every body knows, that the ſolar Rays reflected by the yellow colour of Gold are vaſtly refulgent. But this was never more remarkable, than in that inſtance of a concave *Speculum* in *Saxony*, which being formed of wood very carefully hollowed into a ſpherical form, and then poliſhed, and nicely covered over with leaf Gold, burned with an incredible power. Yellow ones likewiſe.

And left any one should imagine that the efficacy of this was owing to the metalline quality, let him take notice of that other more surprizing one, which too had an exceeding caustic quality, that was made of pieces of yellow straw very accurately fitted together.

In the same manner we may examine the rest.

And thus the red, and all the other capital Colours, so nicely distinguished by the singular penetration of the incomparable *Newton*, may in the same manner be examined, both with regard to the Light that they collect in a *Focus*, and the caustic power they exert there: For if the *Speculums* are made of the same matter, size, and figure, and are polished in the same manner, but are of different colours, then, the difference of the Heat in their *Foci* will give us the doctrine of Colours with regard to their power of generating Fire; and at the same time will shew us what Colours heat, cool, yield a moderate degree of Heat, reflect, retain, and dissipate the Fire that is impressed upon them. But we must hasten to our farther examination of Fire; we can only, therefore, hint at these things at present. Let us see, then, what are the consequences of this Experiment.

COROL. 1.

Burning *Speculums*.

From what has been observed, the true doctrine of burning *Speculums* may be easily understood, with regard to their efficacy as it depends upon the Colour of their polished surface: For if all other circumstances are alike, a few Experiments carefully made will readily determine the proportion of their focal powers in respect of their Colour.

COROL. 2.

Pigments heating, or cooling.

And if we want to know what will be the effect of laying such and such Colours on Bodies with regard to their power of heating, and cooling, we may from the same principles as easily inform ourselves. With respect to the ground that we walk upon, or look at, we know certainly, that black Earth burns the Feet, but is more favourable to the eyes; whereas white scarcely warms the former, but by its bright whiteness dazzles, inflames, and burns the latter. The same thing is easily conceived of pictures, and tapestry. And the knowledge of these things will assist us in a particular manner, in making coverings to secure our Bodies from Heat, and our eyes from the Light. Houses, for instance, that are externally white will be coolest within; and those on the other hand that are black will be hottest; if the walls are made of the same materials, and are of the same thickness. And hats that are very white on their upper surface, and black on the under part of the brim are a vast relief to the Heat when the Sun is exceeding hot.

COROL. 3.

The cause of Heat in the Earth, and Air.

From the same causes the Heat of the ground in some parts of the World grows intolerable, when being very black, it is exposed to a scorching Sun: Whilst in others, the Air is rendered so hot that it cannot be born. This we see particularly in the Island *Ormus*, where the solar Rays are so strongly reflected from the white mountains that run East and West, and the Air is so excessively heated by them, that the people perish in it, if they don't lie covered in Water all but their heads, which are kept above it by proper supports;

ports; as likewife in *Gamron*, where the fame thing happens from a fandy, white mountain, which reflects and collects the Rays in fuch a manner, that the Heat of the Atmofphere is fcarcely any where fo violent as it is there: And yet both thefe places lie beyond the Tropick in north latitude. See *Nieuhof. Itin. Terr. & Mar.* from p. 80 to 91. and other Authors.

Corol. 4.

Water, and other Liquors, are raifed into the Air by the power of terreftrial and aerial Fire. And the lefs they are prefs'd by the weight of the incumbent Atmofphere, the more eafily their Particles recede from one another by the fame degree of Heat. The higher, therefore, they afcend, the farther they are feparated afunder; both on account of their increafed Spaces, and their leffer reciprocal attraction. Hence, of confequence, they collect lefs Fire, grow cooler, and float about through vaft Spaces, in form of exceeding fine corpufcles, whofe refiftance always increafes in proportion to their altitudes. And whilft they are thus driven about, the parts of Water may, poffibly, be refolved into their ultimate, exceeding hard, immutable Elements, which, tho' very rigid afunder, yet being united together again, may conftitute the fame foft Body they did before. When by any means now whatfoever, a confiderable number of thefe aqueous Particles are brought into union in this upper, and confequently, colder region of the Air, it is very probable, that the Air is immediately filled with very fmall icy Bodies; and that thefe, now they begin to defcend, (and thus coming nearer to the Earth, are reduced into fmaller Spaces, and hence are more clofely united,) by their reflections of the Solar rays, form thofe Clouds in the Heavens, which to us appear fo exceeding white, whofe whitenefs, the greater it is, the more certainly we can foretell, that we fhall foon have Snow, Hail, cold Showers, or cold Winds. But the whiter that fide of the Cloud is, that is directed towards the Sun, the colder, of confequence, muft the other fide be in proportion, as it wants at that time the Solar Heat. Hence it evidently appears, that fuch Clouds may increafe the Heat of the Air in a very fhort time, efpecially, if from their different pofitions with refpect to the Sun they fhould be fo fituated as to reflect the Solar Rays into one fmall Space, and thus form a kind of *Focus* in the Air. On the other hand now, if at the fame time that the Sun fhines, we fee exceeding black Clouds in the Sky, there generally very quickly follows Thunder, and Lightning.

Hence Meteors.

Corol. 5.

If we rightly underftand, therefore, what has been faid, we fha'n't wonder at the viciffitudes of Heat and Cold that fometimes happen fo fuddenly in the fame place of the Atmofphere. For if we confider, that as foon as ever the Solar Rays fall directly upon the Air, the Fire, that before tended equally every way, is immediately determined into a Parallelifm, we perceive, that on this account the Heat muft be much increafed. Again, the ground we tread on being thus inftantly expofed to thefe parallel Rays, muft of confequence foon grow hot. And laftly, all the Bodies in the Air, or above the Earth, will be affected with the irradiation of the Sun now fhining upon them, and therefore muft continually grow warmer and warmer. From thefe caufes, therefore, tho' there fhould not be an addition of one particle of Fire more than there was before,

fore, yet the Heat of any particular place may be considerably augmented. And thus we have now discovered in Nature, another manner of exciting Fire, which before did not appear, and that is, the action of the Sun, thus determining the particles of Fire in a parallel direction.

EXPERIMENT XV.

The collection of Fire parallel in a *Focus.*

If we conceive, now, certain Corpuscles perfectly white, exceeding smooth, and very small, to be so fitted together, that the Fire, thus render'd parallel by the action of the Sun, and impress'd upon their Surface, may be so reflected, that all the Rays may meet together in a very small point; then, all this incident Fire will be collected in that place, which, had these Corpuscles been situated in the same plane, would have pass'd on in parallel lines, as it fell upon them.

Hence, therefore, the Fire in this place of collection, which for the future we shall call the *Focus*, will purely, from its quantity, be so much more intense than it was before, as this Space where the Rays are thus united, is less than the whole Surface from whence they were reflected. But the force of it was likewise much augmented before, on account of the parallelism already mentioned.

Perfect in a concave *Parabola.*

Was it possible, therefore, by Art, to construct a concave *Speculum*, whose cavity should be formed by the revolution of the most perfect first *Parabola* of *Appollonius*, and hence would have any exact conoido-parabolical hollow figure; if the matter of it likewise was the densest we are acquainted with, as Gold; and the colour the whitest, as that of the finest Mercury; if it, farther too, like the purest Steel possess'd the most elastic qualitity; and lastly, if the aperture of its Base was very great: Then, if you placed the circle that terminated the *Basis* of this parabolical Conoid parallel to the apparent Disc of the Sun, all the Fire that enter'd in a parallel direction through this circle, would be collected within the *Speculum*, in a point of the *Axis* $\frac{1}{4}$ of the *Parameter* distant from the *Vertex*: And consequently, by enlarging the capacity of the *Speculum*, this force might be always farther increas'd. But the most industrious Artists have never yet been able to discover such a kind of matter, or to give any hollow Body this exact parabolical figure; and hence, tho' we easily conceive of this efficacious power, yet it has never been reduc'd into practise.

But this could never be formed exactly.

The next thing, therefore, was to try, whether it was not possible to give some exceeding solid, white, hard, and elastic substance a spherical figure, and so to polish it, that there should be no unequal vacuities left in the concave polish'd Surface; and this, it was imagin'd, might be effected by the attrition excited in the action of turning: But this upon trial, was not found so easy to accomplish, by reason of the difficulty of the Polish. The Heat, however, that has been by this means generated, has been found to be so violent, that it almost exceeds all credibility.

The incredible power of Fire in *Vilett's Speculum.*

Not to mention many others, it is sufficient to take notice of the most perfect one hitherto known; and this is that, which with a good deal of experience and labour, was made by those excellent Artists, the Father, and his two Sons, the *Vilett's* of *Lyons*. This Mirrour is form'd of a metalline substance, nicely compounded, after a great many trials for this purpose, and is of a concave spherical figure, the Chord of the Segment of the Circle, by the revolution

revolution of which it is constructed, or the diameter of the Circle which measures its Aperture, being 43 inches, and consequently, the *Area* of the plane through which the Rays are admitted, $1452\frac{11}{14}$ *French* inches. Both the concave and convex side of it is spherical; and both Surfaces are polish'd as nicely as possible. The whole Mass of the *Speculum* weighs 400 *French* pounds; and lastly, the Rays which fall upon the *Speculum*, through the aperture abovemention'd, when it is directly opposed to the Sun, are collected in the Air, within a circle of half an inch diameter, which is $3\frac{1}{2}$ feet distant from its *vertex*. Hence, therefore, if all the Rays that come parallel from the Sun, and are receiv'd by the *Speculum*, were reflected into this *Focus*, then the Space they took up in the circle of the aperture of the *Speculum*, would be to the Space into which they are thus contracted in the *Focus*, as 7396, is to 1; and consequently, there would be seven thousand three hundred ninety six times more Fire in this *Focus* than in the Air heated at the same time by the Sun; which is, certainly, a prodigious difference.

Difficult to determine *a priori*,

We must, however, caution you here, that we suppos'd all the Rays, that fell upon the *Speculum*, to be reflected back again into the *Focus*; but this, by Experiment, is evidently found to be false: For neither is the figure exactly spherical, or is it perfectly polish'd, or without vacuities in its Surface, as the Microscope informs us, and as you may be sure, from looking obliquely at it, for you may see its concave Surface on every side of it. But let that be as it will, if the *Ratio* of the reflected Rays to the incident ones, should ever be discover'd, the proportion may be easily computed: In the mean time, however, this we are sure of, that the Fire, which is generated there, is vastly intense. For by a multitude of repeated Experiments, it evidently appears, that every body, that is combustible by any Fire, will, if it is plac'd in this *Focus*, burn furiously in a moment's time. And even those combustible Bodies, which by reason of their aqueous moisture, won't burn easily, except they are first dry'd by the Fire, will here kindle into a Flame instantaneously. This was evident in a branch of green Wood drawn backwards and forwards through the *Focus*, which flam'd in a moment in every part upon which it fell, tho' the branch was then moist and thick, and did not remain at all in the *Focus*. Within the space of a minute, the six Metals were put in fusion in the same *Focus*; as also, all the Semi-Metals that have hitherto been try'd; even stony and rocky Bodies, are melted and vitrified by it in an instant. And how violent its effect must be, Gentlemen, you may see from this instance, that even Bones themselves, whose Ashes you know, in the cupelling test, so powerfully resist both Fire and Lead, are melted by it in the twinkling of an eye; as are likewise Bricks, Clay, Sand, Crucibles, Marble, Jasper, and Porphyry, which are turned into Glass. And lastly, the very Stones which the Masons make use of for building the Furnaces design'd for fusing of Iron, and separating it from its vast hard fossil Ore, melt and vitrify in this *Focus* immediately; which no person, let him understand these things ever so well, or let him have seen ever so much of the violence of confined Fires, could ever have imagined; for these same Stones would have remained many years without alteration, in the intense Fire to which these Furnaces are always exposed: So that the power of this focal Fire, is able to effect that in the least instant of time, which the other, tho'

But by its effects, appears to be very great.

tho' the ſtrongeſt we know of beſides, could hardly accompliſh in the ſpace of ſome years. And yet this Fire reſides in the liquid Air, nay, perhaps, *in vacuo*, the Air being expelled by this vaſt Heat, and that, without the leaſt *Pabulum* to ſupport it; and it always remains there, ſo long as the Solar Rays continue to fall upon the *Speculum*.

Some remarkable circumſtances in this *Speculum*.

Now the colder the matter is of which the *Speculum* conſiſts, the more intenſe will be the Heat of the Fire in the *Focus*; and therefore, the denſer this metalline ſubſtance is, the more powerful will be the effect. But by this coldneſs, the elaſticity is conſiderably increaſed, and hence, too, its efficacy will be ſo much the greater: Whereas on the other hand, as ſoon as ever the body of the *Speculum* grows warm, its action becomes feebler; and as it gradually grows hotter and hotter, its cauſtic power is continually diminiſh'd. Hence, in a very clear, cold, Winter's day, it exerts its force much more powerfully, than in a fine Summer's one. But farther, from what has been already laid down, we know, that the coheſion of the Elements of all Bodies, is conſtantly weaken'd by Fire, and that always, in proportion to the degree of it; that hence, the Pores that are left between their Elements are inlarg'd; and that their power of contraction, and of conſequence their elaſticity, which depends upon it, is hereby weaken'd. Here, therefore, again, is a large field open'd for inquiry; but it is impoſſible for us to enter into all theſe things at preſent. Give me leave, however, on this occaſion, to take notice once more, that when this *Speculum* was directed towards the Moon at the full in a clear Winter's night, and the Bulb of a very ſenſible Thermometer was placed in the center of its *Focus*, there was not the leaſt indication either of Heat or Cold, but the Glaſs remained exactly at the height it was before, tho' at the ſame time the *Focus* was ſo exceſſive bright, that no-body was able to look at it. And this, upon conſideration, ſeems the more ſurprizing, becauſe theſe Rays that thus come from the Moon, were received, by that, from the Sun; and yet we know, by Experiment, that if the image of the Sun is reflected from a very perfect plain glaſs *Speculum* directly upon *Vilettes*'s, the Fire generated in its *Focus* will be vaſtly intenſe, and near as ſtrong, as if the Solar rays had fallen directly upon it. Hence, therefore, again, is demonſtrated a plain difference betwixt Light and Heat, as was before taken notice of. Theſe, now, are the principal phyſical effects of this *Speculum*, with regard to our preſent purpoſe, which I have exactly related, as they are delivered by the worthy Author himſelf from his own obſervation, and which will be of ſervice to us preſently in treating of the nature of Fire.

Generates no Heat by the help of the Moon.

A very great one by the rays of the Sun reflected upon it by a plain *Speculum*.

Inconveniencies of this *Speculum*.

This noble Inſtrument, however, has this one inconvenience, that as the Sun muſt be pretty high to communicate its power to it, and this concave *Speculum* muſt be ſo directed to the Sun, that the *Axis* of the lucid Solar Diſk, and that of the *Speculum*, muſt be in the ſame right line; hence, the Bodies too that are to be examined in its *Focus*, muſt be in the ſame line alſo: For which reaſon, it is impoſſible to prevent their falling, when once they come to be melted; and hence, as ſoon as ever they are put in fuſion, they run from the action of the Fire, ſo that no trial can be made of them farther, which, you eaſily conceive, would be of the greateſt conſequence. But this inconvenience is, in ſome meaſure, compenſated by this property of it, that the external Surface of this poliſh'd Metal, reflects all the Rays that fall upon it, and hence

Conveniencies.

does

does not much diſſipate or change them; whereas your glaſs *Speculums*, that reflect by means of Mercury incruſtated upon the back part of them, muſt neceſſarily cauſe a great diſſipation of the Rays, on account of the multiplicity of images that ariſe from the poſition of the pellucid Particles of the Glaſs. And as for the other manner of burning with convex Glaſſes by refraction, this is ſtill leſs powerful; for theſe muſt reflect a great quantity of the Rays towards every part; and a great many more will be ſuffocated, and extinguiſhed, whilſt they paſs obliquely through their ſubſtance.

COROL. 1.

None of the heavenly Bodies, except the Sun, cauſe any increaſe of Fire, either by determining it in a paralleliſm, or by reflection.

From the conſideration of what has been now laid down, I think it evidently follows, that the celeſtial Bodies, as well Planets, as fix'd Stars, make no alteration in our Fire, with regard to Cold or Heat, that we are capable of diſcerning. For ſetting aſide the Sun, whoſe effects we have juſt explain'd, the Moon is the only one of any conſequence; but when the image of this is received on this *Speculum*, and reflected into this very ſmall *Focus*, it does not produce the leaſt ſign of expanſion, or contraction, no, not even in the Air itſelf. What then can the Light do that comes from the other Planets? Certainly, nothing at all. Nor has the Light of the fix'd Stars any greater effect. If theſe Bodies, therefore, are endued with a power, by which they are able to act upon the Heat and Cold of our Earth and Atmoſphere, which I don't pretend to deny, they muſt neceſſarily do it in ſome other manner, than by the vibration of their lucid Rays. Nor will the Aſtrologer's referring us to the various Aſpects and Conjunctions of the heavenly Bodies, and to the Conſtellations, make any thing againſt what we advance; becauſe it always appears by Experiment, that there is no alteration produc'd by any of theſe cauſes, in the caſe we are at preſent conſidering. We may venture, therefore, to aſſert, that all the Heat that flows from the heavenly Luminaries, and is tranſmitted to us, depends intirely upon the Sun alone, without receiving the leaſt augmentation from any of the reſt that has hitherto been diſcovered.

COROL. 2.

Gravity alone ſeems here to make ſome alteration.

Theſe things, then, being well underſtood, we can't clearly conceive how any conſiderable alterations can be produc'd in the Bodies of our world by the Stars: For in moſt of theſe changes, that we are acquainted with, either Heat or Cold, is concerned, whether new motions are excited, or former ones are altered; but upon Heat and Cold, the Stars have no effect. The influences, therefore, that theſe heavenly Bodies are ſuppoſed to have upon theſe lower ones, muſt depend upon ſome other cauſes; and conſequently, theſe changes are not owing directly to any communication of Fire, or any alteration of it, that the Stars are capable of producing. Nor in reality, has it hitherto appeared by Experiment, that theſe ſuperiour Bodies do exert any force upon theſe lower regions, except what is to be aſcribed to the power of Gravity alone; which is vaſtly different from Light, and Fire, nor has the leaſt dependence upon them. That this power, indeed, on account of the various poſitions of the heavenly Bodies, muſt be liable to frequent changes; and hence, from theſe different degrees of attraction and repulſion, may produce a great many alterations in the Bodies of our world, no-body that is acquainted

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with theſe things will deny; but at the ſame time that they have any other power, with reſpect to us, beſides that of Gravity, we never have yet had ſufficient evidence to induce us to believe.

COROL. 3.

Surprizing Meteors from reflected Light.

These things then being premiſed, we may again venture from Experiments to account for a great many *Phænomena* that we obſerve in the Air, which relate to our phyſical inquiries, which ſometimes mightily diſturb our chemical operations, and which may be eaſily underſtood from what has been ſaid. The famous *Halley* has demonſtrated, that there is an incredible quantity of Water perpetually carried up into the Air: That this aſcends to the greateſt height in very ſerene weather, appears by the clearneſs, and increaſed weight of the Atmoſphere at the ſame time: Nor is it leſs certain, that it will be there turned into Ice, if its Elements happen to be brought into union in thoſe upper regions. Now what hinders, but that theſe particles of Ice thus produced, may in like manner be brought together there, and being gradually united into large globular Bodies, may appear in the form of Clouds? And why may not theſe, from an infinite number of cauſes, be perpetually changing their figure, be ſometimes plain, then ſpherical, and ſo of all other figures by turns? Suppoſing, then, this to be the caſe, will not the action of the Sun irradiating the Air, and ſhining upon theſe *Speculums*, be thence reflected, ſo as to produce very ſudden and ſurprizing appearances of Light? And again, may they not, by being diſpoſed in a different manner, ſuffocate and extinguiſh the Rays of Light, and thus in an inſtant bring on thick Darkneſs? Whenever the Clouds in the Heavens appear exceeding white from the irradiation of the Sun or Moon, there generally follows very quickly, either Snow, or Hail. And after long drought and fine weather in the hotteſt part of Summer, I have obſerved little white Clouds to appear aloft in the Air, which increaſing in magnitude very faſt, become conſtantly leſs white, as they grow bigger and bigger, and a little afterwards, from a large baſe deſcending towards the Earth in a pyramidal form, make a perfect ſhade, and burſt into ſhowers with a great violence; the largeneſs of the drops at the ſame time evidently ſhewing, that they were Hail in the upper, colder regions, but ſuddenly melted as they came down into the lower and warmer ones: Or if the Hail-ſtones happen to be ſo big aloft, that they cannot be thus thaw'd in their deſcent, then they fall to the ground in a ſolid form, and both ways quickly render the lower Air in the places where they fall, much cooler than it was before. Now theſe *Phænomena* may be eaſily accounted for from the ſimple cauſes already mentioned: For the higher the particles of Water are raiſed, the more they will be frozen; and from the greater height they fall, the more violent will be their deſcent, their celerity being conſtantly increaſed in the proportion which *Galileo* has demonſtrated. Hence thoſe little Clouds that are ſeen in *Aſia* in very fine weather, and on account of their ſmallneſs are compared to an Ox's eye, when they fall from the Sky, come to the ground with a prodigious force, put the Air, that is condenſed in that place, in a violent commotion, and thus raiſe Winds, and Whirlwinds, and ſometimes produce Storms that exert their force from a center equally towards every part of the Horizon, their apparent magnitude, during their deſcent, always increaſing in a reciprocal proportion to the ſquares of their diſtances.

distances. Does, therefore, the very bright whiteneſs of the Clouds always depend upon Snow or Ice, that is generated in them? Certainly, Water itſelf never appears white when irradiated by the Sun, unleſs it is firſt form'd into Froth, Snow, or Ice, or receives the Rays and tranſmits them very obliquely to the eye. But again, ſuppoſe this frozen Water to be driven together by the Wind, and to be ſo collected into one Body, as to reflect the Solar Rays by that part of its Surface that is oppoſed to the Sun; and hence, to heat, rarefy, and put in motion the Air that lies betwixt the Sun and this icy Cloud, whilſt at the ſame time the action of the Light, and Heat, continually varies on every other part of it; ſuppoſe farther, the Globe to be large, pretty ſolid, and not pellucid, and of conſequence, the Cold on the part averſe to the Sun to be ſo much the greater, and the Air there ſo much the denſer: From theſe cauſes, then, there muſt neceſſarily follow an extraordinary rotation of this globular Body, which will be ſo much the ſwifter, as the Heat of the Sun is ſtronger, the denſity of this icy Globe is greater, the Cold on the hinder part is more intenſe, and as it falls from a higher very light Air, into a lower one growing gradually denſer, and yielding a greater reſiſtance.

I am perſuaded, now, Gentlemen, if you will but weigh theſe few things with attention, you will never wonder at thoſe terrible ſtorms that often happen, when the Weather has been a long time calm and ſerene; eſpecially, if you conſider at the ſame time, what Attrition, what Heat, nay, what Fire, may be inſtantly produced, by Bodies falling from aloft through the heavier Air that lies underneath them. Theſe conſiderations now lead us to take notice of thoſe intolerable Heats that ſuddenly happen in particular parts of the Earth, and very ſoon after end in horrible tempeſts; and which upon reflexion, we ſhall find to happen generally when the Heavens are full of diſtinct, ſcattered Clouds. For if any quantity of ſnowy, or icy Clouds, eſpecially if they are large ones, are ſo diſpoſed in the Atmoſphere, as to form reflecting *Speculums*, and exert their united force upon one certain place, which you will grant me may be, nay, and often muſt be the caſe, pray what muſt be the conſequence? Why, certainly, an incredible Heat will immediately be excited there; the Air will be vaſtly expanded, ſo as ſometimes to occaſion a very large *Vacuum*; about this *Vacuum* thus heated by ſuch a collection of Fire, the expell'd Clouds, and Air, will be agitated in a ſurprizing manner, and with a great noiſe; whirling *Vortices* will be hereby produced; and preſently after, this *Focus* being deſtroy'd by a different ſituation of the Clouds, the Air, Snow, Hail, Water, and whatſoever elſe is neareſt, will ruſh into theſe *Vacuums* with prodigious violence. And for my own part, I have long been of opinion, that this reflection of the Solar Rays from icy Clouds, and their being hence collected into large *Foci*, are the principal cauſes of thoſe terrible *Phænomena*, which frequently happen in ſo violent a manner, as to make human Nature ſhudder, and be almoſt afraid of preſent deſtruction. A learned *Engliſhman* has ingeniouſly demonſtrated with what force the common heavy elaſtic Air would ruſh into a perfect *Torricellian Vacuum*, which he proves to be ſo great, that the celerity of the moſt rapid Wind, which moves 22 or 23 feet in a ſecond, can by no means be compared with it, as this would run 1305 feet in the ſame time. *Phil. Tranſ.* 1686. N. 184. p. 193. Now, only conſider, what quantities of theſe cloudy *Speculums* may be at once produced in the Heavens; and at the ſame time reflect on

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their possible magnitudes, solidities, and situations; and you will easily see, that they may be able to form Spaces of stupendous efficacy, with regard to the Fire that may be generated in them: To which, therefore, Lightning, Thunder, Whirlwinds, Storms, Winds, and the other Meteors, may owe their production. And hence, perhaps, we may understand, why, tho' the Weather is exceeding hot, yet, if the Heavens are serene, and free from Clouds, these things are seldom observed to happen; whereas, when once the Sky grows obscured with Clouds, very extraordinary alterations often immediately follow.

COROL. 4.

Especially when it thaws.

But these are never more frequent, or more violent, than when it has been a sharp Frost for a considerable time, and the Earth is grown hard to a pretty great depth. For if it then thaws on a sudden, there generally follows Clouds, uncommon Heats, Thunder, and Lightning: And the reason seems to be this: All the Vapours, and pinguious Exhalations, that in warm Weather arise from the Earth, were, during that time, lock'd up within this hard crust, and there agitated by a subterraneous Heat; which appears evident from hence, that if in the hardest Frost, you break the Ice in the ditches, there immediately exhale from them warm Vapours, the quantity and warmth of which are so much the greater, as the Frost is harder, and the Ice thicker. Now as soon as ever the upper frozen Glebe comes to be resolved by the warmth, these Fumes that were thus confined, instantly disengage themselves, and being carried up into the Air, form smaller, and then larger Clouds, which being afterwards roll'd up together, and irradiated by the Sun, very soon bring on the *Phænomena* we have mentioned. Hence, in *Russia*, *Sweden*, and *Denmark*, such excessive Thunders generally follow a thaw. It might be added too, that the Particles that were exceedingly consolidated by the Cold, do still excite a very great motion of attrition.

COROL. 5.

The Heat peculiar to any place, whence?

But let us consider farther, that the reflexion of the Solar Rays from the ground, buildings, and mountains, may be the occasion that some particular places, in the same position to the Sun, may be much hotter than others. For it is easy to conceive, how all these things may either accidentally, or on purpose, be so disposed as to make a very great alteration in the Heat in the center of the place. And then besides, the diversity of the colours of the Bodies round about, may, as has been before observed, very much increase the force of this Heat. But we ought particularly to remember, that in different seasons of the year, the direction of the rays of the Sun upon these Bodies, is continually changing in a very remarkable manner, and hence the reflexion of them, and the Heat of their *Focus*, will be increased, diminished, and perpetually varied. From these principles then, we may easily understand, how it comes to pass, that some places at certain times of the day, or year, are so different from themselves with regard to their Heat, Colour, and Light, (as it is a common observation, that some places are hottest with the morning Sun, and others with the afternoon) for we have nothing to do but to have recourse to the three circumstances just mentioned, and examine them with regard to the places under consideration. And it will then appear, which is much to our present purpose, that a greater or less degree of Fire, may be produced in any particular place, without any other cause than mere reflexion, and the collection, and dispersion of Rays that depend upon it. People generally imagine, that, *cæteris paribus*, the Heat is greatest in places that are levellest and most open; but the contrary is always observed to be true: For in calm, dry, hot Weather, the Air on large plains is always more temperate, and refreshing; that in the vallies, more sultry and troublesome. And hence it comes to pass, that Horses, and other Cattle, are brisk, and run on the plain heaths without being tired, or losing their Wind; whilst, at the same time, they grow languid with the heat in other places. And the reason is evident; for in these level places, there is no Heat but what is owing to the direct rays of the Sun, or the reflexion of them from the Clouds alone. These observations, now, are of great service in helping us to form a right notion of Fire, which, otherwise, is falsly imagined to be peculiar to some particular parts of the Earth; to account for which, many extraordinary causes have been mentioned very different from the true nature of Fire. If we examine this affair, however, in a proper manner, it will always appear, that Fire considered absolutely in itself, is equally diffused through all Bodies, and every part of Space.

Corol. 6.

Conclusion concerning Meteors.

And here let me observe, in one word, before I quit this subject, that the Meteors in the Air, the Heat on the Earth, and the Effects that are thence produced, owe their origin, degrees, changes, and effects, principally, to the various reflexions of the parallel rays of the Sun.

Corol. 7.

The proportion of the Fire collected in a catoptrical *Focus*, difficult to determine.

But it is a matter of vastly nicer inquiry, and would be of extraordinary service, could human industry and penetration ever arrive at it, to determine the true proportion between the quantity of Light falling upon a reflecting Body from a given Space, and the same when it is collected in the *Focus* after reflexion. Suppose, for instance, the Light contain'd in a circle of 2 feet diameter, to fall upon a concave spherical *Speculum*, and to be thence reflected into a circular *Focus* of an inch diameter; we can then easily, by the help of Geometry, find the proportion of the *Area* of this lucid Circle, to that of the collecting *Focus*, since these are to one another, as the squares of their diameters; and hence the Mathematicians presently infer, that the incident Light is to the reflected, in the same *Ratio*. But whoever examines this affair as a Philosopher, will find much greater difficulties in resolving this problem, than he is at first aware of.

First, as we don't know the true solid part of the *Speculum*,

For in the first place, Gentlemen, how will you be able to determine the proportion of the vacuities or pores in the concave Surface of this *Speculum*, to the solid parts of it that cause this reflexion? Every thing that has been hitherto made use of for this purpose, has been considerably lighter than Iron, and consequently, much more porous than Gold; but the solidity even of this, with respect to its magnitude, has never yet been discovered. Hence, therefore, we see, that it is impossible to settle this first circumstance; and yet this is absolutely necessary to the satisfying our present inquiry. Perhaps only a thousandth part of the bulk of this Body is perfectly ſolid and impenetrable; the reſt, with regard to the matter of which the Body conſiſts, intirely vacuity or pores. How great a quantity of the incident Light then muſt neceſſarily be loſt?

Nor the exact figure. But ſuppoſe now, which is however by no means the caſe, that the matter was abſolutely ſolid, by what method will you determine the figure of the *Speculum?* You imagine, for inſtance, it is ſpherical. How do you know it is ſo? Certainly, if it was perfectly ſo, its concave Surface would then appear black, except to an eye placed in the *Focus*, or in the lucid vertical Cone produced from the *Focus*, or a little on the ſides, on account of the diverging coloured Rays, according to the elegant doctrine of the incomparable *Newton*; Whereas we find, on the contrary, that its bottom may be ſeen in every oblique poſition. But if this don't ſatisfy you, and you ſtill fancy ſuch an exact poliſh may be given to Metals, take a concave *Speculum* that is looked upon to be finiſhed in the niceſt manner, and examine it with one of the beſt Microſcopes; and you will ſoon ſee how rough, unequal, and porous that Surface is, which you imagined ſo ſmooth and equable; and will be forced to confeſs, that there is but a very ſmall part of this Surface that is ſimilar, but that the figure is every where perfectly irregular. How, then, can any perſon think it poſſible to determine the quantity of the reflected Light from the figure of the *Speculum?*

Nor the homogeneity of the matter. But again, ſuppoſing we could get clear of theſe difficulties, there is another as conſiderable ſtill behind: For we muſt be certain, whether the matter of this cauſtic *Speculum* is every where perfectly homogeneous, and has, in every point of its Surface, the ſame power of equably reflecting the rays of Light; ſince it appears by the *Newtonian* doctrine, that in this reſpect too, there is a vaſt deal of difference in different Bodies. It evidently appears, therefore, that we can come to no certainty in this inquiry, till this is likewiſe determined. It is poſſible, for inſtance, that, in the ſubſtance of which the *Speculum* is compoſed, there may be ſome matter that we are not at preſent acquainted with, which may have no power of reflexion at all, and which, conſequently, will ſuffocate and extinguiſh the incident lucid Fire, in proportion to the quantity of it that is contained in the reflecting Surface. But, now, tho' we could in theſe three reſpects certainly demonſtrate the proportion of the power of the Fire in the *Focus*, to that of the parallel Fire that fell upon the *Speculum*; yet this will regard only the efficacy of it, as it depends upon the quantity.

Fourthly, becauſe the force of Fire don't depend entirely upon its quantity. But hence, we ſhall never be able juſtly to determine, what proportion the vertue of this focal Fire bears to the ſame, when it was directed by the Sun through the Circle that meaſures the aperture of the *Speculum*, and that, for the following reaſon. We are not certain, whether the *impetus* of Fire is always proportionable to the number of Particles contained within the ſame Space; and conſequently, whether this rule will always hold good, that a double quantity of Fire conſtantly exerts itſelf upon Bodies with a double Force; for notwithſtanding this is generally taken for granted, yet there is a great deal of room to diſpute it: And tho' it is certain, that a larger quantity of Fire in a ſmaller Space, will always be more efficacious; yet, it ſtill remains matter of doubt, whether its active power receives no augmentation, except purely from its quantity.

This ſuſpicion is grounded upon the following obſervation. It is evident from

from Experiment, that there are certain Bodies in nature, which whilst they are separate produce no effects, but as soon as ever they approach one another within a determinate distance, immediately excite new motions which did not before exist, which grow continually greater the nearer they come to one another, and cease again in an instant, when they are removed so far asunder, that their reciprocal vertue can exert itself no longer. For an instance of this, let us take two very good Loadstones: Let one of these be at rest in any particular place, and it will always of itself continue so: Bring, then, another gradually towards it, and you will find by gently proceeding the most distant point in which this latter will be able to put in motion, and agitate the former; and as you successively bring it nearer and nearer, the motion of them both will become more remarkable, the power that generates it always increasing as the distance between them grows less, though in a proportion that is not yet determined. The great *Newton*, indeed, for very weighty reasons suspected it to nearly in a reciprocal triplicate *ratio* of the distances. As appears by an instance in other Bodies.

For the discovering of this the famous *John Muschembroek*, Professor in the *Academy* of *Utrecht*, has taken a vast deal of pains, and that with very good success. Let us suppose a number of Loadstones equally powerful to be suspended so as to be in the same a spherical surface, and so near one another as to be just ready to feel each other's reciprocal attraction: Let us then imagine them all to be brought very gently towards the Center of the Sphere, and consequently nearer to one another. Would not they then, if there was a hundred of them, be all put immediately into a surprizing motion? Suppose again, that at a certain distance they were all perfectly at rest; and then conceive one Loadstone situated in the Center of the Sphere: certainly, in that very instant of time there would arise a very extraordinary motion in all the others together, not one of them keeping their position, though they were all absolutely quiet before. And when these, again, began to come towards the Center, the motion would grow greater at every distance, and be very different from what it was just before; since the action produced between the attracting, and repelling Poles, would continually vary in every point of approach. The same thing might be demonstrated in the Air, and a great many other Bodies, but this Example is sufficient. Supposing, now, such a power as this, or perhaps a greater, to be implanted in the Elements of Fire; it will, then, be possible, that the force, which they scarcely had at all when asunder, may be exceedingly increased when they are collected together; and hence the Fire in the *Focus* may be vastly more intense on account of the nearness of its particles, than of their number. And, indeed, the truth of this doctrine has been a good while certainly confirmed by the following Observation. If the Thermometer, in an open place, irradiated by the Sun at noon in a cold Winter's day, stands at the degree 20; and at the same time your furnace stones instantly melt, and vitrify in the *Focus* of *Vilett*'s *Speculum*; what do you imagine would be the consequence, should the Thermometer be placed in the *Axis* of the *Speculum* five inches distant from the *Focus*? In all probability you would expect some extraordinary effect; and yet by Experiment we find that there is scarcely a Heat there of 190 degrees. Does it not, then, hence appear evident, that this vast difference of Heat cannot arise from condensation alone, but that there must likewise some new agitation be excited in the particles themselves And in Fire itself.

ſelves from the nearneſs of contact? But ſince we have made it clear, from what has formerly been laid down, that it is the peculiar property of Fire to expand both itſelf, and all the Bodies it acts upon; it is poſſible, that this quality may be vaſtly increaſed by this collection of the particles of Fire into one place: And hence, perhaps, its cauſtic power may in a moment be ſo prodigiouſly augmented.

Laſtly, becauſe we don't know the efficacy of the curvature in diſferent parts of the *Speculum*.

But laſtly, we are not yet certain whether the power by which the parts of the *Speculum* reflect theſe igneous Rays, is as great about the *Axis*, to which the Rays fall parallel, as it is in the other parts of the ſurface that are more diſtant; and hence, till this is aſcertained, we may fairly doubt, whether all the Rays reflected from the *Speculum*, and collected in the *Focus*, meet there with ſo equal a force, that we may venture to aſſert, that the Fire excited there is proportionable to the number of the united Rays.

COROL. 8.

A method of determinating this Fire.

I have taken a great deal of pains to diſcover, if poſſible, a method by which we might determine ſomething certain in this point: And at laſt it appeared, that if any part of the *Speculum* is covered with an opake black Body, the Rays from all the other parts of the *Speculum* that are open, will nevertheleſs, be conſtantly collected in the *Focus* without any aberration; nor does it at all ſignify which part of the concave is covered. If we conceive, now, the whole aperture to be covered with a circular braſs plate; then nothing will be received, nor any thing reflected. But as we can divide this Circle from the Center into as many equal parts as we pleaſe, we may by this means exclude, or admit, what quantity we have a mind of the rays that fall upon this circular *Area*. And, hence, the proportion of the admitted Rays, to the whole that were before received upon this plate, we can determine at pleaſure. Thus, therefore, we can collect in the *Focus*, half, a third, a thouſandth, or any other part of the Rays; and then, by comparing the degrees of Heat produced in the *Focus* by theſe different quantities, may be able to diſcover, whether the force of the Fire thus generated, is always in proportion to the number of Rays united in the *Focus*, or depends upon ſome other law. By this method, then, all the Rays of Light that fall upon the whole aperture of *Vilett*'s *Speculum* may be divided in any *Ratio*, in which we can geometrically divide a circle; and the efficacy of the Fires they excite in every proportion may be thus examined.

COROL. 9.

In order to determine its power.

If by proper Experiments, therefore, it was known, what part of this braſs circular plate muſt be open to admit juſt Rays enough to make Water boil when placed in the *Focus*; and this aperture ſhould afterwards be very gradually inlarged till the focal Fire would raiſe the Mercury in the Barometer to the degree 424: Then, this degree of Heat would be double the former, as far as it diſcovers itſelf by this dilatation of the Mercury. We might, then, examine the proportion of this laſt aperture to the former, which produced only half as much Heat; and, hence, by comparing the *Areæ* of theſe apertures thus diſcovered, and the effects of the cauſtic powers we obſerved from each of them, we might at laſt be able to determine, how much of this force depends

pends upon the quantity of the Rays, and how much on this coarctation of them into a smaller space, and the reduction of the Elements of Fire into a nearer union. And this, as it would be of very great service in furnishing us with proper materials for a History of Fire, it seems plainly to demonstrate that the intenseness of this Fire, is not owing only to the number of the Rays, but to their proximity likewise, by which the force of the particles of Fire is continually increased: A few Experiments, at least, that have been made with this view with concave glass *Speculums* induce us to be intirely of this opinion. Thus, then, we have sufficiently explained the greatest force of Fire that has ever yet been discovered; which, in very cold weather, is produced in one simple manner by that quantity of solar Rays that passes through a Circle of three feet seven inches diameter. Had these Rays, now, proceeded on without meeting with any obstacle, they would have excited but a small degree of Heat in the Air; and if they had constantly kept on in the same direction through an Air growing gradually finer and finer, the Heat caused by them would have grown less and less by degrees, till at last perhaps it would have been diminished to a greater degree of Cold than was ever yet discovered. Hence, then, we see plainly what wrong notions persons generally have of the nature, and action of Fire; since it evidently appears, that the difference betwixt the intensest Heat that we are hitherto acquainted with, and the extremest Cold, is caused purely by the action of a resisting Body. And, hence again, we may almost venture to infer, as we did before, that Fire is equally diffused through all Bodies, and every part of space; and that its activity does not appear, except when it meets with some resistance. As, the aperture, now, of the *Speculums* we have been treating of may be constantly increased; hence, the strength of the focal Fire may be augmented *in infinitum*.

COROL. 10.

Attrition produces the effect of the greatest Fire.

No body has ever yet discovered a stronger Fire in any place, than that which is collected by *Vilett*'s *Speculum*; for that which is generated by *Tschirnhausen*'s burning glasses is not so great. Hence, the effect of the greatest Fire that we know of, is the turning Flint into Glass in a moment, in *Vilett*'s *Focus*. A greater effect than this has never yet been observed; for though Lightning has sometimes instantly melted Iron, yet it never has, to my knowledge, vitrified either Stones, or Metals. The vast violence, therefore, of the Fire in this *Focus* we cannot consider without wonder, and astonishment: And yet I assert, that this very same effect of vitrification, may be at once produced in the coldest places, and by the coldest Bodies, without the assistance of any Sun, Light, *Focus*, or combustible matter; and, hence, that the ultimate effect of the most intense Fire is always and every where producible, even in the darkest and coldest parts of space. And this is evident; for if in the sharpest Winter-night, you strike a choice Flint against a piece of well tempered Steel, you may by that means always procure exceeding lucid, vivid sparks, which make a whizzing noise as they fly through the Air. Now if you catch the Corpuscles thus struck off, upon a clean paper underneath, you will find them to be glass Spherules, composed either of the melted Flint, or Steel, or both together, and formed into this figure by their rotation through the Air. Hence, therefore, we are certain, that the force of the Fire generated here, must have been strong enough to have reduced these exceeding hard Corpuscles to such a fluid state, that they might by this equable rotation through the soft Air be reduced into these spherical Bodies, which, upon examination, we find to be perfectly of a glassy nature. But the turning Stones and Metals into Glass, is almost the greatest and ultimate effect of the strongest Fire; so that hence it appears, that the action of this momentaneous percussion is as efficacious, as that of the most violent caustic *Speculum*. If a prodigious large choice Flint, therefore, should be struck against an exceeding great Body of Steel, what a Fire might be instantly produced? Thus, then, I have explained a second method by which the greatest degree of Fire may be readily generated; *viz.* by collecting the parallel Rays of the Sun into a very small point by reflexion.

EXPERIMENT XVI.

The production of Fire dioptrically.

If the same Fire, thus determined into a Parallelism by the Sun, falls upon a very pellucid glass, nicely polished, and perfectly spherical, it will be collected in a *Focus* that burns very violently.

The truth of this has a long time been discovered; but it never appeared more accurately than by the glasses of Mr. *Tschirnhausen* in the possession of the *Duke of Orleans*, which were made use of in the Palace Garden on purpose to try some Experiments concerning the nature of Fire. An historical account, therefore, of this affair can't here be omitted; as it will give us a considerable light into the properties of Fire, the effects produced by these glasses being the greatest that were ever produced by any of the same kind. See *Mem. de l'Ac. Roy des. Sc.* 1699, 90, 1700, 128. 1702. 34.

The greatest known.

The biggest glass is of a circular figure, four feet in diameter, and convex on both sides; and if it is directly opposed to the Sun in the summer time betwixt nine in the morning and three in the afternoon, when the Air is clear, and freed from its Water by preceding Rains, it produces a *Focus* at twelve feet distance from the glass, whose Diameter is an inch and a half. This is what Mr. *Tschirnhausen* made use of himself.

If combustible Bodies are placed in this *Focus* they take fire immediately; Lead is soon melted; and Bricks are vitrified, if they continue there a good while. Now from these effects compared with those of *Vilett*'s *Speculum* we may draw the following Corollaries.

COROL. 1.

The catoptrical, and dioptrical Fire compared.

The Diameter of the circular aperture of *Vilett*'s *Speculum* is 43 inches; hence, the circumference, $\frac{946}{7}$ inches. The Diameter of the Circle of *Tschirnhausen*'s Convex, is 48 inches; its circumference, therefore, $\frac{1056}{7}$ inches: Consequently, the quantity of the incident Rays upon the Circle of *Tschirnhausen*'s glass, is to the same upon *Vilett*'s *Speculum*, as 2304. to 1849; and yet the action of *Vilette*'s *Speculum* is much quicker, and a great deal more violent, than that of this glass *Lens* of *Tschirnhausen*.

COROL. 2.

The catoptrical more powerful,

Hence it appears evident, that Catoptrics rightly improved is better suited to give us the incident Rays in their full force by reflexion, than Dioptrics, with the utmost advantages, is by refraction; and, therefore, that a great many Rays are lost when we endeavour to collect them by diaphanous burning glasses.

COROL. 3.

But how great now, likewise, is the difference of their *Foci?* The *Area* of the circular aperture of *Vilett*'s *Speculum* is $\frac{40678}{28}$ square inches; its *Focus* $\frac{792}{28}$ square lines. The *Area* of the Circle of *Tschirnhausen*'s *Lens* is $\frac{10688}{28}$ square inches, the *Focus* of it, $\frac{7128}{28}$ square lines: And, therefore, the *Focus* of the *Speculum* is to the *Focus* of the *Lens*, as 1, is to 9; whence it appears, again, that the method of generating Fire by reflexion, is more powerful than by refraction. This caustic power, therefore, may be carried to a greater height by opake *Speculums* than by transparent *Lens's:* For an orbicular *Lens* of four feet diameter, is almost the greatest that the Workers in Glass could ever yet make, on account of the construction of their Furnaces; whereas the formation of *Speculums* is not as yet, perhaps, arrived to its greatest perfection; though we have no very great reason, indeed, to expect otherwise. For who, that judges justly of things, don't reflect with some regret, that no Prince should think it worth while to reward the industry of these consummate Artists in a handsome manner, and encourage them to farther Improvements? But this is the hard fate, that the most beautiful Arts are frequently exposed to.

Because it unites the Rays more closely.

EXPERIMENT XVII.

The noble *Tschirnhausen*, however, not being satisfied with the preceding Experiment, began to think of contracting the former *Focus* into a narrower compass, and by this closer union of the Rays rendering its caustic power more intense. For this purpose, therefore, he made use of a smaller glass *Lens*, the Segment of a lesser Sphere, which being placed directly parallel to the former, received all the Rays that were collected by that larger one, and were proceeding on to its *Focus*, and contracted them into a circular space of only eight lines diameter; and consequently, by this new contraction, reduced these Rays from an *Area* of 81 lines square, to one of 16. But though by this method he brought them into a nearer union; yet he lost a great many Rays by this second refraction; though this, however, did not hinder but that the caustic power of this latter *Focus*, was stronger than the former. And this was the ultimate effect of the skill of the celebrated *Tschirhausen*. Thus then, Gentlemen, I have endeavoured to explain to you as fairly and clearly as possibly, the most efficacious methods, hitherto discovered, of generating Fire by the assistance, both of the catoptrical, and dioptrical Science. I imagine, however, that you'll expect as Chemists, that I should lay before you the surprizing alterations that Bodies undergo when they are exposed to the power of these Glasses, for producing of which, you will perceive there is no need of any gross Fire, though these effects are much greater than ever were brought about by the most violent Glass-house, Docimastic, or Metallurgic Furnaces. Nor let any one take it amiss, that I relate here those things, that may be found in the *Memoirs* of the Academy of Sciences: These Books are not in every body's hands, and I am at present professedly treating of Fire. The chief, then, are as follow.

The greatest dioptrical Fire.

1. Moist boughs of green trees, or wood soaked in Water, held in this *Focus*, take fire in a moment, and consume in Flame, Smoke, and Ashes.

The principle effects of such a Fire.

2. Water contained in a ſmall veſſel, begins to boil in this *Focus* immediately. And I wiſh it had been tried by *Fahrenheit*'s mercurial Thermometer, whether whilſt it boiled in that place it was hotter than uſual; that thus we might have ſeen whether the intenſe force of this focal Fire, could communicate to boiling Water a greater degree of Heat, than any other Fires, in all which it is conſtantly obſerved to grow equally hot.

3. Thin plates of Metal placed in this *Focus*, do not melt immediately, but gradually, after they are heated to a certain degree. And if they are ſo thick, that the force of the Fire can't penetrate quite through the plate, they won't very eaſily be melted at all.

4. Bricks burnt, or dried in the Sun, *Talc* itſelf, and other Bodies, grow red in a moment, and ſoon after run into Glaſs.

5. Sulphur, Pitch, and Reſin are melted though they lie under Water.

6. A thin piece of wood covered with Water, and expoſed to the ſtrongeſt *Focus* a good while in ſummer time, ſeems perfectly intire if you look on the outward parts of it, but if you break it, it appears burnt within, and turned to a coal. Now this very extraordinary *Phænomenon* ſeems to me evidently to indicate, that this intenſe Fire cannot heat Water beyond a certain degree; which being leſs than that which will ſet fire to wood, it prevents the *Focus* from burning the wood in thoſe parts that are contiguous to the Water.

7. If the ſubſtance to be examined is fixed upon a very black Body, the power of the *Focus* is vaſtly increaſed.

8. If Metals, or other Bodies, are laid upon charcoal made of green wood, and not thoroughly dried, they will be melted in the twinkling of an eye, throw out ſparks, and fly off. Lead, and Tin, melt ſooneſt of all, fume, calcine, vitrify, and diſappear.

9. The Aſhes of all kinds of vegetable are turned to Glaſs immediately.

10. If a pretty large Maſs is expoſed to this *Focus*, it frequently happens, that this Fire won't put it in fuſion; but if you reduce the ſame to Powder, it generally melts pretty eaſily: If it ſhould ſtill, however, obſtinately reſiſt fuſion, it may readily be effected by mixing of ſome ſorts of Salt with it.

11. All Bodies, that are black, and continue ſo in this *Focus*, ſuffer the greateſt alterations there: Thoſe that are white when they are put into it, and afterwards grow black there, are chang'd with more difficulty, and not under a longer time: Thoſe that are black when they are expoſed to this *Focus*, and afterwards grow white in it, reſiſt its force ſtill much more powerfully, eſpecially if they become white after they are put in fuſion: But thoſe that continue perfectly white in this intenſe Heat, undergo the leaſt alteration of all; as Lime, *Engliſh* Chalk, and Flint.

12. All Metals plac'd in this *Focus*, in a *China* veſſel that is not glaz'd, vitrify immediately, if you take care to heat the veſſel leiſurely, that the ſudden force of the Fire don't break it, and it is itſelf ſo thick, that it won't be melted.

13. If the matter to be examin'd by this Fire is placed in a large glaſs Matraſs, and the *Focus* is ſo carefully directed, that it ſhall affect this matter, but not the Glaſs through which it paſſes, then the *Phænomena* that are produced upon this matter within the Glaſs, will be very ſurprizing.

14. Nitre contained in ſuch a veſſel, and acted upon by this Fire, grows perfectly volatile in the leaſt inſtant of time, and then is intirely changed into

 a volatile

a volatile Spirit of Nitre. This effect now is ſo much the more wonderful, becauſe Nitre, when it is melted by other Fires, ſcarcely undergoes any alteration, but runs juſt like Water; and before it can be reduced by Fire into a Spirit, it always requires a mixture of ſome earthy Body with it, or an addition of true Oil of Vitriol, or its *Calx*, in which there ſtill remains ſome portion of Oil: Here we ſee the ſame thing effected without any mixture at all.

15. The light of the brighteſt full Moon being collected by this Glaſs, gives an exceeding lucid *Focus*, but not the leaſt indication of Heat.

16. It moves, agitates, and drives about almoſt all Bodies, even in *vacuo* itſelf, tho' ſometimes not without exceeding great danger.

From theſe Experiments, then, and a great many more, it appears, that this *Focus* of *Tſchirnhauſen* is weaker than *Vilette*'s, but that, nevertheleſs, it is much better ſuited to the examination of Fire by its effects.

COROL. I.

Dioptrical Fire in the Air.

If Water, or pieces of Ice in the Atmoſphere, ſhould by any phyſical cauſes be ſo roll'd up into a globular Cloud, as to form a pellucid Sphere, tho' its figure continued ever ſo ſhort a time; then, this being irradiated by the Sun, might in an inſtant produce a *Focus* much more violent than *Tſchirnhauſen*'s; which would be at the diſtance of a ſemi-diameter of the Sphere on that ſide averſe to the Sun: The Air, therefore, would be there vaſtly rarified, and hence, again, muſt ariſe very ſudden and ſurprizing *Phænomena*. For whoever conſiders the perfect tranſparency of Water raiſed into the upper regions, and reflects at the ſame time on the vaſt quantity that often falls in ſhowers in a very ſhort time, will eaſily underſtand from Dioptrics, what muſt be the conſequence, ſhould it be formed into a very large Sphere. If we imagine, again, the Rays thus falling upon ſuch a Sphere to paſs through it, and by this means to cauſe a vaſt Light and Fire, behind the Sphere, in a line that paſſes through its center and that of the Sun; whilſt at the ſame time there appears nothing but thick darkneſs on that part that the Sun ſhines upon: Perhaps, it will not ſeem improbable that this is the caſe, when ſome parts of the Heavens appear terrible black, and ſoon after break out into prodigious Thunder and Lightning. But this ſpherical figure of theſe Clouds will in a particular manner produce a very conſiderable difference in the Light and Heat of the Spaces intercepted betwixt theſe Spheres and that of the Spheres themſelves: Hence, therefore, very ſudden and extraordinary appearances muſt ariſe one moment, and vaniſh again the next, from theſe ſwift changes that happen in the Air; which in ſome places will be rarefied and ignited, whilſt in others, at the ſame inſtant, it is condenſed and refrigerated. But theſe hints are ſufficient; if you'll carefully attend to the *Phænomena* of Meteors, by means of this principle, of yourſelves, you will eaſily underſtand them.

COROL. 2.

Fire greater, and more readily excited by attrition than Dioptrical Glaſſes.

On this occaſion, Gentlemen, I can't help reminding you again of what I have taken notice of elſewhere, *viz.* that Metals vitrify much ſooner, and more intimately by the ſole attrition produced by ſtriking Flint againſt Steel, than by this double Dioptrical *Focus*, which is the ſtrongeſt of this kind, that we are acquainted with. The truth of this is evident: For *Vilett*'s *Focus* is much more powerful

powerful than *Tſchirnhauſen*'s; and yet iron is ſooner turn'd into Glaſs by percuſſion, than it is even by that. Hence, therefore, we ſee plainly, that the power of attrition in elaſtic Solids is vaſtly great.

COROL. 3.

No need of any matter from the Sun to the moſt intenſe Fire.

And hence, I infer, that there is no need of any action of the Sun, that we are at preſent acquainted with, to produce the ſtrongeſt Fire, that has ever diſcovered itſelf by the quickeſt and moſt powerful effect; nor is there any inflammable matter neceſſary to put into fuſion, intimately, and in an inſtant, that Metal, which, of all others, is melted with the greateſt difficulty, eſpecially, if when the Experiment is made, it is exceeding cold, and in a very cold place: Nor for this purpoſe do we ſtand in need of any melting Furnace, or ſo much as a veſſel to contain it. All which paradoxes are plainly confirmed by this common way of ſtriking Fire.

COROL. 4.

Perhaps the Sun does not emit ſuch Fire.

I have been a great while in doubt, whether I ſhould venture to publiſh an opinion, which I have long revolved over and over in my own mind; in dependance, however, upon your candour, I'll take the liberty to do it. It ſeems probable then, that the Sun does not in reality emit any igneous matter, to which we can aſcribe any of the actions of Fire that fall under our obſervation; but that it has only a power of determining the pre-exiſtent Fire into parallel right lines, without making the leaſt addition: And hence, that the very ſame quantity of Fire being, after it has obtained this direction, collected, either by reflexion, or refraction, produces all the effects by this union of the Rays that were before diſperſed, and the new power which they gain in conſequence of it. But before I proceed, give me leave, by an eaſy Example, to illuſtrate this affair, which it is poſſible, to perſons that are prejudiced againſt this opinion, may appear ſomething obſcure. Let us take, then, a hollow braſs Cube, whoſe ſides are three feet ſquare; three of which ſuppoſe cloſe, and the other open: Let the open ſide of this Cube be turned directly to the Sun, but be covered with a white paper; and in its cavity let there be placed one of *Fahrenheit*'s Thermometers, made with Spirit that's very eaſily affected with the leaſt degree of Heat. So long, then, as the Paper hinders the Sun from ſhining into the Cube, ſo long will there be a great degree of Cold there, if the ſeaſon at that time is very cold. Let the Paper, now, be at once taken away, and that very moment the whole cavity of the Cube will be irradiated by the Sun, and the meaſure of the increaſed Heat will be determined by the Thermometer that's fix'd there. The Philoſophers now aſſert, that the Fire that produces this new Heat, is emitted from the Body of the Sun with an inconceivable velocity. On the other hand, it ſeems probable to me, that the Sun does no more now, than it did before, and indeed, than it always does, and that is, it determines what we call Fire into right lines, when it meets with no opake Body to intercept its power: And hence, that the Fire in this Cube remains exactly the ſame that it was before, and has only received a new rectilineal direction towards that ſide of the Cube that is oppoſite to the open one; whereas the Fire, whilſt the Cavity was cover'd with the Paper, exerted its force equally upon all ſix. In this manner, then, I imagine the Sun equably heats this whole Space, this ſide in particular, and

and causes this difference in the Thermomer, purely by this determination, without the least addition of any new matter. But again, suppose *Vilette*'s *Speculum* to be directed to the meridian Sun, but to be cover'd with a very white linnen Cloth; then, there will be no more Fire or Heat in the Cavity betwixt this covering and the *Speculum*, than there is any where else. Now remove this Vail, and in an instant the Fire that was in the cavity of the *Speculum*, and tended every way equally, is driven in parallel lines upon its concave Surface, and thence being reflected into the *Focus*, produces a most violent Fire there, which, in reality, did not proceed from the Sun: Nor is there, indeed, either more or less Fire than before, but only it is determined in a different manner. In a refracting *Lens* too the case is exactly the same. Hence, then, neither the Fire excited by attrition, or produced by this *Speculum*, or *Lens*, would upon this supposition depend at all upon the Sun with regard to its matter.

Corol. 5.

What now is the greatest degree of Fire that human skill, and industry, can at present produce? Why, from what has been laid down, it plainly appears, that it would be in that place where the *Focus* of *Vilette*, and the strongest of *Tschernhausen* should be made to meet together in an opposite direction, and coincide. For since the *Focus* of the *Speculum* is in the open Air, and in a point of its *Axis* three feet and a half distant from its *Vertex*; hence, this *Apparatus* of *Tschirnhausen* may be so placed between the *Speculum* and the Sun, in the *Axis* of both of them, that this dioptrical *Focus* shall exactly unite with the former catoptrical one, and that without at all preventing the Solar Rays from falling upon the *Speculum*. In this place of concourse then will be found the most intense Fire, that human art at present is capable of exciting. I confess, indeed, that the force of this vast Fire can't conveniently be directed upon any Bodies placed in the *Focus*, for more than a moment; since as soon as ever they are melted, they will drop out of it: The greatest possible Fire, however, is thus determined. If, then, it is no ways repugnant to nature, that the globular and concave Clouds of Ice may have their *Foci* united together in the manner just mentioned, what prodigious effects may thence be produced?

A physical manner of producing the greatest Fire.

Corol. 6.

Suppose, now, this greatest Fire to be really excited in the place described; it will then continue there so long as the *Axis* of the Sun, dioptrical Glasses, and *Speculum*, remain in the same right line, and the distance between the *Speculum* and the Glasses is not altered. And, hence, if these instruments could be kept in the same situation, and at the same time be contrived to move in such a manner, as to be always directly opposed to the Sun; then this immense Fire might, in a clear Summer's day, be kept up from nine o'clock in the morning to three in the afternoon; nor would it, during all that time, want the least *Pabulum* to support it, but would persist in the same manner as it was produced. Thus, then, we form an *Idea* of the greatest Fire, very different from what any body ever had before: For from the laws of Nature thus discovered, we see it is possible that Fire and Light, of a determined power and magnitude, may exist, and continue in any place of the universe without the least *Pabulum* to sustain it.

Which continues a great while without any *Pabulum*.

Corol.

COROL. 7.

And instantly acts with vast force.

And what is principally furprizing in this Fire, is this, that the very inftant that its caufe begins to act, it immediately exerts itfelf with its full force, and with as great a degree of violence, as it ever acquires afterwards: Except, perhaps, you may look upon it as ftill more wonderful, that upon covering the *Speculum*, there don't remain in the *Focus* the leaft phyfical figns of that Fire which exifted there, and acted with immenfe power but the moment before; nay, on the contrary, the Light, Heat, expulfion of the Air, and every other effect, difappear at once, without leaving any marks behind. Who could have believed thefe things? May, therefore, the brighteft Light, and the ftrongeft Fire in the Univerfe, be generated, and deftroy'd again, in an inftant? But the Fire now in the *Focus* thus defcribed is not vifibly bright, except in the *Axis* of the Sun and the *Speculum*; on the fides there is no Light to be feen at all; and, hence, it gives no indication of its prefence by any lucid appearance, except to an eye placed in this *Axis*, where the immenfe brightnefs confounds and deftroys the fight in a moment.

COROL. 8.

A new pofition concerning the nature of Fire.

Now, whilft I examine thefe things carefully, I think I difcover a farther confirmation of that furprizing phyfical property of Fire, by which when it is left to itfelf, it conftantly, like the *Radii* of a Sphere, expands and diffufes itfelf uniformly and equably from the center of its magnitude. Since, therefore, this Fire exifts every where alike, its power, of confequence, will be every where in *equilibrio*, and, hence, will fo long produce no fenfible effects; but as foon as ever this *equilibrium* is by any means deftroy'd, then, immediately it may appear by its operation to be infinitely powerful. In which cafes, perhaps, we fhall be miftaken, if we imagine, that any new fire is produced, or that there is any increafe in the power of that which exifted before.

EXPERIMENT XVIII.

Fire may be united with Bodies, and fixed for a time.

True Fire may be united with every folid Body on which trial has hitherto been made; and when it is once communicated to it, it will adhere to it a confiderable time; and therefore, does not inftantly difappear in Bodies, as it does in the *Foci* we have been juft treating of.

For if we commit any of thefe Bodies to a pure ftrong Fire of any fort, we find that they may be heated fo as to fhine, grow refulgent, and melt. This, the Experiments of *Tfchirnhaufen*, *Homberg*, *Hartfoeker*, and others evince; as likewife, thofe of your Smiths, Cooks, and all others that are converfant about Fires; as well as thofe which the Earth itfelf irradiated by the Sun offers to our Obfervation: In all which the fame thing is found to hold good by every kind of Experiment. And this, the trial upon all fixed Earths, all kinds of Stones, Gemms, rocky Subftances, Glafs, fixed Salts, Wood, folid Foffils, and Metals, confirm the truth of. And hence the great *Newton* very juftly obferves, that if Water itfelf could be converted into Earth, it might be fo impregnated with Fire as to become lucid. Now there is nothing in this affair that deferves more to be taken notice of than this, that there muft be fome caufe, by which the Fire is connected to thefe Bodies during this time, befides the

the Fire itself. This is plain; for in *Vilette*'s *Focus*, that intense Fire is destroy'd the very moment that the parallel irradiation ceases. Fire, therefore, in that place, does not hold together and detain Fire: On the contrary, all those Fires now fly asunder, and leave one another, which the instant before were so closely united together. But now, if an iron Ball, whose great Circle, suppose equal to the Circle of the *Focus*, had been held there so long till it was quite hot through; then, the Fire of this *Focus* being associated with the matter of the Ball, would be detain'd in it a considerable time, and thus this focal Fire, which would otherwise have vanished in a moment, will, now it is received within this body, remain united to it a long while, and be secured from this instantaneous extinction. What now is properly the cause of this effect? Body. By what means does it thus retain Fire? By its corporeal Mass. Was there, therefore, no other corporeal substance in this *Focus* but Fire, the Air itself being expelled by the force of it? And did the Fire, therefore, vanish so suddenly, because there was no other Body to secure and detain it? Do the particles of Fire, then, when collected together, immediately restore themselves to their former *equilibrium*, if they are not kept together by some dense Body? And, hence, is there no mutual attraction between the elements of Fire? Or don't they, rather, repell, and fly from one another?

Experiment XIX.

When this pure elementary Fire is thus communicated to Bodies, it discovers itself to be real Fire by a true physical effect, which it produces all around them from every point of their surface, so long as it remains in them. And that very pure.

In this case, certainly, we observe the principal mark by which the Thermometer demonstrates that Fire is actually present: For if, as you see, I hold this Thermometer at a certain distance from this red hot Iron, you perceive the Spirit instantly rarefies in the Tube, and so much the more, the nearer I bring it; and again, you observe it is condensed, as I remove it back again. Nor does it at all signify on which side of the Iron I hold it, if I take care to keep it always at the same distance. This Fire, therefore, that now resides in the Iron, and acts upon the Thermometer, is, in reality, the very same as the former; but it now persists in this place without any attrition, or parallelism, and produces the very same effects there, as elementary Fire does. Observe, now, this Brimstone Match; as I bring it very gradually from some distance towards this red hot Iron, you see it begins to smoke, melt, sparkle, shine, and kindle into a Flame. But, again, pray take particular notice of this surprizing Experiment that follows. This small Vial in my hand, contains some very pure Alcohol; a little of which I'll pour very gently and cautiously upon this red hot Iron. What do you imagine, then, will be the consequence? That it will take fire? to be sure no body doubts it. But the case is far otherwise. For observe, as soon as ever it falls into the hollow of the Iron, it forms itself, like Mercury, into a globular figure, and runs up and down in that manner, without the least appearance of any Flame; and yet you see the moment it comes to the colder part of the same Iron, it is then in an instant dissipated into the Air; tho' then too, without flaming. What now, Gentlemen, should be the cause of this? Sulphur, Gunpowder, Wood, and other Bodies, when apply'd to this Iron, flame immediately: And yet Alcohol, which being gently heated, fires sooner than almost any thing, is able to bear the Heat of the same Iron, without taking fire. The solution of this Paradox is worthy your penetration.

EXPERIMENT XX.

Without any increase of weight,

Since, therefore, it is certain, that this Fire may be thus detained in a solid Body, and that, during so long a time, and in such a degree; it is our principal business to enquire, of what kind this Fire is, which in this manner remains there: And as weight in particular is one of the chief, and most general properties of Bodies, I have taken pains to examine whether this Fire does in reality add to fixed Bodies any weight that our senses are capable of discerning.

As appears by an Experiment made upon Iron with a Ballance.

To this purpose, then, I made choice of a Body, that would bear a strong Fire without losing any thing of its weight; and at the same time, should be able to receive a large quantity of Fire into it, and preserve it there a considerable time: And I made use of a very accurate ballance, that moved very easily upon its *Axis.* Observe then, this parallelipiped, made of the best sort of Iron, which weighs 5 pounds, 8 ounces, *Amsterdam* weight, now it is cold. I'll put this, as you see, into this large Fire, which shall be blown till the Iron is perfectly red hot all over: Thus bright, then, as it is now it is taken out, when I have struck off the dust, I'll put it into one scale, and at the same time put weights in the other, till there is a perfect *equilibrium.* You observe now the beam is perfectly at rest, and upon examination, you find, that the weights in the scale make exactly 5 pounds, 8 ounces. I'll leave it now in the scale till it is quite cold, and the *equilibrium* will still be maintained: For after letting it alone thus for twenty-four hours, I have found, that even in this large Mass, there was not the least difference in the weight of the Iron when it was red hot, and after it grew cold.

Another upon Brass.

I made the same trial with a large solid piece of Brass; and the event was exactly the same. It is necessary, however, to give you this caution, that in making these Experiments, the heated Body sometimes seems to be lighter than it was when it was cold; and this happens when the scales are fastened to the beam with ropes, or any thing of that kind, that is capable of admitting moisture into it; for when the Metal is put into the scale, the heat of it makes the moisture evaporate, and by this means the strings on that side grow lighter than they were before. On this account, therefore, we must always, for this purpose, make use of chains made of Metal.

COROL. I.

Fire is free in Space and Body heated.

The Fire, therefore, thus adhering to a heated Body, diffuses itself all around just in the manner of an Atmosphere: For from every point of the Body it exerts its force to a considerable distance, and thus produces those true physical effects that are peculiar to Fire: and these are found always to be the greatest, the nearer you approach to the heated Body. If a Globe, therefore, was thus heated, it would form a Sphere of Heat round it, whose center would be hottest of all.

COROL. 2.

And, hence, we understand, that there is great quantity of true Fire in such a Body;

Body; and that it continues there for a very considerable time. For if we consider, that round such a Ball of Iron or Brass, there is a great degree of Heat on every side to a considerable distance, as appears by its proper effects; and at the same time reflect, that during the continuance of this Heat, it must be constantly diminished by the cold of the ambient Air: We shall then easily see, that the quantity of Fire in this heated Ball must at first have been exceeding great. And, hence, the greatest quantity of Fire must be in the Body itself, with respect to the surrounding Air that is heated by it. And again, if such a Sphere is kept in the Fire so long till it is perfectly red hot quite through; then, in its center the Heat will be most condensed, and greatest of all: The truth of which is confirmed by all its effects.

Greatest in the Center, and decreases towards the Surface.

COROL. 3.

But from this center towards the surface, the Fire grows gradually weaker and weaker; for its surface that is contiguous to the Air, will first be affected with the coldness of that, and, hence, will first grow cold. And this is equally true of the Atmosphere of Air that surrounds the Sphere, for those Orbs which are nearest it, will be hottest, and thence grow successively cooler, till they come to that which determines the boundaries of the Heat, and is itself as cool as the ambient Air. Hence, again, we are certain, that in this whole heated Sphere, the center expands itself every way with the greatest violence. This is the nature of Fire, which is here greatest in the center. But the contiguous Orb will be less expanded, and therefore will confine the expansion of the center, and in some measure repell it; for this Orb is not quite so hot, that is, it is a little less expanded, or a little more contracted. And, since this same expansion and repulsion will hold true in all the Orbs that compose this whole heated Atmosphere; hence it appears, that so long as the Heat, communicated to the Sphere, continues greater than that of the common Air, so long there will be a continual dilatation and repercussion throughout the whole Sphere, as well in the solid Mass itself, as the Air that is heated round about it. And this vibration, considering the violence of the Fire, must of necessity be very great. Does therefore the vibration and repercussion in this case agitate the particles one amongst another? And is there by this means new Fire excited, as we have explained already in the first manner of generating Fire by attrition?

So that at last it comes to the common temperature.

In a heated Sphere a continued oscillation.

COROL. 4.

It were here much to be wished, that we could find a way of determining the proportional quantity of Fire, that is contained in such a Body, with regard to its very substance! But this is not so easy to accomplish as people generally imagine: For tho' we are able to discover the force of the Fire by its sensible effects; yet we cannot from its force make a certain judgment of its quantity; and for this reason in particular, because we don't yet know how much its power may be increased, purely from the near approach of its Elements. So long, therefore, as we are ignorant what proportion the power that depends upon this condensation of Fire, bears to that which arises from its quantity, so long we can't pretend to make use of the effects of Fire, as a certain measure to

The measure of the quantity of this Fire difficult.

determine its quantity. These niceties may to some persons seem unnecessary; but a great deal of caution will never do any harm in physical inquiries.

COROL. 5.

This Fire does not become a concreted Mass with the Body,

This Fire, however, tho' it thus continues in a heated Body, does not seem to be concreted with it into one corporeal Mass; for notwithstanding the Body grows bigger than it was before, yet it don't become at all heavier; unless you will suppose, that the Fire may be concreted with it, so as to increase its bulk, without making any addition to its weight. This, in the mean time, we are absolutely certain of, that the Body is constantly extended in its bulk, so long as the Fire remains in it.

COROL. 6.

Nor renders it lighter;

Nor does the Fire at all lessen the weight of the Body, whilst it is in it, and the Cold restore it again: For the contrary is always found true by Experiment.

COROL. 7.

Nor as to its weight makes any alteration.

Hence, therefore, we may conceive of the Fire, in a red hot Globe of Iron, for instance, as a Fluid, dispersed, both through the Body itself, and all round about it, whose Particles are mov'd every way freely, and without any particular tendency: For if you suppose any determination of them one way more than another, it seems necessarily to follow, that the Mass, when it is thus heated, must be either heavier, or lighter, than it was before.

COROL. 8.

The cause of the continuance of Fire in any Body.

There must, therefore, be some cause, by which the Fire is during all this time detained in the heated Body, and which prevents its being dispersed again, as soon as ever it is produc'd. For the Fire in the *Focus* of *Vilette*, or *Tschirnhausen*, is as strong, nay stronger, than this in this iron Globe; and yet we see that that vanishes in an instant, if it is not every moment renew'd in the same place. Hence, therefore, Fire is not able to keep possession of the place it exists in, but must be retain'd there by somewhat of a quite different nature.

COROL. 9.

First the Mass itself.

Let us examine now this affair ever so nicely, we find nothing here that can effect this but the Body itself, considered as it stands in opposition to Space, *viz.* as it is somewhat resisting and impenetrable, or, as it is a real corporeal Mass: For it appears by Experiment, that if Fire is communicated by the same cause to Bodies of different densities, they will indeed acquire exactly the same degree of Heat; but then it will afterwards be retained in them so much the longer, as they are denser, heavier, or contain a greater quantity of matter under the same bulk. If you immerge, for instance, bodies of different specific Gravities in boiling Water, and keep them there till they are equally hot; then those that are very heavy, will keep hot for a considerable time, whereas the light ones will grow cold immediately. And as far as we have been hitherto able to judge by Experiment, this seems to be almost a general rule: *Torricellius's Vacuum* loses the Heat generated there instantaneously; Air heated in

a vessel

a vessel, very quickly; Alcohol still slower; Water retains its Heat yet longer than Alcohol; and Mercury longest of all. In the same manner among Solids; Wood, Stones, Metals, if they are made equally hot, are exactly so much the longer before they grow cold, as they are denser than one another.

Secondly, the quantity of Fire.

But again, a greater degree of Fire is longer disengaging itself from Bodies to which it is united, than a less: So that it seems to hold almost generally true, that the greater the degree of Heat is, that is communicated to the same Body, or the more it is expanded by the force of the Fire till it begins to be melted, so much the longer will it always be, before it grows cold: For if you take two Bodies, that are perfectly alike, and give them different degrees of Heat; then the hottest, after it has lost the surplus of Heat by which it exceeded the cooler, will still remain as hot as the other was at first, and consequently will then require as much time to grow cold in as that did. But it still remains nicely to be examined, whether there is not some other cause, besides the density of Bodies, and the degree of Heat, that is capable of preserving Fire for a considerable time, when once it is generated? If Water, for instance, and Oil, should be heated to the same degree, supposing the Oil lighter than the Water, which of these two would grow coldest within the same time? Why, certainly, the Philosophers would generally imagine, that the Fire being intangled by the tenacity of the Oil would remain longer there, than it would in the Water. To determine this, therefore, I took two vessels of the same size, one of which I filled with Water, and the other with Oil of Olives. These I put into boiling Water, and kept them there till I was sure, that both of them had acquired the same degree of Heat with the Water which was kept continually boiling. I then took them out, and placed them both in the same Air, in order to discover the time in which they would be reduced to the same temperature with it, and I found it to be exactly in proportion to their comparative weights.

Of which a greater may be communicated to some particular Bodies than others.

There seems, in the mean time, to be some very abstruse cause, why Fire itself, nay a very strong one too, is not able to heat Bodies beyond a certain degree; as we see in Water, Alcohol, Oil, and Mercury, when they are once made to boil. As ebullition, however, does not happen equally soon in all, hence lighter liquors are very often capable of receiving a greater degree of Heat than heavier, if they take up a longer time before they boil. Water, for instance, is heavier than Oil of Linseed; boiling Water has 213 degrees of Heat in it, and can, then, with the strongest Fire be made no hotter: This Oil, which is so much lighter, requires a greater Fire, and is longer before it boils, and has then acquired almost 600 degrees. Who, now, is able to account for this? Mercury, we see, which is 15 times heavier than this Oil, arrives only to just the same degree of Heat when it is made to boil. Hence, however, it appears evident, that there is something else besides the corporeal mass, that makes some Bodies susceptible of a certain quantity of Fire only; whilst others are capable of receiving a great deal more. The true cause of this, perhaps, no body is able to assign.

Why does Water extinguish Fire.

From these considerations, however, we see plainly the reason, why Fire that is raised by combustible matter, may be extinguished by Water; for by this means it is incompassed with a less degree of Heat than is necessary to set these combustibles on fire, which is always greater than 213.

And

Why does Water keep Tin from melting.

And for the ſame reaſon, a ſtrong Fire won't melt a tin veſſel when it is full of Water: For this requires a greater degree of Heat to put it in fuſion than that of boiling Water, which is all it can receive ſo long as the Water remains in it. But ſet, now, this ſame veſſel on a Fire with Oil in it, and you will find it will ſoon be melted before the Oil begins to boil. The ſame thing is true, too, of Lead if you put it on the Fire with Water in it. From a careful examination of all theſe circumſtances it ſeems probable, that when the Fire has ſo diſpoſed Bodies, that it can paſs, and exert itſelf equably through their Pores, then, no more Fire can be united with them, than what is actually in them at that time; and this ſeems to be the caſe in Fluids as ſoon as ever they begin to boil; in Solids, when the force of the Fire has perfectly melted them, ſo as to make them run in the form of a ſparkling, or boiling Fluid, which we find happen in Metals, Glaſs, Salts, and other Bodies thus put in fuſion.

By the help, then, of theſe uſeful Obſervations, we learn at laſt, that there is in reality ſome *nexus*, or connexion between Fire, and Bodies: That the greater it is the longer it adheres to them: That the ſame degree of Fire remains longeſt, in thoſe that are denſeſt: That a greater quantity of Fire may be united with ſome certain Bodies, oily ones in particular, than other: That theſe require a ſtronger Fire, and a longer time to acquire this greater degree of heat: That the denſer bodies are, the longer they are before they grow actually hot with rarer Bodies, when they are expoſed to the ſame degree of Heat: And that when they are heated they require ſo much the longer time to be reduced to the ſame temperature with theſe rarer, which grow cold ſooner. Now whoever rightly conſiders theſe things will underſtand a great many of Nature's laws with regard to the properties of Fire, which are confirmed by Obſervation, and if carefully attended to, will be of excellent ſervice in our Philoſocal Inquiries. And it is my opinion, if this doctrine ſhould be ſtill farther improved, we may at laſt from Experiment be able to ſolve the following Problems: *To fill a given Space with ſuch a Body, as cannot be heated by the greateſt Fire beyond a determined degree:* And again, *To fill a given ſpace with ſuch a Body, as ſhall be able to retain in it the greateſt poſſible Fire.* Is not Iron, which is fuſed with more difficulty than Gold, hotter when it is in fuſion than melted Gold, though that is denſer? The thing is worth inquiring into.

COROL. 10.

Heat preſently diſappears upon the application of a denſe cold Fluid.

But whilſt we are engaged upon this head, there is another *Phænomenon*, that offers itſelf to our Obſervation, *viz.* that when Bodies have a greater quantity of Fire in them than the ambient Fluids, or neighbouring Bodies, then, the denſer the Fluid is into which they are immerſed in order to be cooled, the ſooner will they loſe their Heat. My meaning is this, Take three veſſels, one full of Air, another of Water, and a third of Mercury, when they are all three exactly of the ſame temperature: And let three equal pieces of iron be made perfectly red hot. Let, then, the degree of Heat in the Air be obſerved, and let one of the pieces be left in that; let the other be immerſed in the Water, which is exactly as cold as the Air at that time; and let the third be thruſt into the Mercury, of the ſame temperature, too, as the former: What then will be the conſequence? In the rare Air the Iron will keep its Heat a long time; in the Water it will loſe it ſooner; but ſooneſt of all in the Mercury. And, indeed, it ſeems to grow cold ſo much ſooner in the Water than in the Air, as the Water is denſer than the Air, that is, 800 times. And that in the Mercury, perhaps, 14 times ſooner than that in the Water. And this, your Workers in Metals are well acquainted with, who, when they would ſoften their Metal for particular uſes, make it perfectly red hot in the ſummer time, and then leave it in the Fire which will gradually moulder away to Aſhes, and thus let them all grow cold together: But on the other hand, when they want it hard for other purpoſes, they chuſe the Winter for this work, and inſtantly throw it into the coldeſt Water they can get.

The cauſe of refrigeration three-fold.

Thus then, we ſee there are two cauſes that haſten the cooling of Bodies when they are heated; *viz.* the Coldneſs, and Denſity, of the Fluid into which they are immerſed. But there is yet a third which promotes the ſame end, and that is, the moving the hot Body about in the cold Fluid; which is the moſt expeditious way of cooling it; for by this means it is continually expoſed to ſome new cold part of the Fluid. Hence, then, we ſee the phyſical reaſon of that method which is made uſe of, when we would render Iron as hard as poſſible, *viz.* the drawing it ſwiftly through very cold Water when it is juſt ready to melt, ſo that it may be perfectly cooled in an inſtant: For by this means the Elements of the Iron, which were vaſtly relaxed, and ſoftned by the Fire, are now intimately united, condenſed, and compreſſed together by this ſudden Cold that is on every ſide applied to them; and, hence, after they grow cold they remain moſt cloſely compacted together, and exceeding hard, though at the ſame time very brittle.

Corol. II.

Why do denſe Fluids deſtroy Heat ſooneſt.

Whence, then, does it come to paſs, that the denſer Fluid ſhould ſo ſoon cool the hot Body that is put into it? Before this was immerſed, the Fluids were all equally cold, and conſequently, one's cooling the hot Body ſooner than the other cannot proceed from any difference in their coldneſs. Does the denſer matter, therefore, of the cold Fluid attract more Fire out of the hot Body, and that, in proportion to its denſity? For the determining this queſtion we muſt again have recourſe to Experiments. To this purpoſe, then, take two equal quantities of the ſame Fluid (Vinegar, for inſtance, Water, Alcohol, or Oil) and give them different degrees of Heat; and you will find if you put them together at once, and mix them intimately with one another, they will acquire a degree of Heat, which will be half the exceſs of the hotter above the cooler. For example, If a pint of boiling Water 212 degrees hot, is mixed in this manner with a pint of the ſame Fluid, that has but 32 degrees of Heat, then this Mixture will have 90 degrees, which is half 180, the differenee betwixt 212, and 32. Hence it appears, that this diſtribution of the Fire is in proportion to the bulk; and that, therefore, when Bodies of the ſame nature are mixed together, the one hot, and the other cold, the Fire immediately diſengages itſelf from its contact with the Elements of the former, and unites itſelf with thoſe of the latter, till this becomes as hot as the other. This, then, being conſtantly the caſe, we ſee that the common degree of Heat is deſtroyed, and the difference is then equally diſtributed through them both. But, now, if this Experiment is made with Mercury, and Water, exactly of the ſame meaſure, but different degrees of Heat, and theſe are in the ſame manner

The effect of mixing a hot and cold Fluid.

ſwiftly

swiftly mixed together; then the Heat that is produced by this Mixture, will be very different from what was observed in that just now mentioned.

And the difference observed here.

For if the bulk of the Water, and Mercury to be mixed, is exactly equal, but the Water is hotter than the Mercury; then, the Heat of the Mixture will be always greater than half the difference of their separate Heats. And, on the other hand, if the Mercury is hotter than the Water; then, the degree of Heat in the Mixture will be constantly less than half this difference. And this diversity is always found to be the same, as if, in the first case, you had mixed three parts of hot Water with two of cold; and in the second, you had mixed three parts of cold Water with two of hot. But, now, if the bulk of the Mercury is to that of the Water, as three is to two; then, it don't signify at all, whether you heat the Mercury, or the Water: For the mixture will always have a degree of Heat equal to half the difference of their separate Heats, as we found to be the case when we mixed the Water together in equal quantities.

Fire is distributed through Bodies in proportion to their Bulk.

In this Experiment, then, we plainly discover the law by which nature distributes Fire through Bodies; which is not in proportion to their densities, but in the same manner as it is diffused through space. For though the specific gravity of Mercury is to that of Water pretty nearly as 14 to 1; yet its power of producing Heat when measured by its effect, appears to be only the same, as if Water had been mixed with an equal quantity of Water. But the same thing is abundantly confirmed by every kind of Experiment as I took notice before, when I told you, that I had been convinced by Experiment, that all sorts of Bodies, if they are long enough exposed to the same common temperature, acquire exactly the very same Heat, or Fire, without any difference at all except what arises from the different spaces they take up: That, hence, it did not appear from Observation, that any Bodies whatever have a power of attracting Fire, though their greater density makes them capable of retaining it longer when once it is united with them. The Experiments, I have just mentioned, were performed for me by the famous *Fahrenheit.* What then is the reason, that Fire will leave the Body it possesses, to enter into a heavy Body, so much sooner than into the most light, and subtil space, into which one would imagine it should penetrate with a great deal more ease?

COROL. 12.

The greatest Bodies retain Heat longest.

Hence, again, we understand that the bigger any particular Body is, the longer it will *cæteris paribus* keep the Heat it has once conceived: For the density of the outward surface always prevents the quick egress of the Fire which endeavours from the inward parts to make its way out. The next orb then restrains the third, this the fourth, and so on to the end. And for this reason if a Body is heated perfectly through, its inmost parts are always longest a cooling. Hence, therefore, since the magnitude of any Body is capable of farther increase, it may at last become so large, that the Heat communicated to it, shall continue in it a prodigious long time.

COROL. 13.

It is demonstrated by the Geometricians, that if Bodies remain the same in all other circumſtances, the bigger they are, the leſs ſurface they will always have in proportion to their ſolidity. Hence, again, if we conſider, it will preſently appear that very large Bodies, if they are once heated, muſt on this account retain their Heat a very conſiderable time. From this law, then, it follows that every Body will preſerve its Heat ſo much the longer, as it has more ſolidity contained under a leſs ſurface; that is, in compariſon of others.

As well as Bodies of the leaſt Surface.

But again, the Mathematicians have proved, that if the corporeal maſs continues the ſame, a Body can never be reduced under a leſs ſurface than when it is formed into a Sphere. This Figure, then, is the moſt tenacious of Heat; both on account of the ſmallneſs of its ſurface in reſpect of its ſolidity; and the equal diſtribution of all the parts quite to the center, and the equal receſs from the ſurface. Hence, a very large ſpherical Body, if it is once heated, will retain its Heat a vaſt while. And this poſſibly may be one reaſon of the globular figure of the Sun, and the fixt Stars.

Hence ſpherical ones.

COROL. 14.

When a Body is divided into parts, without any other alteration, then its ſurface will be always increaſed, though its quantity of matter continues the ſame; and then it will, of conſequence, conſtantly grow cold ſo much the ſooner. A Cube by being divided into two equal parallelipipeds, has $\frac{1}{3}$ more ſurface than it had before. A Sphere by being ſplit into two Hemiſpheres, has its ſurface inlarged by the *Area* of two great circles, which is equal to [$\frac{2}{4}$] of the ſurface of the Sphere: And, hence, if they were heated, and afterwards thus divided, they would loſe their Heat ſo much the ſooner. The dividing, therefore, of a hot Body into ſmaller parts, and the reducing it from a ſpherical ſurface to a plain one, are two cauſes, by which the cooling it will be chiefly promoted; for its contact with colder Bodies will, by this means, be wonderfully increaſed. A pint of boiling Water reduced to a ſpherical figure, will retain its Heat for a long time; but if it is poured upon a large cold plate of Iron it grows cold in an inſtant.

When they are divided they cool ſooner.

COROL. 15.

Now the right conſideration of theſe things, will help us to diſcover the reaſon of the continuance of Heat in other caſes likewiſe. It is an old Obſervation, that thoſe Bodies, that are denſe, hard, ſtrong, are uſed to exerciſe, and are filled with compact heavy Fluids, are always found to be hotter, and to be longer growing cold than others, for the ſolution of which, a great many very different cauſes have been aſſigned: But from what has been ſaid, it plainly appears that ſuch Bodies muſt, by the ſtrong application of their ſolids to their Fluids, condenſe them by this compreſſion, and of conſequence, collect more Fire within them, and retain it very tenaciouſly when it is united with them. In the ſame manner it is obſerved, that in dead Bodies, that want this vital Warmth, the internal parts cool very leiſurely. the external very quickly. The reaſon of this is evident from what has been laid down; nor is there any need to ſuppoſe a veſtal Fire in the internal *Viſcera* to account for this *Phænomenon.* On the other hand now, your lax, ſoft, unactive, weak Bodies can never communicate ſo much Heat to their watery humours; for they always ſuffer leſs attrition, are leſs condenſed, and are relaxed into

The different Heat of Human Bodies.

larger surfaces; and for this reason too, are not disposed so much as to retain the Heat when once it is generated. Hence, then, we see, what ill consequences are to be feared from both these extremes; and what kind of Medicine, in particular, should be made use of, if we expect a happy success in the curing them. And thus the usefulness of this doctrine becomes very extensive.

COROL. 16.

Where is the greatest Heat in the Human Body?

Now I am upon this subject, I can't help making use of this doctrine of the refrigeration of Bodies to give a solution of that question, which has so much exercised the skill of the Chemists, Physicians, and Philosophers; *viz.* whether the human Blood has the greatest degree of Heat in the Heart? And if this is the case, what is the reason of it? What dissertations do we find amongst Authors upon this subject! and what very different opinions about it! This affair, therefore, I will endeavour to explain in the simple manner following. In the veins the blood is coldest. This is universally agreed on, and therefore needs no demonstration: It returns from those parts that are farthest from the Heart; and from the external parts which are coldest; it is mixed with the new juices that are received into the Body, which are rather colder than itself; it circulates in a weak, large, lax, unactive vessel; and is thus discharged into the right ventricle of the Heart. For these reasons, therefore, the venal Blood of itself would be colder in no part of the Body than in this right ventricle. But as such a degree of Cold in the Heart would be prejudicial to the Human Body, and even endanger life itself; hence, the Blood in its return through the Veins to the Heart, is rendered something warmer, by the Heat supplied by Arteries, which is communicated to the Body, and applied to the Veins. Notwithstanding this, however, the venal Blood is coldest of all in the right ventricle if compared with the arterial. But this cool Blood, now, being pressed, and driven into the narrow, elastic, strong branches of the pulmonary Artery, by the force of the right ventricle, and the vast action of respiration, must necessarily pass through the Lungs alone, in as great a quantity as it does through the whole Body, and all its parts, in the same time. Hence, therefore, the Blood would in no part of the Body, suffer so great an attrition, and of consequence acquire so much Heat as in the Lungs alone. But this degree of Heat, again, would be intolerable, and more than we could be able to support ourselves under. This, therefore, nature has secured us against by the Air we draw into the Lungs in inspiration, which is always a great deal colder than the Blood. And it appears from the Observations of the ingenious *Malpighi*, that the Blood is here distributed through a vast number of exceeding fine Arteries, which are applied all around the thin vesicles of the Lungs, and by this means is exposed to the Air under a prodigious large Surface; but the Air is every moment renewed, and therefore always cold; and, hence, the Blood, of itself, is cooled in no part of the Body more, in this respect, than it is in the Lungs. Is not this, now, very surprizing, that in the very same part of the Body, where for some necessary uses the Blood must have the greatest degree of Heat, there again, for reasons as necessary as the former, it should require the greatest cooling? The Blood, and recent Chyle, could not be propelled through all the vital pipes of the whole machine without endangering the animal life, if it was not first vastly divided, and reduced into its most subtil Elements by the forcible attrition of the Lungs;

What is the Heat of the Air we inspire?

Lungs; but this could not be effected without a great production of Heat: Should this Heat, however, thus communicated to the Blood remain in it, and there ſhould be other cauſes to cool it at the very ſame time; certainly the Blood, in a very little while, would intirely putrify, and we ſhould die of a moſt peſtilential diſeaſe. By accident, I obſerved ſome time ago, in that part of the Sugar houſes where the Sugar loaves are dried, that the Air was ſo exceeding dry, and hot, that I could not ſtay in it a moment without danger of preſent ſuffocation. I thought, therefore, I had got a very good opportunity of examining the degrees of Heat in the Air that Animals could breath in; but though I was vaſtly intent upon it, the multitude of my affairs, that could not be diſpenſed with, neceſſarily called me another way. I deſired, therefore, that induſtrious Gentleman Mr. *Fahrenheit*, whom I have ſo often mentioned with reſpect, and my very good friend and kinſman *Jodocus Provoſt*, to make ſome Experiments for me in the manner I ſhould direct, and to let me know exactly the ſucceſs. This they were ſo good as to comply with, and gave me the following account, upon hearing which, I am apt to think you will be of opinion with me, that there is ſcarce any Experiment to be met with that will help us better to underſtand the effects of this heat of Air upon the Bodies, Humours, and parts of Animals. Nor, perhaps, is there any other, that is of greater ſervice in the Art of Chemiſtry.

The wonderful effects of hot Air.

The Baker, then, in one of theſe Sugar houſes was heated till an accurate mercurial Thermometer, after it had remained in it a ſufficient time, roſe to 146 degrees. A Sparrow was then ſet down in it in a cage, at ſix a clock in the evening. When it had been there about a minute, it began to open its mouth, and pant with a great deal of trouble, and uneaſineſs, the number of reſpirations increaſing every moment, ſo that in a very ſhort time the repetition of them was vaſtly quick, and with ſuch a diminution of ſtrength, that he could ſit no longer upon his perch, but leaving it went to the bottom of the cage, where, with violent ſtruggling, and panting, he died within ſeven minutes. At the ſame time a Dog was confined in the ſame hot room; who, after he had been there ſeven minutes, by opening his mouth, lolling out his tongue, and breathing very quick gave evident proofs that this great Heat was not a little troubleſome. He remained, however, at that time quiet in the wooden cage in which he was incloſed. When a quarter of an hour was near paſſed, he began to breath very ſtrong, and with a great deal of noiſe, and made ſuch efforts to get out of his confinement, as were quite ſurprizing. A little afterwards his ſtrength failed him, his reſpiration began to grow ſlower, and ſlower, till at laſt each inſpiration, and reſpiration continued a long time, though they were ſtill performed with a great deal of force. Theſe, however, grew afterwards more and more languid, ſo that a little before his death they could not be heard at all. During all this time, a great quantity of *Saliva* ran out of his mouth, which was perfectly reddiſh, and ſtank ſo intolerably, that no body preſent was able to bear it: And this terrible ſmell, thus ſuddenly produced in the Animal, was of ſo hurtful a nature, that one of the perſons that was making the Experiments, upon coming near him, was in an inſtant fainting away, ſo that it was neceſſary to refreſh him with ſome Spirit of Wine, and Myrrh; by which means it happened, that he could not put the Thermometer into the mouth of the Dog the very moment he died. A little afterwards, however, being recovered by the abovementioned liquor, he thruſt it in, and the Mercury ſtood at the degree 110. In this very great Heat now, and with all theſe vaſt ſtruggles, there did not appear upon the dog the leaſt ſign of ſweat. This Dog weighed ten pounds. At the ſame time theſe Experiments were made upon the Sparrow, and Dog, a Cat, too, was ſhut up in a wooden cage, and placed in the ſame ſtove. When ſhe had been there a minute, ſhe began to lay upon the ground, and pant; and in a quarter of an hour made a hizzing noiſe as ſhe breathed; ſhe then ſtruggled prodigious hard to get out, and after ſhe had ſuffered exactly in the ſame manner as the former, underwent at laſt the ſame fate: But ſhe was all over as wet with ſweat as if ſhe had been taken out of a River.

We learn evidently, then, by theſe Experiments, that the Air when it is † 48 degrees hotter than the Blood in the mouth of a healthy child, is capable of producing the moſt acute diſeaſe in an inſtant, and ſoon after deſtroying the Animal with the moſt terrible ſymptoms. But how ſurprizingly muſt all the humours of the Body here be changed, as they gave ſuch evident ſigns of a moſt fetid putrefaction? Certainly there is not in nature a more abominable ſtench than this terrible rancid one, more loathſome than that of a dead carcaſe, which was ſo ſoon produced, and exhaled from this Animal which was perfectly well but juſt before? For this, we ſee, purely by its contagious quality, brought a ſtrong man, and one uſed to labour into imminent danger of preſent death. And what greater proof can we have that all the Juices were reſolved, and changed from their natural diſpoſition, then, that even the *Saliva* in ſo ſhort a time was become red. But the Fire of the room did not alone effect all this; for the fleſh of the dead Animal, being hung up in the ſame Heat, was only dried thereby, and did not diſſolve into ſuch a noiſome *ſanies*. But the vital motion in theſe creatures, whilſt by its attrition it generated Heat and a Tendency to putrefaction, muſt of neceſſity have produced a prodigious degree of Heat in the Lungs; and theſe having nothing to help to cool them, the Heat muſt have grown much greater there than even in the ſtove itſelf. And, hence, the Oils, Salts, and Spirits of theſe Animals were reduced to putrefaction within, perhaps, 28 minutes; whilſt the Bird was affected within one. And here we may obſerve, when theſe rooms are heated to ſuch a degree, the ſervants, who are obliged to attend there, ſtay in but a very little while at a time, and then go out for ſome refreſhment. In the ſame manner, in the Melting-houſes, where they cut the melted iron into large plates, the Workmen can bear the exceſſive Heat but for a moment, and then are forced to retire into ſome cooler Air, where they lie down, and recover themſelves, or otherwiſe they would inſtantly fall into a *Deliquium*. And whenever the Air is heated but to ſuch a degree, as is the ſtandard of a man in health; if a perſon is then placed in it, he ſoon perceives the exceſs of the Heat, which grows ſo troubleſome, that he can't remain in it any conſiderable time, but ſtrives with all his might to get into ſome cooler place, or otherwiſe would faint away. Hence, therefore, we ſee, that hot Air enervates the ſtrength; cold reſtores it: And, indeed, except the Heat was tempered by an alternate interpoſition of Cold, there would ſoon be an end, both of Plants, and Animals.

† This muſt be underſtood in the very greateſt latitude in which it is ever obſerved; the Heat of a child in health very rarely riſing higher than the 96th degree in *Fahrenheit*'s Thermometer.

From what has been ſaid, then, we at laſt make this concluſion; that the Heat of the Blood in the Veins, Arteries, Heart, Lungs, and other parts of the Body, is pretty equable. In the Lungs, however, it is, in reality, both hotteſt, and coldeſt; and hence, tho' it undergoes thoſe effects in the Lungs, which are abſolutely neceſſary, yet by this means it is ſtill kept of a proper temperature.

Corol. 17.

The larger any Body is, the denſer the matter is of which it conſiſts, and the more exactly ſpherical its figure is, the more diſpoſed will it be to retain the Fire which it has received into it; which is every where confirmed by Experiment. If ſuch a Body as this, therefore, ſhould be placed in an exceeding rare Fluid, or in a perfect *Vacuum*; then, all the phyſical cauſes that are at preſent known to promote this preſervation of Heat, would be united together. What Bodies do contain their Heat longeſt.

Corol. 18.

Nevertheleſs, all the ſolid, large, ſpherical Bodies, that we are converſant with, tho' they are brought to the very point of fuſion, if they are placed in the common Air, ſoon return to the temperature of the ambient Atmoſphere. Even theſe grow cold.

Corol. 19.

Can we then look upon the vibration of the conſtituent Elements of Bodies, as the whole, and only cauſe, that Fire continues in a Body that is heated? As was the opinion of the illuſtrious *Newton*. It is true, indeed, if a large Bell is ſtruck but in one place with an elaſtic metal Clapper, it will continue its ſonorous undulations for ſome ſeconds, and its tremulous concuſſions a good while after we are able to hear them, as appears by ſprinkling a little Sand on it: But in other caſes, this vibratory motion of elaſtic Bodies is commonly pretty ſoon over. What does vibration do towards Heat?

Experiment XXI.

The denſer Bodies are, whether fluid, or ſolid, the longer time they require to grow equally hot, if they are expoſed to the ſame Fire. Denſe Bodies are longer heating.

For making this Experiment, take a braſs hollow Parallelepiped, open at top, and filled with Water; upon this, let there be placed ſome cylindrical glaſs Veſſels of the ſame ſize, and filled to the ſame height with Fluids of different ſpecific Gravities: Then, if you make a Fire underneath, ſo that the Water being conſtantly in motion, may acquire a very equable degree of Heat, you may with the naked eye perceive the lighteſt, and conſequently, the rareſt Fluid to be expanded very ſoon, but the denſeſt a great deal ſlower; and the ſame is confirmed by the application of the Thermometer. Air grows hot very quickly, then Alcohol, next very liquid *Petroleum*, then Oil of Turpentine, and then in order, pure Water, ſalt Water, very ſtrong *Lixiviums*, Metals, Mercury, Gold.

Corol. 1.

The matter, therefore, of Bodies, both admits, and parts with Fire, with ſome difficulty; and hence, Body, as Body, does, in this reſpect, retain its temperature, nor ſuffers it to be changed without ſome reſiſtance.

EXPERIMENT XXII.

The larger Bodies are, the longer they are, *cæteris paribus*, in growing hot with the ſame Fire; and the contrary. The truth of this is ſo well known from the moſt common Experiments, that it may be almoſt made uſe of as a phyſical Axiom.

EXPERIMENT XXIII.

What Bodies are heated with the moſt difficulty?

The denſer and larger Bodies are at the ſame time, and the more exactly ſpherical their figure is, the more Fire they require, and the longer they are, before they arrive at their greateſt Heat. For if one pound of Iron is hammered into a thin parallelipidal Plate, and another is form'd into a Sphere, and both theſe are immerged into boiling Water; then, the Plate will ſoon receive the Heat of the Water, but the Sphere ſlowly: So far therefore, the Surface ſeems to determine the time, which a Body takes up, in admitting, and parting with Heat, and Cold.

EXPERIMENT XXIV.

No Body of itſelf hotter than every other.

Among all the Bodies of the univerſe, that have hitherto been diſcovered and examined, there never was yet found any one, that had ſpontaneouſly, and from its own nature, a greater degree of Heat than any other. This ſurprizing paradox has already appeared to be true by an induction of particulars: For, as I informed you before from Experiment, all thoſe Bodies which are eſteemed the hotteſt, will be reduced exactly to the ſame degree of Heat, or Cold, if they continue a good while in Air of the ſame temperature. Certainly, Phoſphorus itſelf made of Urine, is as cold as the ambient Water, whilſt it is immerſed in it; tho' it ſoon grows exceeding active, and hot, when it is expoſed to the Air. In like manner the Phoſphorus that is prepared from calcin'd pinguious ſubſtances, and Alum, ſo long as it is ſecur'd in its glaſs Vial, has no more Heat than the Glaſs, nor has the leaſt effect upon it; tho' upon the admiſſion of the Air, indeed, it takes Fire, and burns immediately. Linſeed Oil, which is never harden'd into a ſolid Maſs, but remains always fluid in the greateſt natural Cold, is even at that time as cold as the coldeſt Ice. Nor is the choiceſt Alcohol then at all warmer than the pureſt Mercury. That wonderful Spirit of Nitre, called the fiery Spirit, which is a curious preparation of *Glauber*'s, and that diſtilled Oil, which the Chemiſts draw from Saſſafras, whilſt they remain quiet in cloſe Veſſels, are as cold before the mixture, as the coldeſt Ice; tho' when they are mixt together, they produce a moſt terrible Fire. The coldeſt Steel and Flint, by a momentaneous percuſſion, excite in the ſharpeſt froſty Air, the moſt intenſe Fire that we are at preſent acquainted with. And this is ſo univerſally true, that of all the natural Bodies that have hitherto been examined, there has not been found one, that of itſelf inclines more towards Heat, than Cold, not one, that is naturally hotter than the reſt. I know people are generally ſtrongly prejudiced in favour of the contrary opinion, and think it evident, that the Bodies of Animals, at leaſt, have a greater degree of Heat in them, than others. And this, I confeſs, is true, if you conſider them whilſt they are alive; for ſo long there is a perpetual collection of Fire, and communication of Heat, by that attrition of the parts, which is necessary to the support of the animal life: But, now, if you examine a drowned Body, that was just before strong, and in perfect health, and remains still in all respects exactly the same, except wanting this vital attrition; you will then find it exactly as cold as the Water. But you'll be apt to say, sure the contrary of this appears to be true; for we often see, that Bodies have a great degree of Heat after they're dead. And this, Gentlemen, I acknowledge to be frequently the case. Hence, you'll probably insist, that there are in reality, therefore, Bodies of Animals, that are disposed to keep up, and cherish Heat in them. Nor do I deny it: But then please to consider, that when this is the case, then putrefaction is actually begun, by which there is excited a constant, and pretty violent motion too, which by its attrition, and friction, is capable of communicating new Fire to the Body, which did not naturally belong to it. Take for instance, a quantity of cold Hay, press it hard down in a large heap, and then moisten it quite through with Water, and it will by this means grow very hot, and sometimes burst out into Flames. Fermentation, putrefaction, effervescence, and the mixture of Bodies together, will certainly very often produce the greatest degrees of Heat, as I shall hereafter expresly demonstrate, nor ever deny'd; but then these motions are never observ'd to happen in one single simple Body alone, and therefore are never spontaneous, or belong properly to any Body in particular. Any other objection of this kind that may be raised against what we have asserted, you yourselves will easily be able to answer.

COROL. 1.

Does therefore a dense Body receive more of the substance of Fire into it, as it grows by degrees hotter and hotter? Is this greater comparative quantity of Fire, owing to the greater degree of Fire that the Body is exposed to? And is the continued application of this Fire likewise another reason, that a Body thus heated has a greater quantity of Fire communicated to it?

COROL. 2.

Is Fire itself, that is so long insinuating itself into a Body, and enters into it in so great a quantity, the true physical cause of the long retention of the Fire in the Body when it is once heated?

COROL. 3.

Or rather, is not this effected, by the heated corporeal Mass, and the Fire communicated to it, both their powers conspiring, and being united together?

SCHOLIUM.

Thus far, Gentlemen, I have endeavoured by a few simple Experiments, to lay before you those evident truths that I have been able to discover, concerning the nature of that Fire, which Philosophers call elementary Fire. And this we have considered: First, as it is a created Being, existing separately, and without every other Body whatever; then, as it resides in Bodies, and remains there pure and simple, nor receives any *Pabulum* from them, being determined in parallel or converging Rays; and lastly, as the same is collected in

Conclusion of the doctrine of elementary Fire.

in Bodies, purely by motion and attrition. And I have taken a great deal of pains to give you a right notion of this Fire, before I proceed to examine into that, which is ſupported by combuſtible matter, which is ſuppoſed to be of quite another nature from the former, and differs very much from it in its effects: For the not carefully diſtinguiſhing betwixt theſe two kind of Beings, which by univerſal conſent are called Fire, has given riſe to a great many errors in the chemical Art. Let us now, therefore, ſet about the examination of common Fire, which by many people is looked upon as the only real Fire. Give me leave, however, before I proceed, to give you a ſhort account of ſome obſervations that may be underſtood from the doctrine that has been already laid down, and which properly belong to the Hiſtory of Fire; that ſo both this Hiſtory may be as compleat as poſſible, and every perſon may have the honour of his proper diſcoveries.

The Diſcoveries of other Authors.

An iron Rod a foot long, made red hot, gained $\frac{1}{60}$ of its length. A glaſs Cylinder, a ſpan long, made red hot, gained $\frac{1}{50}$. *Sturm. Coll.* part II. p. 101. A metal Ring made red hot, had its diameter increaſed by $\frac{9}{100}$. *Sagg. di Nat. Sper.* p. 182. A glaſs Globe was diſtended in its capacity $\frac{1}{1000}$, purely by the Heat of the hand. *Des Amontons, Mem. de l'Ac. Roy.* 1704. p. 12. 1705. p. 4. If a Thermometer is immerg'd into a warmer liquor than itſelf, it firſt deſcends, and afterwards aſcends; if into a colder, it firſt aſcends, then deſcends. *Sagg. di Nat. Sper.* p. 178. *ad* 181. And this is proved by a great many arguments to depend in the firſt caſe upon the expanſion, and in the ſecond upon the contraction of the Glaſs, before the included fluid can be equally affected, *ibid.* In warming of Liquors, the Heat is ſuppoſed not to expand them equably, but by alternate impulſes. *Halley. Phil. Tranſ. Abr.* T. II. p. 34. Mercury being put in a glaſs Vial, and then immerg'd in cold Water, which was afterwards heated by degrees, till it began to boil, aſcended very equably; but when the Water boiled, tho' the Fire was increaſed, it could not be dilated any farther, but remain'd at the ſame point. Hence, therefore, Thermometers made with Mercury, will be moſt accurate. *Id. ibid.* And theſe following obſervations I chooſe here to ſubjoin, as matters that deſerve conſideration: Since one very often corrects another. If two metal Rods are of the ſame weight when they are cold; then, if you make one of them hot, and hang it to a balance, it will be lighter than the cold one; but if you place a live Coal under the cold one, the *equilibrium* will be again reſtored. If two metal Rods are exactly in *equilibrio*, then by holding a hot Coal over either of them it will grow lighter, and on the contrary will preponderate if you hold it underneath. *Sagg. di Nat. Sper.* p. 256.

Of the Pabulum of Fire.

Fire in Bodies in a twofold manner.

Since, then, it appears almoſt certain, that the very ſame Fire does always exiſt, in the ſame quantity, and without alteration; and farther, that when it is collected in ſome ſort of Bodies, ſuch for inſtance, as Gold or Silver, it will continue in them a conſiderable time, without any perceptible deſtruction of them; we come now in the next place to examine thoſe Bodies to which Fire may be likewiſe communicated, and in which it may be preſerved too a pretty while, but then, under this circumſtance, that at the ſame time that the Fire is thus detained in them, nay, and ſometimes increaſed, the very Bodies themſelves

ſelves

ſelves are ſo far conſumed in this action, that they almoſt diſappear from our ſenſes. For when Fire is once collected in Bodies in this manner, it generally remains in them, and perſiſts in its activity, till it has diſſipated thoſe parts of them, by which it was continually ſupported: But as ſoon as ever theſe parts are diſperſed by the power of it, then the Fire likewiſe diſappears too, exerting itſelf but very little longer upon thoſe that are left behind.

Why ſome Bodies are called the *Pabulum* of Fire.

Since therefore the Fire itſelf, and the Body in which it was collected vaniſh from our ſenſes both together, hence people have univerſally called thoſe Bodies, or thoſe particular parts of them, the Aliment, or *Pabulum* of Fire: And thus far it may be allow'd, without any inconvenience. But when they pretend to call them ſo in too ſtrict a ſenſe, becauſe they look upon them as the nutriment of real Fire, and imagine them to be changed by the Fire into the very ſubſtance of elementary Fire, and thus to have their own proper nature deſtroy'd, and to put on that of Fire; then, they propoſe ſomething vaſtly different, which ought very well to be conſidered before it's admitted for true; for tho' the aſſertion of it is very eaſy, yet the demonſtration of it is exceeding difficult. And certainly, whoever overhaſtily runs into this opinion, muſt neceſſarily ſuppoſe, that thoſe Bodies which nouriſh, and ſupport Fire, in the manner we have mentioned, are by this means conſtantly diminiſhing: And hence the quantity of all other Bodies in the univerſe muſt be continually leſſened, whilſt that of elementary Fire muſt be in proportion increaſed. Of conſequence, therefore, Fire being thus perpetually augmented, and at the ſame time didiminiſhing every thing elſe, would neceſſarily have deſtroyed all other Bodies long enough ago, and remained ſuperiour, and alone in the Univerſe. In the mean time, however, if we examine the obſervations that have been made from the moſt ancient times, quite down to our own, we ſhan't find the leaſt indication of any ſuch increaſe. But on the contrary, the power, and conſequently, the quantity of Fire is obſerved to continue the ſame, nor ſeems by any means to ſuffer any conſiderable augmentation or diminution. An Example, or rather Proof of this, are thoſe very accurate Meteorological Tables, ſo nicely contrived, and ſo carefully perfected many years ago for public ſervice, by that excellent Geometrician *Nicolaus Cruquius*, in which you may ſee what an extraordinary *equilibrium* of Heat is maintained. Nor is it a little to our purpoſe, that after burning of Woods, which has been continued ſometimes for whole months together, there has never appeared the leaſt ſign of any increaſe of Heat remaining after it was over. Can you believe, Gentlemen, that after almoſt ſix thouſand years, as in this time all the combuſtible matter of the whole inhabited Earth, where Fires are in uſe, muſt neceſſarily have been ſo many times conſumed; I ſay, can you believe, that after all this long and conſtant augmentation of Fire, the Heat ſhould not yet be grown intolerable to tender Plants, and Animals? In every part of the world at leaſt, the Heat has always continued the ſame: For the very ſame warmth of the Air is always requiſite, that the tender *Embryo*'s of Plants, whilſt they lie incloſed in their Seeds, and are nouriſh'd, fill'd, and diſtended with a kindly moiſture, may expand their very fine, and feeble *Stamina*; for if the Heat increaſes beyond the bounds they are able to bear, it ſoon burns up the almoſt fluid Machine in its original ſtate; nor does it leſs certainly periſh if the Heat grows too languid: Why ſhould I make mention of Animals? The animalcles of the

Does this *Pabulum* become Fire itſelf?

Male Seed, when they have insinuated themselves into the Eggs of the Female, require such an exact temperature, that the 100th degree of Heat in *Fahrenheit's* Thermometer will burn them to death, and in the 70th, by reason of the Cold, they will hardly ever be brought to maturity: Nay, the very impregnated Eggs of Insects, that are able to bear the sharpest winter Frosts, are most certainly destroyed, if they are exposed to a degree of Heat that's a little too intense. In short, therefore, examine Nature in her whole extent, and you'll evidently find, that the quantity of Fire in the Universe, always continues the same: For it's certain, after so many terrible conflagrations occasion'd by Meteors; after such prodigious eructations of burning Mountains; after such infinite numbers of culinary, furnace, and workhouse Fires; and, after all, the devastations that have happened since the invention of Fire-Arms: I say, after all these extraordinary methods of producing Fire, there does not appear to be the least quantity more at present, than there was in former ages. And I'll almost venture to promise, that our following examination of the *Pabulum* of Fire, will make it appear beyond contradiction, that the case is here very different from what people generally imagine. Let us therefore set about this very useful, and agreeable inquiry; and in the first place let us consider combustible matter as we find it, in the Vegetable, Animal, and Fossil Kingdoms. Now here we shall come at its Nature more readily, if we first examine it in the class of Vegetables; for 'tis by these that Animals are nourished and supported; and these may more easily be examined, and understood, than Fossils.

This scarcely credible.

The *Pabulum* of Fire in Vegetables.

All Vegetables that we are hitherto acquainted with may be burnt with Fire, and will feed the Fire whilst they are burning; the Larch-tree itself not excepted. But as these now may be exposed to Fire, either crude, whilst they are yet perfectly alive and full of green juices, or when they are dead, and dry; hence they ought to be considered in both these circumstances: And as a right knowledge of the green ones, will help us more easily to conceive of the dry ones, for this reason, a proper regard to method leads us to examine what it is, that is properly combustible in Vegetables whilst they are alive.

An examination into that part of those that feed Fire.

All crude Vegetables, therefore, of what kind soever, contain in them, Water; Spirits, as they are called, or invisible exhaling Corpuscles, which are generally odorous, and for the most part reside in this Water, and are dispersed into the Air as soon as ever separated from it; an acid volatile Salt, which almost always appears in a liquid form; a volatile alcaline Salt; a light volatile Oil, which has generally the peculiar scent of the Plant; a more fixed, heavy Oil; a black Coal, which tho' it is forced with a strong, and long continued Fire, in a close vessel, yet continues fix'd, and black; white Ashes, which are the remains of this black Coal, when it has been burnt in an open Fire; a fix'd alcaline Salt, which is contained in these Ashes, and may be procured from them, by making a *Lixivium* with them; and lastly, another part of these Ashes which remains after this Salt, is separated, and is called pure Earth. This, Gentlemen, is an exact account of those parts that have been discovered in combustible Vegetables. In these, therefore, as they are changed by the various actions of the Fire, we must examine what part it is, that is in reality inflammable, or combustible.

If crude Vegetables then, containing all the parts abovementioned, are committed

mitted to a brisk Fire, whilst their Moisture is yet in them, the first thing they yield is a Smoke, or vapour, which ascends in the appearance of a Cloud, and may be collected in form of Water, either acid, or alcaline, according to the nature of the Plant, the proper scent of which, in some measure, it almost always carries along with it. This Vapour is light, thin, and almost pellucid.

A particular account of what happens; First, in a green Plant.

After Vegetables have been deprived of this first part by the Fire, and, hence, begin to grow dry, then another kind of Smoke begins to arise, which is generally black, thicker, acrid, opake, dense, and fetid; which every moment grows thicker, and denser, till at length it becomes of a pitchy blackness, and is rolled up, and whirled pretty strongly about the Vegetable.

Not long after this there bursts out a brisk, lucid, crackling Flame, and succeeds this thick Smoke; for this ceases when the Flame appears, and there always remains so much the less of it, as the Flame burns more clearly: But if you extinguish this Flame, then this dense black Smoke soon appears again. If this liquid, volatile Smoke now, is catched upon any Body, and by that means condensed; then wherever it fixes, it will form a very black, pinguious, and tenacious Pigment, which is bitter, and fetid, and goes by the name of Soot.

Vegetables being in this manner consumed by Fire, into Smoke, Flame, and Soot, there remains another part at the bottom, which may be made red hot indeed, in the same manner as Metals, but is absolutely unfit to feed, and support Fire; and this is called, Ashes. These now are found to be different according to the different nature of the Vegetables that were burnt: For if the Smoke they emit when they are exposed to the Fire, is of a very volatile, acrid, saline, and alcaline nature, then the Ashes that are left are for the generality insipid; as appears, in Garlic, Onions, Scurvy-grass, Rocketts, Hedge-mustard, Cresses, Leeks, Water-mint, Mustard, Mithridate-mustard, and the like acrid antiscorbutic Plants, which when they are burnt yield scarcely any fixt Salt. On the other hand if the Plants are succulent, and acid, and their fumes are so likewise, there then remains a great deal of Salt in their Ashes; as we find in the green branches of almost all Trees, which if they are large when they are laid on the Fire, there distils from their ends, an acid Water in great quantity. And lastly, if the Vegetables are of the austere-acid, or the aromatic-bitter kind, then the Ashes of these too yields a Salt in great abundance.

If Vegetables are moderately dry, and their Water is exhaled when they are exposed to the Fire, but yet are not too old; in this case the very same things happen as in the former, and in the same order, but there will be a much smaller quantity of the first watery Vapour.

In a dry one.

If the Vegetables are worm-eaten, fungous, light, very dry, and very old; then if they are laid on the Fire, they will hardly burn with such an open Flame but will grow red hot, shine, continue lucid some time, and then moulder into Ashes, in which there will be hardly any Salt at all; nor will they scarcely yield any Smoke, or Soot.

In a very dry one.

Since, therefore, these things that we have mentioned hold true in every kind of Vegetable that is burnt, we may hence upon inquiry be able to discover, which of all these parts it is that is in reality properly combustible.

First then, let us examine the Water which constitutes a considerable part of every kind of Vegetable. And this we find is capable of admitting, and

An examination of the particulars here. First, of the Water.

retaining for some time any quantity of Fire, not exceeding 212 degrees or a little more, but then, the Elements of the Water have received such a disposition from the Fire, that no more can be disposed, and confined in it. Hence, therefore, it is not possible by any known Art whatever so to impregnate Water with Fire, as to make it put on the brightness of a red hot Body, and thus to become perfectly lucid. Nay if Water, whether hot, or cold, is thrown in large quantity upon a burning flame, or any kind of matter that is on Fire, it will immediately reduce that violent Fire to 212 degrees, and by this means stops every kind of Fire, takes away the redness from Bodies that are heated, and extinguishes flame. Nay, if by the action of Fire, Water is resolved into Vapours, that are very active, and expand themselves every way with a great deal of force, yet even then, when it is reduced into this form, it has the very same effects with respect to Fire. This is evident; for if you hold a live-coal, or lighted Torch in the densest steam of boiling Water, it will be perfectly extinguished as if you threw Water upon it. And our chemical distillations likewise demonstrate, that Water, exert what force of Fire you will upon it, will always retain every character of pure Water. In the mean time, however, I cannot deny but that there are a great many effects produced by the Water in the burning of Vegetables, that would not otherwise happen: For if you fling Water upon Oil, whilst it is boiling hot upon the Fire, there will arise a new action betwixt the Fire, Water, and Oil, very different from what would have happened had not this been done. Suppose a pound of Oil, for instance, actually boiling, and on flame in a copper vessel, the Fire then in this Oil will have 600 degrees of Heat; but it will keep within bounds so long as it is moved equably through the Oil, and disposes it into a bright flame: Let now an ounce of Water be thrown at once into this Oil, whilst it is thus boiling, and flaming, and there will be immediately produced a rumbling, crakling noise, the mixture will fly about in a surprizing manner, and the motion of the whole will grow perfectly unequal: For the Water as it falls by its own weight through the Pores of the boiling Oil, meets every where with a degree of Heat three times greater than that of the hottest Water, whence the Elements of the Water being expanded with a prodigious force, and agitated with an exceeding swiftness, they put the more tenacious particles of the Oil into motion, dissipate them, and carry them with them into the Air. If whilst Bodies are burning, therefore, any Oil, and Water happen to meet in them, the Fire that is excited will be very different from what it would be otherwise: And this your Smiths are well acquainted with, who when they have a mind to blow up a very brisk Fire generally sprinkle a little Water upon their Coals. But there is another circumstance too in this affair that ought to be taken notice of, and that is, that Water is capable of receiving a greater quantity of Fire when it is compressed by a greater weight of the Atmosphere: And indeed this augmentation is so considerable, that for every increase of this weight there is a sensible addition of a degree of Heat. Hence, therefore, should it ever be so confined within Bodies on fire, as to be compressed with a double Atmosphere, what a terrible explosive force would it hereby acquire? And from this consideration I have often thought, and not without astonishment, how vastly the quantity of Fire that may be communicated to Water, would be increased, should the

 Water

Water be placed in the Center of the Earth. For Air at the depth of 409640 fathoms from the ſurface of the Earth would be as heavy as Gold, according to *Mariotte*'s Calculation, if the law he ſuppoſes always holds good: With what force then muſt Water be compreſſed in the ſame place? And of conſequence how much more Fire would it be there capable of receiving? Would not Water, if it was made to boil ſtrongly there, ſhine as much as Metals that are made ever ſo hot? Certainly this appears more than probable. Compare *Hiſt. de l'Acad Roy. des Sc.* 1703. 6. and *Mem.* p. 101. But again, there is yet another power of Water, when in the Fire, that is very particular and ſurprizing. If you melt, for inſtance, a fixed alcaline Salt with a ſtrong Fire in a Crucible till it runs like Water, and then inſtantly pour it out into an iron or copper mortar, if there is ever ſo little Water at the bottom of the veſſel, it will be ſo agitated in a moment by this exceſſive Heat, as to be able to make the Salt fly about with an incredible *impetus*; as the Chemiſts have often experienced to their great loſs, and danger. But the effect of Water with reſpect to Fire is never more violent, or terrible, than when it happens to meet with melted Braſs: For if whilſt this Metal is in fuſion in the large melting Furnaces, a little Water unfortunately falls among it, there ariſes immediately a terrible noiſe with ſo violent an exploſion, that the ſtrongeſt Furnaces are inſtantly tore to pieces. If a few grains of melted Braſs are thrown into Water, the force thus produced likewiſe is ſo prodigious, that it will burſt the ſtrongeſt veſſel aſunder, and reduce it to powder in an inſtant. *Hiſt. de l'Acad. Roy. des Sc.* 1699, p. 110. Hence, therefore, it appears, what are the effects of that Water which naturally reſides in combuſtible Vegetables, with regard to the Fire that is burning them, if you conſider it ſeparately as Water; and how much it is capable of increaſing the force of Fire, if it happens to meet with Oils, Salts, or Metals: So that the ſame Body, that is looked upon as peculiarly proper to extinguiſh Fire, we ſee, may under ſome particular circumſtances, be the greateſt inſtrument of rendering its power more intenſe.

The Spirits, then, as they are called, of Vegetables, come next under conſideration, and that, as they naturally ſwim in this Water, and float about with it, before the Vegetables have undergone any degree of fermentation. And theſe, though you take ever ſo much pains to ſeparate them from the Water, and collect them pure together, are never found to contain any thing in them that will feed, and ſupport flame, or Fire. On the contrary, let them be depurated ever ſo nicely if you throw them upon the Fire, they will ſoon put it out, in caſe they have no mixture of Oil in them. The very fragrant Water that exhales from green Roſemary when it is chemically managed, has nothing in it inflammable. Nay, if with a very gentle Fire you ſeparate the moſt fragrant part of this again in a cloſe veſſel, neither was this ever found to yield a proper *Pabulum* for Fire, but on the contrary it extinguiſhes it when it is burning. Secondly, of the native Spirits.

The third ſort of Bodies, that enter into the compoſition of Vegetables, are what the Chemiſts call acid Salts, which exhale too with the ſcented Water, and Spirits abovementioned. Theſe volatile Salts, now, have long ago been diſcovered to be very often exceedingly acid, as the ſmoke that ariſes from acid Wood when it is burnt demonſtrates, as well as the acid Soot that is Thirdly, of the acid volatile Salts.

ſometimes

ſometimes produced by it. Nay, the Spirits that ariſe in the diſtillation of the very heavy Woods, ſuch as Box, Juniper, *Guaiacum*, Oak, and the like, are found to be as acid as Vinegar itſelf. Thus if you take ſhavings of *Guaiacum*, and diſtill them with a moderate Fire in a very clean veſſel, you will have a liquor, that by every characteriſtic diſcovers itſelf to be very acid. If you then carefully ſeparate it from all the Oil that is mixed with it, which may be eaſily done, by filtration, and gentle diſtillation, you will by this means have your Acid perfectly pure, limpid as Water, and even then conſiderably volatile: And yet, when it is by this management rendered as pure as poſſible, if you throw it upon flame, or Fire, it is ſo far from ſupplying them with fuel, that it will ſoon extinguiſh them. Nay, and that pure acid, vegetable Spirit, that is procured by Fire from the native Balſams of Vegetables, is perfectly of the ſame nature. If with an exact Fire you diſtill ſome pounds of fine Turpentine, in a very clean veſſel, you may draw from this oily, pinguious Balſam, a liquor of a perfect acid taſte, that may be intimately mixt with Water, and is perhaps the nobleſt diuretic we are acquainted with; and yet this, which poſſibly you would not imagine, will extinguiſh Fire in the ſame manner as common Water does. We evidently ſee, therefore, from theſe Experiments, that the volatile, acid Salt that riſes from Vegetables when they are burnt, is not a proper fuel for flame, or Fire, but on the contrary put them out. But here, perhaps, you will be ready to ſay, don't we ſee plainly, however, that Sulphur will burn? Certainly it will. But, you'll go on, Sulphur is compounded of a foſſil Acid of Vitriol, Alum, or the Pyrites, united with a vegetable, or foſſil Oil. And this is generally true. Hence, then, you'll be apt to infer, that the latent Acid of the Sulphur is a proper *Pabulum* for Fire. But, Gentlemen, if we will but look into this affair with proper care we ſhall find that it is the Oil only that in this caſe feeds, and ſupports the Fire; for the Acid does not remain in the flame, but is diſſipated in fumes, which being afterwards collected, compoſe that liquor which goes by the name of the *Oleum*, or *Spiritus Sulphuris per Campanam*, and is the true original Acid of the Sulphur without any alteration.

Fourthly, of the volatile Alcali.

But again, if we examine the volatile, alcaline Salts, that exhale from moſt kind of Vegetables whilſt they are burning, and are found to be contained in their Soot; or that are procured from ſome of them purely by diſtillation, as we ſee in Garlic, Onions, Scurvey-Graſs, Rockets, Creſſes, Leeks, Horſeradiſh, Muſtard, Mithridate-muſtard, and others: I ſay theſe Salts, if they are carefully ſeparated from the Water, Spirits, and acid Salt beforementioned, are never obſerved to burn, or flame in the Fire, but either fly off immediately, or diminiſh its power. And laſtly, even that volatile alcaline Salt, that is artificially produced from putrified Vegetables, which is in larger quantity, and more acrid than the former, appears by no effect whatever to be a proper *Pabulum* of Fire. Give me leave, however, here to give you this caution, that what I aſſert of theſe Salts, muſt be underſtood of them, when they are reduced to their greateſt purity, ſo that there is not the leaſt Oil adhering to them. For in the diſtillation of Vegetables, as well as in the burning of them, when the ſaline, alcaline, volatile part riſes, it carries up with it a conſiderable quantity of a fetid, volatile Oil, which it pretty intimately unites with itſelf, ſo that a perſon may eaſily be deceived if he makes this Experiment with

with the Salt, whilſt this Oil remains mixed with it; for then if it's expoſed to the Fire it will really burn. But as ſoon as ever this Salt is perfectly freed from its Oil by the methods which we ſhall hereafter explain, and is by this means rendered quite pure, then its inflammable power is intirely taken away.

The fifth part that enters into the compoſition of Vegetables, is the Oil that's procured from them by diſtilling them with boiling Water in a cloſe Alembic; and this is called their eſſential Oil, and is the moſt volatile of all the Oils that are drawn from them, as well as the moſt pure, not having ſo great a mixture of heterogeneous parts with it, as the reſt have. If this Oil, when it is well ſeparated from all the other parts, is ſet upon the Fire, in a clean veſſel, and ſuffered there to grow hot, and boil, and then a Flame is apply'd to it, it will take fire, flame, burn away, emit a little Smoke, conſume and leave behind it a few *Fæces*, that are of the nature of Coal, black, ſpungy, brittle, and earthy. If this very Oil now, which is generally reckoned ſo pure, undergoes a ſecond diſtillation in boiling Water, it then becomes a great deal purer, thinner, and lighter than it was before, and leaves behind it a good deal of new *Fæces*, that will not riſe in this ſecond operation: And if you then take this Oil thus rectify'd, as the Artiſts call it, and expoſe it to the Fire in the very ſame manner as you did the former, it will take fire, yield leſs ſmoke whilſt it is burning, and the quantity of the *Fæces* that are left behind, will be a great deal leſs than before. And as for thoſe that remain in the Water after this ſecond diſtillation, they are nothing near ſo combuſtible as this rectify'd Oil. Hence, therefore, it appears, that the inflammable matter is by this means diminiſhed, but at the ſame time, that part of it which remains, becomes much more diſpoſed to feed and ſupport Fire. If the purification now of this Oil by diſtilling it in boiling Water, is frequently repeated, then at laſt, a large quantity of this Oil, that was at firſt look'd upon as inflammable, will appear to be of an earthy Nature, that will not ſo eaſily burn in the Fire: In the mean time, however, the Oil that riſes in diſtillation, and is ſeparated from the new *Fæces*, grows every time lighter, finer, and more limpid, burns away with a clear Flame, generates leſs Smoke, and leaves behind it leſs *Fæces*, than it did in any preceding operation. And this may be proſecuted ſo long, till this Oil becomes ſo vaſtly ſubtil, that it will at laſt almoſt conſume without any Smoke or *Fæces* at all. But again, if you take this diſtill'd Oil after it has by this means been rendered totally inflammable, and put it freſh into a clean glaſs Retort, and with a gentle Fire gradually increaſed, carefully diſtill it again, and repeat this frequently as before; then, as the famous *Boyle* has taught us, the greateſt part of this Oil will be changed into earthy *Fæces*, that are left at the bottom, and are not very combuſtible; but the Oil that ſtill remains, becomes every diſtillation, purer, and more inflammable, ſo that it burns away in form of Flame, without any conſiderable Smoke or *Fæces*. If then all the *Fæces* that are left behind after every diſtillation are collected together, and torrify'd, and made red in an open pure veſſel, they'll emit Sparks, and Smoke, and ſometimes Flame, and at laſt will moulder away into Aſhes that are abſolutely incombuſtible. Theſe Experiments now, Gentlemen, I beg you will conſider very carefully: For hence we may already diſcover, how ſmall a portion of this Oil, when pureſt of all, truly burns away in Flame, without

Fifthly, of the Oil.

Smoke

Smoke or *Fæces*, that is, is totally and perfectly combuſtible. And this will be of ſingular ſervice in helping us to an accurate knowledge of the nature of Fire, conſidered as it acts upon this its *Pabulum*, and as it is likewiſe affected by it. This then being rightly underſtood, pleaſe to give your attention to an Experiment of another kind. Obſerve this live Coal, which as you ſee, is very full of Fire: I'll put this now into this copper Veſſel, and pour upon it this cold ætherial Oil of Turpentine, which of all Oils is eſteem'd the moſt inflammable; and you ſee, contrary 'tis probable to your expectation, that this red Coal is as ſoon extinguiſhed with a Smoke and Hiſs, as if it had been immerſed in Water. So that hence it appears, that Oil is not ſo ſoon lighted by a live Fire as people generally imagine; but in order to this, there are ſome particular circumſtances requiſite in the application of them to one another. It is very likely you may imagine, that Flame is neceſſary to ſet it on Fire. To try then, whether this is the caſe or no, I have diſpoſed a Candle as you ſee in this veſſel, in ſuch a manner, that the extremity of the Flame is below the brim; and hence, if the veſſel is fill'd with Oil, the Flame will be below the ſurface; I'll pour in now the ſame pure diſtill'd Oil of Turpentine till the Flame is cover'd, and you ſee it is perfectly extinguiſh'd, nor does the Oil take Fire. But again, I have heated ſome of the ſame Oil in another veſſel, till it ſmokes and is ready to boil, into which you ſhall ſee me throw this little glowing Coal: Don't you all now certainly expect that I ſhall ſet it on fire? Nothing leſs; but it ſinks as you perceive with a noiſe, and goes out. And laſtly, I'll invert this burning Candle, and thruſt it into the ſame almoſt boiling Oil; and here again you ſee that it is perfectly extinguiſh'd without lighting the Oil, or being lighted by it, contrary to what one would imagine. But thoſe vegetable Oils remain ſtill to be examined that are drawn from them by diſtillation, without the addition of Water, which have a fetid empyreumatical ſcent, are opake, and of a thicker conſiſtence. Theſe now, if they are managed in the ſame manner as the diſtill'd Oils abovementioned, exhibit exactly the very ſame *Phænomena*. At firſt they are inflammable, burn away, emit a great quantity of black Smoke, and leave behind them a great deal of *Fæces*; but afterwards, by repeated diſtillations, they become purer, lighter, more limpid, more inflammable, yield leſs Smoke, and leave fewer *Fæces*, and every operationare depurated more and more, and grow more combuſtible. And when by this means they are rendered like the eſſential Oils, they are perfectly affected by Fire in the ſame manner. Since then all theſe things are conſtantly obſerv'd to hold true in every vegetable Oil, exiſting in what condition ſoever; whether it is naturally concreted in ſome parts, or naturally ſecreted in others, as Gums, Balſams, Reſin, and Pitch; or procured by diſtilling the Vegetables; or laſtly, by burning them: I ſay, ſince what we have ſaid holds good of them all, we may hence form a true notion of the matter that is chiefly combuſtible, and hence be able to draw a great many inferences that are abſolutely neceſſary to a juſt Hiſtory of Fire; and which indeed, if we are not firſt well acquainted with, we ſhall certainly run into a great many errors, if we pretend to explain either the nature of Fire, or combuſtible Matter. If we rightly underſtand now, what has been laid down concerning that part of Vegetables, which alone, is really burnt when they are ſet on fire, *viz.* their Oil, or as it is call'd, their Sulphur, we ſhall then be able hereafter to proceed more

more readily in the reſt: This therefore I recommed to your careful conſideration, as it will be of ſervice to us in our future inquiries.

If any kind of Vegetables are burnt in the Fire to ſuch a degree, as to be glowing red quite through, but are not yet reduced to Aſhes, then, if they are on a ſudden ſuffocated in cloſe Air, extinguiſhed with Water, or buried deep under Aſhes, or any other Bodies that exactly cover them, they loſe their Fire, and are changed into a Body that is perfectly black, after you have ſhook off the Aſhes that may poſſibly lie upon their outward Surface; and the Body thus prepared is called a Coal. Again, if you take any ſort of Vegetable whatever, put it into a metal, earthen, or glaſs Receiver, and with a violent and long continued Fire, urge it ſo long till ſcarce any thing more will come over into the Receiver; then, if the veſſels were ſo perfectly cloſed that not the leaſt Air could find admittance, there will remain at the bottom of the Retort, a Vegetable ſubſtance intirely black, which is likewiſe a true Coal, exactly of the ſame nature with the former. Now either of theſe, if it is laid upon the Fire when it is throughly dry, very readily takes fire, retains it ſtrongly when it's once kindled, burns as long as any blackneſs remains in it, and thus almoſt totally conſumes without any Smoke: during all this time, however, it emits an exhalation, which if received into a cloſe place, quickly, and inſenſibly, proves fatal to every kind of Animal; nor does it at all ſignify, whether the Coal is prepared from Plants, Woods, or bituminous Turfs. When every thing then, that was black in the Coal is thus conſumed by the Fire, what remains is a whitiſh Powder, which goes by the name of Aſhes, and which it is impoſſible to excite into a Flame by the application of any degree of Fire whatſoever: The moſt you can do with them, is uniting Fire with them in the ſame manner, as you may with Metals, Stones, and the like, which we gave an account of before in our Hiſtory of Bodies, that are capable of retaining Fire without being conſumed. In this affair now, it is particularly remarkable, that the Coal then only grows unfit to feed the Fire, when it changes its black Colour for this cineritious one, it conſtantly affording a *Pabulum*, ſo long as the former remains. This we ſee evidently in that common, yet elegant Experiment made with that exceeding fine vegetable Coal, Paper, when burnt to a blackneſs: For if a Spark falls upon ſuch a black Paper, it ſoon begins to run up and down in form of a fiery Spark, and leaving thoſe places that are whitiſh, and will no longer burn, it perpetually ſhifts about to thoſe that are black, which it in like manner conſumes, and then quits for the next black Spot, till at laſt by this means, all the blackneſs being perfectly deſtroyed, there remains the form of a very thin Paper, conſiſting purely of white Aſhes, which in ſome meaſure ſtill cohere together. A vegetable Coal, therefore, is that part of Vegetables, from which the Fire has expell'd the Water, Spirits, volatile Salts, and ſome of the lighter Oil that is not ſo cloſely united with the other parts; and in which there ſtill remains an Earth, and fix'd Salt, whoſe increaſed Surfaces the Fire has covered over with a rarified attenuated Oil, which by burning has acquired a black Colour: For all that appears black in the Coal is purely Oil, which being put into a rapid motion, and greatly expanded by the action of the Fire, was in ſome meaſure extricated from thoſe parts that were not inflammable, tho' not perfectly freed from them, and hence being neareſt to the Flame, and attracted towards the Surface, upon this ſudden extinction, it remained apply'd

Sixthly, of the Coal.

to the exteriour *Superfices* of those little cells, in which the Water, Spirits, and volatile Salts resided before the Coal was thus prepared. From what has been observed then, we may at last conclude, that the combustibility of Coal, consists intirely in the Oil that remains united with it, the other parts being by no means capable of flaming or burning so as to be consumed by the Fire that is received into them, as those Bodies are, which are a proper fuel for Fire.

Seventhly, of the Ashes.

But not to omit any thing this is requisite to make this History fair and compleat, let us yet farther examine these very Ashes that remain, after Vegetables are thoroughly burnt. These now, if they are produced from pure Vegetables, will be almost always of a pretty white colour, and a salt taste, a few as I hinted before excepted. If you boil these Ashes in Water in a clean vessel, the *Lixivium* will have an acrid, alcaline, fiery, urinous taste. If you, then, pour off the Water that is thus impregnated, and add more fresh Water to the remaining Ashes, boil this again as before, then pour off this, and put on more, and repeat this operation, till at last the Water that is thus boiled with the Ashes comes off as insipid as it was poured on; then, if you mix all these *Lixiviums* together, and evaporate them to a dryness, you will always have at the bottom of the vessel an acrid, alcaline, fiery, fix'd Salt: This now will grow perfectly red hot in a strong Fire, and retain a lucid Fire in it for some time, but will never support Fire, excite Flame, or be itself consumed by them as a proper *Pabulum*. Fix'd alcaline Salts therefore are incombustible; as Stones, *&c.*

The Salt of which is not a proper *Pabulum* of Fire;

But let us now look back to that part of the Ashes, which after the separation of all the Salt, remains at the bottom of the Water; and this, if it is carefully dry'd, and kept perfectly by itself, is found to be a light white Earth, vastly simple, and exceedingly immutable by the action of the Fire: This evidently appears in the Cupels, which are made of these Ashes, with the addition only of Water; for these, when they are exposed for a long time, to a very intense Heat, grow red hot as other incombustible Solids do, but the Earth itself will never burn, flame, or supply the Fire with a proper *Pabulum*.

Nor their Earth.

Eighthly, of the Smoke.

Thus, then, we begin by degrees to discover what parts of Vegetables it really is, that properly feeds, and supports Flame, and Fire, and which must necessarily remain in the Fire so long as it continues to flame, or burn. But farther, whilst Vegetables are thus on fire, there constantly rises from them a dense Smoke, which at first is watery and thin, grows thicker and thicker every moment, at last grows very black and dense, and then is blackest and densest of all, when the Flame is just appearing, which generally soon breaks forth with a crackling noise; and as soon as ever the Flame appears, the Smoke immediately diminishes, and so much the more, as the Flame is more vivid; so that when it is brightest of all, the Smoke seems quite to cease rising, tho' even then, indeed, we are sure that there is actually Smoke. Hence, therefore, it seems probable, that Smoke is a confused mixture of different parts of the vegetable *Pabulum* of Fire, which are put into a violent motion by the action of the Fire, are carried upwards, and agitated among one another, but not thoroughly set on fire: If this action, however, is continued, and increased, and these Particles are urg'd with a stronger Fire, they then grow red hot in the Air, the Smoke is converted into Flame, and the Particles of the Smoke being now grown bright, and at the same time vastly attenuated, appear purely igneous.

And

And hence, likewiſe, it is evident, why a vivid Flame, when it encompaſſes the whole burning matter, ſeems to conſume all the inferiour Particles that are agitated by the Fire, in the form of Flame, without any Smoke; for it is certain, that except the watery part, Smoke may be totally changed into Flame. This, indeed, has long ago appeared to be true, by that elegant Experiment of the *Focus Acapnos*; in which, one may evidently ſee, that the black Smoke which riſes from burning Vegetables, is in reality a Coal, which is combuſtible in a ſtrong Fire, or great Flame: For when it is expoſed to either, it is reduced to mere Aſhes, or its matter is ſo far attenuated, that it eſcapes our ſenſes, and is diſſipated into the Air. Which is a volatile Coal.

The Inventor of this Inſtrument was that ingenious Artiſt *Daleſmius*, who contrived it in the Year 1686 at *Paris*, as we have an account in the 116th Page of the *Journal des Scavans*, publiſhed that year. The famous *Juſteleus* afterwards firſt publiſhed a Cut of it in the *Philoſ. Tranſ.* almoſt at the ſame time, which is as follows. ABCD is a hollow Cylinder made of Plates of Iron, open at both ends, within whoſe inferiour Baſe BD, there is fitted the Grate BD. This Cylinder, which is the Fire-place of the Inſtrument, is joined to the cylindric Tube EFG, in ſuch a manner, that there is a communication between their Cavities. And this Tube EFG, which is of the ſame capacity with ABCD, made of the ſame Metal, and in the ſame manner, is open at G, and cloſe at E. If then the Tube EFG is made very hot, and ſome live Coals are laid on the Grate BD, and over them ſome combuſtible matter, then the Flame that is produced, will deſcend into the Tube EF, and paſs through FG, and all the Heat will go out at G; and the Smoke likewiſe that is generated following the ſame courſe through the Tube EFG, will be forced to paſs through the Flame that fills the whole Tube; and hence, being acted upon by the Fire in all this paſſage, it will loſe the thickneſs and diſpoſition of Smoke, will be converted into Flame, and in this form paſſing out of the Aperture G, will diſappear, without any viſible Smoke, or Soot. The famous *De la Hire* has added ſome Notes upon this Machine in the place in the Journal above cited. In order now to give you an ocular demonſtration of the ſame thing, I have provided this Inſtrument which is made of Plates of malleable Iron. ABCDEF, is a hollow veſſel conſiſting of five equal iron Plates well ſoldered together, and open only at the top ABCD. At the height EI within this veſſel there is a Grate IKLM. In the ſide DF, there is an elliptic Hole NO, of the breadth MK, and height EI, to which is joined the Tube OGH, open at ON, and H, and every where of the ſame capacity. Pleaſe now to obſerve the effects of this Machine. On the Grate IK, I lay ſome live Coals, that the veſſel may grow hot; and that the Air in the cavity of the Tube NOGP, may at the ſame time be heated likewiſe, I put ſome more on the part of the Tube NP. As ſoon as ever now the Air below the Grate, and in the Tube NOGP grows hot, the Heat that was produced by the Coals above the Grate in the veſſel CK is diminiſhed; and the Heat in LF below the Grate, and in the Tube NOPG, is in proportion increaſed; ſo that now you obſerve the force of the Fire, with its little Flames, tend downwards, by which means a new degree of Cold is generated above the Coals that are laid on the Grate. The Machine then being thus prepared, when I lay this Straw upon the Coals, you ſee with what rapidity the Flame drives downwards through the Grate, and

A Fire-place and Chimney without Smoke, the Smoke being burnt.

Pl. IV. Fig. 1.

Fig. 2.

through all the Tube OGH, ſo that it breaks out at the top H, without Smoke, and there produces a very great degree of Heat; whilſt at the ſame time the ſpace CK continues cold. But farther, whilſt I add Wood, Turf, Sulphur, and Oils, it proceeds exactly in the ſame manner, and the force of the Fire is ſo great within the Tube, that the Tube you ſee is now red hot, and the Fire burns with ſo much fury and rapidity, that one may hear the noiſe that is produced by the agitation of the Flame. You take notice too, at the ſame time, that theſe Bodies, which commonly, when they are burnt, diffuſe an intolerable fetid, or a very agreeable ſcent, now they are laid on this Fire, don't diſcover any ſmell at all, but perfectly conſume without the leaſt ſign of it, leaving nothing behind them but pure Aſhes at the bottom of the veſſel under the Grate. All the other parts are driven by the force of the Air preſſing upon the Aperture of the Fire-place, into the Tube which is higher, and narrower than the Veſſel that contains the Fire; ſo that all the Flame, and the power of the Fire, exerts itſelf within the ſpace LFOGH; and hence, the combuſtible parts that are reduced into a very denſe Smoke by the action of Fire, are now carried through this pure Flame, and not into the open Air; by which means, being thus ſtrongly agitated by the violence of the Fire, even within the Fire itſelf, they are ſo attenuated in their paſſage, that every part of them that was combuſtible, or could be ſo divided by the motion of the Fire as to become perfectly imperceptible, is diſſipated into the Air, without diſcovering the leaſt ſign of any particular quality. Smoke therefore is combuſtible matter, exceedingly agitated, but not yet ſhining, or red hot; Flame is the very ſame matter, only thoroughly red with heat, and divided into very minute Particles. But it appears likewiſe by other Experiments that Smoke is inflammable. If you take, for inſtance, ſhavings of *Guaiacum*, and with a ſtrong Fire force it out of a Retort in a denſe Smoke, then, in the end of the operation when nothing riſes by the action of the Fire but a very attenuated and rarefy'd Oil, if this Smoke inſinuates itſelf through the cracks of the Lute, and a Candle is apply'd to it, it immediately takes fire, and flames, and that not without a great deal of danger. And the ſame thing is true of all parts of Animals, if they are treated in the ſame manner. Hence, therefore, Smoke comes neareſt to Flame, and the blacker it is, it comes ſo much the nearer; for then it becomes a true Coal, exceedingly thin and attenuated, perfectly volatile, and eaſily combuſtible; as any one may eaſily underſtand from the Hiſtory of Coal, that has been already delivered. And hence, therefore, laſtly, there is nothing in Smoke that ſupplies Fire with any *Pabulum*, except the Oil; but this will appear more evident hereafter.

Laſtly, of the Soot.

In the laſt place, in the burning of combuſtible vegetable Matter, the Smoke which is carried upwards applying itſelf to the ſides of the Chimney, inſtills into them a penetrating black pinguious moiſture, changes them of a very black colour, and faſtens to their outſide in form of black, looſe flocks, that eaſily drop off; and the matter thus collected is called Soot. This now is in reality a true volatile Coal, but exceeding fat, and hence if it is dry, it is very eaſily inflammable. It is exceſſive bitter like Oil that is burnt; very pinguious from the quantity of Oil it contains; and from this Oil's being burnt, is very black, as all other Coals are. This matter now, tho' it appears thus ſimple, if it is nicely reſolved into its parts by a chemical diſtillation, in the firſt place yields a

Water, in pretty great plenty, which being carefully ſeparated and collected, extinguiſhes both Flame and Fire. And the very watery Vapour that thus exhales in this firſt diſtillation puts out Fire intirely; ſo that you can ſcarcely properly call it a Spirit. If you then increaſe your Fire, there comes over from this Soot, a large quantity of yellow, inflammable Oil, which yields a plentiful *pabulum* to Fire and feeds and ſupports Flame. That part likewiſe of this Oil which is exceeding ſubtil, and goes by the name of a Spirit, is in the ſame manner inflammable. But it farther yields, too, a very volatile Salt, one leſs volatile, and then one that is drier; from all which if you perfectly ſeparate the Oil and Spirits, juſt mentioned, you will find nothing at all in them that is any ways inflammable, but only a Salt that is incombuſtible. And laſt of all, this *analyſis* will give you a Coal, which we have ſufficiently conſidered already, under our ſixth and eighth Obſervation. Hence therefore it appears, what Soot is, and what part of it is really combuſtible. If this Soot now is taken dry from the Chimney, and thus laid on the Fire, it burns fiercely, and breaks out into Flame, in the ſame manner as any other combuſtible matter does; which perſons experience, ſometimes, to their great danger, when they let their Chimneys go too long without ſweeping; for the Soot being, by this means, collected in large quantities, frequently takes fire, and flames out of the top of the Chimney.

From all theſe Obſervations, then, that I have fairly related to you, we plainly perceive, what part of crude Vegetable it is that is properly inflammable, and may be eſteemed a true *Pabulum* of Fire, *viz.* the Oil alone, and that, in what form ſoever it exiſts, whether in a thick one, or a thin one, like that of Spirits. Concluſion concerning the crude *Pabulum* of Fire.

Since every thing, however, muſt be conſidered and examined that will give us any light into the nature of Fire, and that it may be perfectly evident, what it is in Vegetables that properly and ſolely yields a matter proper for the nouriſhment of Fire, let us now ſuppoſe, that we certainly knew, from what has been premiſed, that there is nothing contained in crude Vegetables that will feed and ſupport Fire, and is, at the ſame time, capable of being diſſolved in Water. But if we will turn our ſpeculations farther, to the vegetable Subſtances, that, by a true chemical fermentation, are produced from thoſe Vegetables that are thus diſpoſed to ferment, we ſhall then find, that by this method a liquor may be produced from them, which goes by the name of Wine; this, now, when it is fined according to Art, and hence rendered pure, if it is thrown upon a large Fire, will ſoon intirely extinguiſh it; nor is it any way fit to ſupport Flame. Nay, and after you have examined it in this manner, if you put it into a clean glaſs veſſel, and, with a very gentle Heat, evaporate the moſt volatile part of it, and reduce it to a Fume; even this, if you apply a Flame to it, will ſcarcely burn, but on the contrary, for the moſt part, rather puts it out. Wine don't take fire.

But if this Vapour, when it is afterwards grown cold, is collected in form of a liquid, and this is treated in the ſame manner as the former, then this will yield a liquor that may be mixed with Water, and at the ſame time will perfectly take fire, will afford a plentiful *Pabulum* to Flame, and be itſelf conſumed in it. That part of the Vegetable, now, that is ſeparated from the Wine, whether in form of Lees, or the *Reſiduum* in the diſtillation juſt mentioned, if it is examined by the fire, will yield almoſt the ſame parts, which But its Spirit does.

are found to be procured from crude Vegetables, under the ſame management. By this inſtance therefore it appears, that by Fermentation there is generated from Vegetables, a liquor that will mix with Water, and feed Flame, which did not really exiſt in them, when they were crude.

Putrefaction of Vegetables produces Fire.

But it will be worth our while to examine Vegetables whilſt they are managed in another manner, different from the former. If Vegetables then are thrown into large heaps, when they are juſt cut down, and full of their natural juices, or are diſpoſed under the ſame circumſtances, in great wooden veſſels, cloſe and hard preſſed down, they will there grow warm, then very hot, and emit a watery Fume, a diſagreeable Smell, a black Smoke, Flame, and Sparks. On the other hand, if they are expoſed to air after they are mow'd, till they are grown ſufficiently dry, then, though you heap them together in the ſame manner, they will continue dry, and will not undergo the ſame alterations: But however, even in this caſe, if you pour Water upon them, till they are thoroughly moiſtened, they will conceive Heat, and take fire in the ſame manner as the green ones juſt mentioned. After Vegetables, now, have by theſe means acquired this ſpontaneous Heat, and retained it for ſome time, if they grow cold again, without taking fire, they then are found to be quite putrified, and converted into a fetid, pappy Matter. If then you diſtill this putrified Pulp, the firſt part that comes over will be a watery Vapour, which will extinguiſh Fire and Flame: And when this firſt watery liquor is drawn off, if you expoſe the remaining dry parts to an open Fire, they will yield almoſt all the ſame principles as crude, or fermented Vegetables do in the ſame circumſtances.

But laſtly, if you take Vegetables that are perfectly putrified, and diſtill them in a Glaſs retort with a moderate Heat, till they are become nearly dry, you will then have firſt a fetid ſubpinguious or cloudy Water, in which there is found to be contained a volatile, alcaline Salt, tho' then intirely diſſolved; and indeed it is rather from the admixture of this Salt, than from any true Oil that the Liquor appears thus pinguious. Whether now this Water thus impregnated with Oil, is thrown upon the Fire; or whether you firſt reſolve the compound Liquor into a purer Water, and its Salt, and then throw both theſe ſeparately upon Fire, the Event in both Caſes will be exactly the ſame; for in both the Fire will be extinguiſhed.

And ſome inflammable parts.

But again, when this firſt Liquor is ſeparated, and the putrified Matter remains now almoſt dry in the Retort, if you urge the *Reſiduum* ſtill further with a ſtronger Fire, there will come over a fluid, oily, thin Liquor, which ſwims upon Water, is fetid, and yields a *Pabulum* to flame, like Oil, or Spirit of Wine. After this Spirit, or fine Oil, is drawn off, if you ſtill increaſe your Fire, then a volatile, alcaline Salt, and an Oil thicker than the former will riſe together in a conſiderable quantity. And here again, as the Oil is found to be inflammable, ſo the Salt appears perfectly otherwiſe. But farther, if when you have ſeparated all theſe, you ſtill urge the *Reſiduum* with a ſtrong Fire, and continue it a good while, you will have another Oil, ſtill thicker, and more tenacious, almoſt like pitch, which is exceedingly combuſtible: And at the ſame time there will come over a denſe Vapour, which, upon the Application of a lighted Candle, will inſtantly take Fire in the open Air. This being done, if the Fire is ſtill conſtantly kept up to its greateſt Degree, you will at

laſt

laſt force out a *Phoſphorus*, which, though it is not of ſo ſolid a Form as that which is procured from animal Subſtances, yet it comes very near it in a great many of its Properties. Laſt of all, when this fluid Matter is intirely gone off, there is then left in the Retort, a very black Coal, ſuch as we deſcribed before, in which there remains indeed a black inflammable Oil, but not the leaſt appearance of any fixed Salt.

Concluſion concerning all that is combuſtible in Vegetables.

If we thoroughly underſtand then what has been laid down, we may boldly and ſafely determine, concerning all the parts of Vegetables, naturally contained in them, that are endued with ſuch properties, that if Fire is applied to them, they may be conſumed into Flame, and will ſo long feed and continue Fire in that place; as likewiſe of thoſe which may by certain methods be procured from them, or produced in them, ſo as to diſpoſe them to have the ſame effect. It is evident then, that amongſt theſe Parts, the Water, the native Spirits, as they are called, all the kinds of Salts, and the Earth of Vegetables, are capable of being heated by Fire, and hence of admitting Fire into them, and of retaining and preſerving it there for a conſiderable time, but this only under the limitations above mentioned. The Fire likewiſe, when it is thus united with them, may, by the help of them, be at pleaſure communicated to other Bodies: And the fixed Salts may, by a ſtrong Fire, be heated thoroughly red hot, and will retain this ſhining Heat a conſiderable while. In the mean time however, neither of theſe four Parts can, by any contrivance whatever, be raiſed into Flame, or, by the application of Fire, be conſumed in it, in the ſame manner as thoſe Bodies are which are generally called the *Pabulum* of Fire. But farther, the Oils of Plants of what kind ſoever, their Balſams, the Gums that are generated in them, the Reſins likewiſe, and the Subſtances compounded of theſe two laſt together, hence called Gummy-reſins; theſe five other ſorts of Parts, I ſay, that are found in Vegetables, are diſpoſed likewiſe to grow hot with Fire, to retain it a great while, to apply it to other Bodies, and that without taking Fire, or flaming themſelves; though if you urge them with a ſtronger Fire, they will melt, boil, and yield a true *Pabulum* to Flame or Fire. But yet even in this caſe, their Inflammability is only confined to thoſe particular parts of them that are of an oily nature; for all the reſt are chiefly of an earthy diſpoſition, and are only acted upon in the ſame manner as the former which we juſt deſcribed.

But the vegetable Spirits now that are generated by Fermentation; the other Oils that are drawn from firmented Vegetables; and laſtly, the Spirits and Oil that are procured from Vegetables by putrefaction; all theſe, I ſay, conſidered as they are perfectly pure Spirits, or Oil, are conſtantly obſerved to be abſolutely inflammable. It evidently appears therefore, from every kind of experiment, that the Oils of Vegetables, in what Form ſoever they exiſt, are the only Matter contained in Vegetables, that without the addition of the other Parts is capable of being ſo agitated by Fire, as by its aſſiſtance to produce true Flame, and then to ſupport and continue it ſo long as any of theſe oily particles ſtill remain: That in the mean time this very Matter is by degrees conſumed by the Flame, and diſappears; and that then too the Flame immediately goes out. And though this Oil is found in Vegetables to have very different appearances, and undergoes conſiderable alterations from various cauſes; nevertheleſs, in the ſenſe above explained, ſo long as it re-

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mains Oil, it will always continue to be inflammable. And yet farther, when by Fermentation or Putrefaction this Oil is so attenuated as to be reduced to very subtil Spirits, that will bear to be diluted with Water; even these Spirits likewise are intirely inflammable, and as a *Pabulum* of Fire have the very same effect which we just now observed of real Oil. But whenever now you have perfectly extracted every thing that is of an oily nature, either from the whole Vegetable, or from any of its parts, then the remainder, treat it in whatsoever method you will, can never be made susceptible of Flame, or capable of supplying it with any nourishment. In the mean while, however, the watery, spirituous, saline, and earthy parts, as they contain and confine these Oils within them, must necessarily, when the Oil is set on fire, be agitated, put in motion, vibrate, and very much increase the force of the Fire; for whilst this is supported by the Oil, this violent agitation of all their particles will of consequence excite a prodigious attrition in the very Flame itself; and hence, being thus agitated, they will apply the Fire more forcibly to any other Bodies. And lastly, they serve for a time to defend the Oil itself from being too soon consumed by the Flame, that thus the *Pabulum* of the Fire might not be so quickly destroyed and dissipated as it would be otherwise.

Whoever, therefore, duly considers all these effects, will easily see that the force of a Fire raised by Vegetables, does not depend only upon elementary Fire, and the Oil set on Fire by it, but principally, and most of all, on the other parts that are incombustible, but which at the same time are agitated by the Fire with a vast *impetus* within the sphere of its activity. And for this reason, when elementary Fire acts upon the purest Alcohol, which is the simplest of all combustible matter, it then neither produces such violent effects, nor so much Heat as it does by a ponderous fossil Coal, a great part of which is not inflammable. Nay, even a Torch made of the rich, pinguious wood of the Pine, gives a stronger Fire than its Oil, let it be ever so pure, or be separated ever so carefully from all those parts that are not combustible. And thus we understand the reason of this paradox, that pure Fire, applied to inflammable matter alone, very often produces a less degree of Fire than if the inflammable matter was mixed with something else that was not so. Hence, the wise Author of Nature has no where created any inflammable substance by itself, but always disposed it in the bosom of some other Bodies that are not combustible, that by this means it may be capable of producing greater effects. As the right notion of this now is of very great consequence in our present inquiry, give me leave to explain it to you in the following manner: When a pinguious piece of Wood is laid upon a Fire, the Oil that is contained in it, in conjunction with the Fire, is capable of exciting, and really does excite a Flame. This then being thus produced, plays upon the surface of the Wood, attracts, fires, consumes and converts into new Flame all the Oil that lies open and exposed to its action; and hence the first Flame is supported, and constantly increased, so long as this Oil comes within the sphere of its activity. The Salt in the mean while, and Earth, that are intimately united with this burning Oil, will at the same time be attenuated, and reduced to very minute particles, by the rapidity of the Oil, and will hence be agitated with more violence within the Flame, than even the Oil itself,

and

and suffer as vehement an attrition as any we are acquainted with. This violent attrition then of these particles, that are exceeding hard, and are very forcibly compressed together by the weight of the atmosphere, will of course collect more fire in this place, and thus make it both larger and stronger; and of consequence will still put this Oil in a more rapid motion; which will very easily account for the vivid appearance of the burning Fire. Whilst these things then proceed in this manner, the solid body of the Wood grows hot to its very innermost parts, dissolves, rarifies, expels the elastic parts contained in it with a very great *impetus*, pours out its melted Oils, and by these successive actions continues and maintains the Fire so much the longer. On the other hand now, if exceeding pure Oil only is kindled by the application of Fire, then the tenacious, oily particles alone will be rapidly agitated by the elements of Fire, which being of a softer nature than the Salts, Earth, *&c.* must necessarily produce less attrition, and a weaker Fire. They will, it is true, burn away faster; but then their *impetus* will be of short continuance, nor will they collect Fire so powerfully, as when they are mixed with something that is not inflammable. And thus I think I have sufficiently explained what is the true *pabulum* that Fire receives from Vegetables.

Of the manner in which Fire is fed by this *Pabulum*.

It will be our business then in the next place, to examine with the utmost attention, what it is that nature is really effecting, whilst this matter which we have described in the Vegetable Kingdom, is so apply'd to Fire, as to feed and support it. And upon this head, certainly, I have not taken a little pains to come at the truth. After considering the affair then in every light, I have discover'd, first, that all those parts of Vegetables, that in conjunction with Fire are capable of exciting a true Flame, are of that nature, that they will bear to be mixed with one another; especially, if there is no heterogeneous mixture with the pure, simple, inflammable Particles. For to come to the matter more closely, Alcohol is the only Body that we are acquainted with, that is absolutely inflammable; but this, let it be prepared from what you will, if it is perfectly pure, may be intimately united with any other sort of simple Alcohol whatever, so that there won't appear the least sign of difference after the mixture. All kinds of Oils, in the same manner, if they are thoroughly depurated, and separated from every thing else, may be intirely mixed together; as appears by every kind of Experiment. I confess, indeed, in some Oils procured from a semi-fossil Matter, as Amber, and the like, as you increase your Fire successively, the Oils that ascend, will lie upon one another in distinct *Strata*, without being mixed together: But you know very well, that these ponderous Oils, that are at last forced out by the strongest degree of Heat, have almost the very melted substance of the Bodies themselves united with them; and besides, I am here treating only of Vegetables. All vegetable Oils, then, are of that nature, that they'll easily bear to be compounded into one liquid concrete, which will scarcely afterwards be found to have any dissimilarity. But again, all kind of Oils, if they are carefully depurated, may be intimately mix'd with pure Alcohol, so that the Fluid that arises from this Mixture will be absolutely homogeneous, all the parts of it appearing perfectly uniform to the nicest Microscopes. But here, I take for granted, that there is not the least drop of Water, either in the Alcohol, or Oil, for otherwise such union could not possibly be expected. But farther, Camphire, which is a solid vegetable

Subſtance, and totally takes fire, will intirely diſſolve, not only in Alcohol; but in every kind of pure Oil likewiſe. And the other parts of Vegetables that are perfectly inflammable, may in the ſame manner be mixed with Oils and Alcohol, and always the more intimately, the more they are purely inflammable. In Reſins, Balſams, and Gumma-Reſins, this is every where found to be the caſe. And when they are capable of being mixed in this manner, they are obſerved to be either naturally fluid, or diſpoſed to be rendered ſo by a ſmall degree of Heat. How eaſily does Camphire run by a ſlight action of the Fire? And what a gentle Heat is ſufficient to melt Balſams, Colophonies, and Reſins? Nay, many of theſe inflammable ſubſtances, are able to withſtand the greateſt degree of natural Cold that ever was obſerved, without being frozen, as is evident in Linſeed Oil, and a great many others. It is particularly remarkable now, that all theſe Bodies that are purely inflammable, whether ſeparate, or compounded together, by their tenacity conſtantly diſcover a viſcid coheſion of their Particles, which does not a little reſiſt their ſeparation. Obſerve, for inſtance, this Alcohol, which of all known Liquids is the moſt ſubtil. Don't you perceive, that even the Particles of this run down in ſpiral *ſtriæ*, which cohere and hang together? If you pour Alcohol into clear Water, you obſerve that the Particles of the Alcohol affecting this coheſion run about in the Water in form, as it were, of little Eels, and by their convolutions ſufficiently evince their tenacity: Nay, and even if you dilute Oil with Alcohol, you may diſcover the ſame kind of ſtreaks. But it is farther obſerved, that all Oils that are inflammable, burn ſo much the eaſier, the more perfectly, with the leſs Smoke, and leave the leſs Aſhes behind them, the thinner they are, and the nearer, by their exceeding fineneſs, they approach to the ſubtlety of Alcohol; which is every where confirmed by Experiment: But at the ſame time, the thinner the Oils are, their Flame is always ſo much the weaker. Thus, Gentlemen, I have laid before you a collection of Obſervations concerning the nature of the *Pabulum* of Fire, which are conſtantly found to hold good, and which will help to give us ſome light into the manner in which Fire acts upon its *Pabulum*, and that again upon Fire. And to this purpoſe, let us again make uſe of the following *Series* of Experiments.

EXPERIMENT I.

The extinction of Fire and Flame by Alcohol.

In this clean, braſs, cylindrical Veſſel, is contained ſome very pure cold Alcohol, which of all the Fluids that we know of, is the moſt totally inflammable; into this, you obſerve, I dip this Match whilſt it is burning; upon which no doubt you imagine the Alcohol will be ſet on fire: Nothing leſs; for you ſee it is perfectly extinguiſhed, all one as if it was immerg'd in pure Water. But again, which is more ſurprizing, I'll immerge this burning ſparkling live Coal juſt taken from the Fire, in the ſame Alcohol; and what is the conſequence? Why it is extinguiſhed in the ſame manner as if it had been thrown into cold Water. But now, if I dip the end of this lighted Match, ſo cautiouſly into the Alcohol, that ſome of the burning part, which is of a conſiderable length, ſhall be above the ſurface of the Alcohol, then the attracted Alcohol will begin to take fire, and the Flame will in a little time be diſperſed over all its ſurface.

COROL.

COROL. 1.

Hence, therefore, it evidently appears, that burning Fire will not ſet fire to the moſt inflammable matter that we are acquainted with, except in its upper part only that is contiguous with the Air, but will be perfectly extinguiſhed itſelf, when it is ſo diſpoſed within the inflammable Body, that no part of it remains in the Air above its Surface. And yet this very remarkable *Phænomenon* is ſcarcely taken notice of.

COROL. 2.

It is not true, therefore, that active Fire will ſo eaſily kindle even thoſe Bodies that are vaſtly inflammable.

EXPERIMENT II.

The preſervation of Flame and Fire by Alcohol.

I have fill'd the ſame clean Veſſel with very pure Alcohol, which I have heated you ſee till it emits a Vapour; if I bring now this lighted Match towards this Fume that exhales from the hot Alcohol, as ſoon as ever the Flame of the Match touches the Vapour, it immediately takes fire, flames, and burns, and the Flame extends itſelf intirely over the whole ſurface of the heated Alcohol. And this Flame remains ſpread accurately over all the ſurface as a firm *Baſis*, nor can by any Art whatever be made to convert into Flame that part of the Alcohol that lies cover'd under its Surface: For all this you perceive it intire, pellucid, not on fire, but remains under the flaming Surface without being conſumed, except ſo much of the Spirits as are ſeparated from it by the Heat, and thus raiſed and brought to the Surface that is contiguous with the Air; for then theſe, and no other, immediately take fire and flame; nor is it poſſible to ſet on fire more at a time, than thoſe which are now ſo diſpoſed that they can float in the Air: This I have obſerved moſt evidently; for if the Alcohol is cold, and you light it leiſurely on its Surface, by dipping a burning Match in it, as I mentioned before, ſo that ſome part of the Flame ſhall ſtill remain above the Surface of the Alcohol; then the Flame that is in this manner excited, will be gentle, weak, and very ſmall. On the other hand, if this Alcohol is firſt heated, and by this means emits a large quantity of Spirits from its Surface, then the Flame will be greater, and burn with more ſtrength and violence; for then more Particles coming to the Air may be ſet on fire by the Flame. In this Veſſel therefore, the Alcohol will always yield more Flame, the more it is heated through its whole Bulk; and of conſequence, if it is made ſo hot as to boil, then will its Flame be ſtrongeſt of all. But again, if the agil Vapours that exhale from a Veſſel of boiling Alcohol, and float about in the Air, are confined by any means within a narrow compaſs, then if you bring a burning Candle within this ſpace, thus full of Vapours, the whole place will be inſtantly filled with a flaſhing Flame, which ſhines for a moment with a faint light, and then tends towards the Surface of the Veſſel, and fixing there, ſo covers the exhaling Surface of the Alcohol, that no more Spirits can any longer be diſperſed into the former ſpace, or be ſet on fire there; for now it is all forced to paſs through the incumbent Flame, where it is ſo changed, that during its ſtay there, it creates Flame itſelf, but then, is afterwards converted into a Fluid, that is no longer Alcohol.

That this is the cafe, I have abundantly learned from Obfervation. And farther, this Flame continues to burn fo long as there is the leaft drop of Alcohol left in the Veffel, and then it goes out. All the Alcohol, therefore, can't poffibly be confumed by this Flame at once, but only that part of it which forms the Surface contiguous with the Air. The broader therefore the Surface is, the fooner will it be burnt up; and confequently this wafte may be increafed or leffened at pleafure. Thus then we have two methods of accelerating the Flame, and of confequence the confumption of Alcohol, *viz.* making it boil, and difpofing it under a large Surface. This Alcohol now, when it is intirely burnt away, leaves no *Fæces* behind it; nay, if it is perfectly pure, there does not remain the leaft fpot or fign of it: Nor in the Surface of the Flame, is there the leaft Smoke that the Eye is capable of difcerning. Nay, if you hold a very white clean Paper over the burning Flame, it will be no ways foiled with any Soot; but it will receive only a pure Moifture. The olfactory Nerves, however, will perceive a fragrant fmell like that of Alcohol. The Flame now of this Alcohol, when it burns in a very quiet Air, is of a conical figure; for the Fire being ftrongeft about the center, elevates the incumbent Atmofphere in that place more powerfully than that does which is towards the circumference of the *Bafe*, which is lefs confined and comprefs'd, and confequently weaker. If you look flightly upon this Flame, you'll take it to be blue; but if you look upon it very intently, the *Bafe* of it is always blue, but its *Apex* appears double, the inner of which is conftantly yellow, but the outer is blue likewife. But there's nothing, it's poffible, will feem fo furprizing in this Experiment, as what I am going now to fhew you. You perceive the Alcohol in this little Veffel burns very fiercely; I'll now throw into it this live Coal which is perfectly red quite through; and you fee in finking it is extinguifhed immediately, nor is able to retain its Fire when it is cover'd with the Alcohol. What now is the caufe of this wonderful effect? Why the live Coal requires a great deal more Fire to keep it burning, than is contained in Alcohol, whilft it is boiling; and Alcohol when it once boils, cannot afterwards acquire a greater degree of Heat. The hotter Coal therefore being flung into this colder Fluid, muft of neceffity lofe that greater Heat, which was requifite to keep it on fire; and therefore it will be extinguifh'd or reduc'd to 180 degrees of Heat, which are fufficient to make Alcohol boil, but can never fet on fire any fort of combuftible matter, that is, can never, by the affiftance of the Oil of any fuch matter, produce a lucid Fire. But farther, as the Coal is totally immerfed in the Alcohol; hence it is intirely kept from any communication with the external Air, and for this reafon the Coal is not able to fet fire to the Alcohol, but only with its firft *Impetus* puts the Alcohol into a greater motion, makes it throw out more of its Spirits, and by this means, as we explained before, juft for that inftant, increafes its Flame. If this glowing Coal now had been fo laid on the flaming Alcohol, that one part of it had been above the Surface of it contiguous to the Air, then it would have continued burning with the Alcohol, and that pretty fiercely.

EXPERIMENT III.

An examination of the pureft Flame.

I took a good deal of pains formerly to find out fome Experiment that fhould be fufficiently evident to the fenfes, by which I might come at the knowledge of of the action that Fire exerts upon its *Pabulum*; and at last, I brought the affair to the issue that I am now going to explain to you. To this purpose then, I again set fire to this pure Alcohol contained in this clean cylindrical Brass Vessel; and thus burning, as you see, I place it upon this Table, and put over it this large glass Cucurbit, which is one of the biggest that the Glass-makers can blow for chemical uses, and whose bottom I have carefully cut out in a circular figure, so that it is now a true Bell, whose diameter at bottom is ten inches, and whose top has an orifice that will admit one's little Finger. This clear glass Bell then thus every way surrounding the burning Alcohol, you'll evidently perceive all the *Phænomena* that I related to you, and shew'd you under the former Experiment. Fig. 3.

The first thing, then, remarkable here is this, that the whole surface of the Bell appears, as you see, opake, from the action of the Flame burning within, so long as the Bell itself remains cold: But now, as it grows warm by the Fire that's under it, you perceive that it begins again to look clear. By the same action continued, it is at present actually hot; and it is now become perfectly pellucid. If you look ever so attentively, now, you will not perceive the least kind of Fume in the whole cavity of the bell, but the Air throughout the whole space appears perfectly clear. And as the vessel in which the Alcohol is contained is cylindrical, hence the Flame, as far as the eye can discern, continues exceedingly equable, from the beginning to the end. At the bottom, however, of the inside of the Bell, you perceive something running down in streaks, like those that are formed in the distillation of Spirits.

This yields an exceeding limpid thin Vapour.

This liquor now is by no means the true spirit of the Alcohol, for it has a perfect watery taste. But that you may perceive this evidently yourselves, observe the fine Vapour that exhales through the upper Orifice: This, if it was really the Alcohol, raised by the Heat, would immediately take fire upon the application of this lighted match, as we saw in the preceding Experiment; but, on the contrary, when I move it into this exhalation, you observe the Flame of the Sulphur is extinguished by the Vapour, exactly as if it was held in the steam of hot Water. But again, I'll put this burning Match under the Bell, and thus hold it in the very place where the Alcohol is burning, and diffusing its Vapour; and you see, now, that it remains a'light, and burning, till it is quite consumed, but not in the least sets fire to the fumes that rise from the flaming Alcohol, and fill the whole Bell; which, had they retained their former nature of Alcohol, after they had passed through the Flame, must necessarily have taken fire upon the application of the burning Match. Hence, therefore, it seems to appear, that this matter, which, of all that we know of, is the most inflammable, whilst it is thus converted into Flame, and by this means, likewise feeds the Fire, is really changed into another substance, which, after this alteration, is no ways capable of supporting it any longer, but as far as we are able to judge, acquires the nature of Water. Did, then, this Water actually reside originally in the Alcohol, and so as not to be separated from it by any other method than this? Or did the Fire, by burning the Alcohol, convert it into Water, by a true transmutation? Or, lastly, was not this Water, in reality, supplied by the Air, during the time that the Alcohol was burning? These things, farther Experiments,

And indeed an aqueous one.

made

made by men of judgment, may hereafter determine. But here give me leave to caution you, that it's neceſſary, that the Alcohol uſed for this purpoſe ſhould, by a gentle diſtillation, in a tall veſſel, be drawn off of the drieſt Alcaline, fixed Salt of Tartar, that, by that means, the true Spirit of Wine may be freed from all the Water that it is poſſible, by any Art, to ſeparate from it; and with this ſort it is, that I make theſe Experiments before you, very well knowing, how cloſely the Water coheres with the pure Spirits, even with ſuch an union, that is not eaſy to be diſſolved. After I had examin'd Alcohol in this manner, I found, that the famous *Geofry*, the younger, a Gentleman of great application, and a particular genius for theſe Inquiries, had, in the *Mem. de l'Ac. roy.* Ann. 1718, publiſhed ſome very accurate and ingenious Obſervations, which, though made with another view, yet elegantly confirmed what I had before diſcovered by the method I have juſt mention'd. For my part, I was vaſtly ſolicitous to know what phyſical alteration it really is that inflammable matter undergoes, when it is ſo expoſed to fire, as to produce Flame, which is the pureſt of all Fires; and what at the ſame time, happens to fire, whilſt this combuſtible matter, in conjunction with it, riſes into Flame: For I imagined, if I could once come to a certain knowledge of this, it would be a good ſtep towards getting a better inſight into the nature of Fire itſelf. For this purpoſe, therefore, I prepared a matter, which being burned in a cylindrical veſſel, and thus being forced to paſs through the Flame, that intirely covers the whole ſurface, would totally feed the Flame, and be itſelf totally converted into Flame, without Smoke, Soot, or *Fæces*. When this, then, was expoſed to the pure Air alone, (without the admiſſion of which all Flame goes out) and ſo ſet on fire, I found it was intirely conſumed into Flame, that this Flame produced a very fine Vapour, and that this Vapour might be condenſed into Water, or, at leaſt, wou'd generate it: And thus far I was then able to proceed, and no farther. But had I now as much leiſure as I have inclination for theſe inquiries, I wou'd endeavour, by the help of more of theſe glaſs Bells, to collect ſome quantity of the Water thus produced; for I obſerved, as you yourſelves likewiſe did juſt now. that far the greateſt part of the Vapour paſſed through the upper Orifice, and was by this means diſſipated. Over this Bell, therefore, there ſhould be hung another of the ſame kind, that this Vapour, likewiſe, might be there received, condenſed, and rendered fit for examination. And a third, again, might be ſuſpended over this, ſo that by this means at laſt the Vapour might be totally collected. The propereſt time, now, for making this inquiry is, when the weather is exceeding cold, that the Vapour may be very quickly condenſed by the Cold, and frozen in the upper Glaſſes. And theſe Experiments ſhould be likewiſe made in a place that is very dry, and not incommoded with wind: Nor do I at all doubt, but that the thing will ſome time or other be diſcovered, the knowledge of which is as valuable as any thing in natural Philoſophy, and will be of infinite ſervice in the chemical Art. I know, indeed, that the worthy *Geofry* has inferred from his Experiment, that he could procure from pure Alcohol, by converting it into Flame, more than half its quantity of Water; and it is certain, that he did exhibit ſo much. But this excellent Chemiſt is well apprized what a great quantity of Water is diffuſed about through the Air; how imperceptibly this Water quits the Air, and inſinuates itſelf into ſaline, dry,

ſpirituous

ſpirituous Bodies, and, by ſubtilly mixing itſelf with them, often overturns our Obſervations: The blue Flame of the dryeſt burning Sulphur exhales into the Air, to a great compaſs, and, if it is collected under a Bell, produces a very ſharp, acid Liquor; which, if the weather is dry, is in a ſmall quantity, and always ſo much the ſtronger; but if the Air is moiſt and cloudy, it is in a greater, but then it is more watery. From this we can, by a gentle Fire, ſeparate a large quantity of inſipid Water, and from the remainder prepare a ſmall portion of a thicker liquid, that is exceedingly acid: If you expoſe this laſt now to the Air, in a broad veſſel, when thus ſimple, and freed from its Water, the Water in the Air will immediately unite itſelf with the pure Acid, increaſe both its weight and its bulk, and at the ſame time dilute, weaken, and render it leſs efficacious. Perhaps, now, the very ſame thing may happen to the Spirits, whilſt they are burning. Theſe things, however, bring again to my mind the expreſſions of the ancient Alchemiſts, who called them, the moving, or governing Spirit, the Child of the Sun, the Offspring of Fire, and the internal Fire of Bodies.

And another part that does not fall under the cognizance of our ſenſes.

Is it not poſſible, then, that this pure Spirit, which, in conjunction with Fire, produces Flame, and is abſolutely, and totally inflammable, may be but an exceeding ſmall part of the Body in which it is contained, but diſperſed thro' a large quantity of Water, and intimately united with it? Certainly, though we endeavour ever ſo artfully to confine this principal, we always find it ſo infinitely ſubtil as to eſcape our niceſt Obſervations. Tired in theſe inquiries, I confeſs, for my own part, that I have for a long time paſt deſired nothing more earneſtly, than rightly to underſtand the proper nature of that Matter in the Alcohol, which is truly inflammable; for I knew that I here was in poſſeſſion of ſomething which is perfectly inflammable. And I have for a good while been ſatisfied by Experiments, that all other inflammable Bodies are only ſo, as they contain Alcohol in them, or at leaſt ſomething, that on account of its fineneſs, is exceedingly like it, the groſſer parts of them that are left behind, after the ſeparation of this ſubtil one, being no longer combuſtible. I had the pleaſure, therefore, of believing, that if I could but once diſcover this in Alcohol, I then could very eaſily comprehend how Fire is ſupported in all other combuſtible Bodies. But how was I diſappointed when I found that Alcohol, by paſſing through Flame, would burn away into a Vapour, in which I could not diſcover any Alcohol; ſo that if this was really the remains of the Alcohol, it left nothing behind it but an exceeding pure Water. Theſe therefore I acknowledge the boundaries of my knowledge upon this ſubject: The *Pabulum* of Fire, when conſumed by Fire, leaves a Water behind it, but becomes itſelf ſo vaſtly fine, that it is diſſipated into the Chaos of the Atmoſphere, and gets beyond the reach of our ſenſes.

EXPERIMENT IV.

But by this new Experiment, the Opinion which I juſt now laid down, will appear more evident. For this purpoſe I have provided a live Coal, in this earthen Pan, which is ſo perfectly red quite through, that, as you ſee, there is not the leaſt appearance of Smoke; the Pan too is perfectly clean, and very dry. Upon the Coal I place this pure braſs porringer, which is about an inch deep, round at bottom, and four inches in diameter. Into this I now

A inſtantaneous production of the pureſt Flame.

pour ſome choice Alcohol of Wine, to the height of half an inch; and then cover the whole, as before, with the glaſs Bell. You may perceive, now, that the Alcohol, by means of the Coal in the Pan underneath it, boils pretty ſtrongly in the braſs veſſel, but does not take fire, or diffuſe any Fume that is viſible within the cavity of the Bell; nay though the exhaling ſurface of the boiling Alcohol is ſo broad, yet there does not appear the leaſt Vapour coming out of the upper Orifice. In the mean time, however, you begin to perceive ſome ſtreaks of the Spirits running down the ſides of the Bell, eſpecially about the lower parts of it. As you ſee, now, a conſiderable part of the Alcohol is, by boiling, exhaled out of the braſs porringer, it's time for us to try what will be the effect of applying a lighted Match to the upper Orifice of the Bell. This then I'll do; and you obſerve, that whilſt I thus hold it over the mouth, the Flame of the Match does not ſet fire to the Alcohol, that is floating about within the Bell, but is rather itſelf extinguiſhed. Hence, therefore, as the Alcohol, that is now diſperſed in the Bell, does not, by this means, take fire, you will be apt to imagine, that it does not appear, by the former Experiment, that the Alcohol, which was burnt by paſſing through the Flame, did really loſe its inflammability, or elſe, that this has loſt it likewiſe, purely by exhaling without burning at all: But pleaſe to attend, with a little patience, and you will ſoon be of another opinion. Obſerve then this lighted Match, which I now hold in a pair of Tongs, that I may be at a convenient diſtance from the effect of this dangerous Experiment. In this manner, then, I cautiouſly carry it along above the Table, in a horizontal direction, towards the glaſs Bell, 'till the Flame of it comes underneath the lower rim of it; and you ſee as ſoon as ever the Flame reaches within its cavity, the whole ſpace within the Bell, that is now filled with the Vapour of the boiling Alcohol, like Lightning, inſtantly flaſhes out, and that with a great noiſe, and ſuch a violence, that the moment it takes fire the Flame ruſhes out at the bottom, between the Bell and the Table. This happens, now, becauſe the whole cavity, being filled with the very minute particles of the Alcohol, and at once ſet on fire, is not able to contain all the Flame, which, therefore, will diffuſe itſelf through thoſe parts where there is leaſt reſiſtance, *viz.* in this caſe at the bottom; at which place, could it not have found a vent, it would have either blown off the Bell, or burſt it in pieces, not without a great deal of danger to the perſons about it. If ever, therefore, you make this Experiment, take this caution, never to come too near the Bell when you apply the lighted Match, nor ever to hold the Match in your hand, without a pair of Tongs; for otherwiſe, that Flame which burſts out at the bottom may very eaſily burn your hands and face. This, then, may ſuffice for the firſt part of this Experiment; let us now turn to the other.

Which ſets on fire boiling Alcohol.

The very moment, then, that the Flame was excited in the Bell, you obſerved the whole ſurface of the Alcohol that was boiling in the braſs Porringer to be likewiſe perfectly covered with a bright Flame; which you ſaw did not in the leaſt take fire before, tho' the Fire underneath it made it boil pretty ſtrongly. Hence, therefore, it is very evident, that Alcohol will not eaſily be ſet on fire without the application of Flame to it. But the Flame of the Alcohol, now it is once lighted, continues burning under the Bell, till the Alcohol is quite conſumed, nor goes out before the Diſh is become perfectly dry.

dry. In this beautiful Experiment, now, nothing formerly gave me more pleaſure, than what you have all ſeen at this time, *viz.* that

The Flame that was raiſed by the match, at ſome diſtance from the veſſel in which the Alcohol was boiling, diffuſing itſelf through the whole cavity of the Bell, ſet on fire the Alcohol that was contained in that veſſel: But the very moment that this began to flame and burn, the Flame in all the other parts of the Bell inſtantly diſappeared, and this only upon the ſurface of the burning Alcohol remained quite to the end, till all the matter of the Alcohol was perfectly burned away; nor was there, from the firſt moment of accenſion, during the whole time, any other flame excited throughout the whole capacity of the Bell, than what juſt hovered over the Alcohol in the Porringer. Does it not, therefore, evidently appear, that pure Alcohol, though it is agitated with a pretty ſtrong Fire, provided it is not lighted, may be diffuſed through large ſpaces, without undergoing any alteration, and that it will ſtill poſſeſs its inflammability in the ſame degree that it did before, ſo that if you apply a Flame to it, it will in a moment take fire, and burn with a great deal of violence? Nor is it hence leſs certain, that the very ſame Alcohol, when it is forced to paſs out of its veſſel through the Flame that covers its ſubſtance, and is by this means forced to feed the Flame itſelf; I ſay, when it has thus exhaled through the Flame, into the cavity of the Bell, it is not leſs certain, that it has ſo perfectly loſt its aptitude to Flame, in an inſtant, that though the parts of the Alcohol are now attenuated by ſo much ſtronger a Fire, yet they can never afterwards be ſet on fire by the Flame that continues burning under the Bell. This extraordinary and ſurprizing *Phænomenon*, now, deſerves, certainly, the matureſt conſideration; for it does not at all ſeem probable, that the Fire can perfectly expell all the Alcohol, out of the large ſpace of the Bell, the very moment it has burnt it: And yet if the particles of the Alcohol, when they have paſſed through the Flame, float about in the cavity of the Bell, which ſeems very likely, then, if they remained ſtill inflammable, they muſt neceſſarily be ſet on fire by that very Flame. What ſhall we ſay, then, Gentlemen, in this caſe? If the only pure inflammable matter that we know of in nature, when it once takes fire, totally loſes its inflammability, muſt not there, of conſequence, ſo much of the true *Pabulum* of Fire be every day deſtroyed, as is thus conſumed by Flame? And for this reaſon, therefore, muſt not this at laſt be quite ſpent, if it could not, by ſome means or other, be recruited? Is this, therefore, continually ſupply'd by the operations of nature, in the bowels of the earth? And by which of them? By thoſe, certainly, by which it generates Oil and Spirits. And, hence, in particular, by vegetation, fermentation, putrefaction, and diſtillation. But all theſe operations, whether artificial, or natural, are performed by the efficacy of Fire alone. Fire, therefore, which deſtroys combuſtible matter, is that cauſe in the univerſe, by whoſe energy it is again renewed. Or does the other opinion ſeem more agreeable, which we propoſed before, when we made this Query, whether the matter that is intirely inflammable, does not, in reality, conſiſt of a large quantity of Water, intimately united with a ſmall portion of ſome other principle, that is vaſtly ſubtil, and very much reſembles, nay is, perhaps, Fire itſelf? Whence this Fire being ſeparated from the Water, by the

And is, at the ſame inſtant, extinguiſhed itſelf.

action of burning, would again be freed from its confinement, and become true elementary Fire. If you suppose this to be the case, then ultimate, inflammable matter would be Fire itself; and, hence, when it is set at liberty from every other Body, would, of consequence, be dissipated into the Air.

EXPERIMENT V.

The extinction of Flame by Oil.

I dip this flaming Match into this pure, cold, distil'd Oil of Turpentine, and you see it is put out in the same manner as if it was immersed in cold Water, exactly as it happened before in the Alcohol. And again; I throw this live Coal into the same Oil of Turpentine, and by this means it is perfectly extinguished, without producing the least appearance of Flame. Hence, therefore, almost all those things that we before asserted of Alcohol, will hold true likewise of this Oil; and for this reason, as they may be consulted there upon occasion, it is needless to repeat them here.

EXPERIMENT VI.

The increase of Flame by the same.

I have again put some of the same pure distill'd Oil of Turpentine into this brass cylindrical Vessel, and set it upon the Fire 'till you see it begins to boil. To the Vapour now that exhales from this boiling Oil, I'll apply this lighted Match; and you perceive that when I do this, it is much longer before it takes fire than the boiling Alcohol was, tho' at last it does light and burn. You observe farther, that a black Smoke arises gradually from it, and as this appears, the Oil burns with more violence, till at last you see the Flame grows very fierce and vehement: And now it is burnt out, there are no *Fæces* left at the bottom, but it is all intirely consumed. The purer now, and more limpid this Oil is, so much the less black Smoke it always emits, and burns away more quietly. This therefore is the case, when it has been purify'd by repeated Distillation, for in every Operation it gets rid of some of its *Fæces*, but at the same time approaches so much the nearer to Alcohol, in lightness, limpidity, purity, and disposition to burn. But tho' by this means it constantly comes nearer to the nature of Alcohol, yet still it does not in reality ever become Alcohol, as it is never capable of being mixed with Water.

EXPERIMENT VII.

Examination of the Flame of burning Oil.

The same Oil of Turpentine being exposed to the Fire in this brass Vessel till it boils, and being then set on fire, I'll place it now, whilst it is burning, upon this earthen Plate, and cover it with the glass Bell. It burns now you see as in the sixth Experiment, but then with this difference, that it sends forth a black, thick Smoke, that fills the whole cavity of the Bell, rises through its upper orifice, sullies its sides with Soot, and fixes at the same time a kind of watery Vapour all round it: So that one would believe, that Water was here likewise produced from the burning Oil, or else by the concurrence of the Air. Hence, therefore, it appears, that Oils, which come nearest to Alcohol, tho' they are acted upon by Flame, and compelled to pass through it, yet will still retain some inflammable parts, that are not perfectly burnt away, but are only converted into a Coal; and that these being expell'd by the Fire out of the Flame in form of a sooty Smoke, are dissipated to a great distance, and afterwards being deprived of their first motion fix to the sides of Chimnies.

And

And this the fetid ſmell of burning Oil, which may be perceived a great way off, ſufficiently demonſtrates. Theſe parts therefore, ſeem of too thick and tenacious a nature to be ſo ſoon reduced by the quick action of the Flame, to the ſubtlety of the fineſt Alcohol. When theſe Oils now are made uſe of for common Lamps, and have a Wick in them that is every way ſurrounded by the Air, they then burn with a ſmaller flame, and much more leiſurely; and at the ſame time they produce a great deal more Soot, as the Blackneſs that ſoon ſettles upon a clean Paper held over them plainly evinces. But when they are thus ſet on fire in a cylindrical Veſſel, the whole Surface of the burning Oil being perfectly covered with the incumbent Flame, all the Particles of the Oil as they conſume, muſt neceſſarily paſs through the Flame itſelf, and conſequently will be more forcibly attenuated, and changed by the action of the Fire, than they are in the Lamps abovementioned; for there the oily Particles being put in agitation, have a free paſſage into the ambient Air, from every point of the Surface of the Flame, and hence fly off, without being totally altered by the force of its Fire. From all that has been obſerved then, it ſeems exceeding probable, that if by any Art Oils could but be reduced to the ſubtlety of Alcohol, then the Flame that is excited by them, would be free from Smoke, and the Fire from Soot.

Experiment VIII.

Examination of Alcohol and Water burning together.

I have in this clean braſs cylindrical Veſſel, mixed ſome very pure Water, with an equal quantity of the choiceſt Alcohol, ſo that now after ſhaking them together, they appear you ſee a homogeneous Liquor. This Mixture then being heated, and ſet on fire, I'll place again under the glaſs Bell. You obſerve now, that the Flame that riſes hence, is much weaker than that which we ſaw in the firſt Experiment upon this Subject; nor does the colour of the Flame by any means come up in brightneſs to that of the pure Alcohol. And you perceive too likewiſe, that this Flame, before it goes out, hovers a long while over the Surface of the Liquor, and then diſappears, leaving the Water behind it in the bottom of the Veſſel, in which there remains but a very ſmall portion of the Alcohol, as the taſte of it evidently demonſtrates. Hence then we underſtand, that tho' Alcohol is mix'd with Water, yet it will be extracted thence by the power of Fire, and conſumed by it; and that at the ſame time the Water is repell'd both by the Alcohol, and the Fire.

Experiment IX.

Of Alcohol and Camphire.

In this very pure Alcohol, I have diſſolved ſome fine Camphire. This Mixture now, I'll ſet on fire, and place burning under the Bell, as in the former Experiments: And the event is pretty remarkable. For firſt you ſee it takes fire exactly in the ſame manner as if it was ſimple Alcohol, and all the *Phænomena* appear perfectly the ſame; and that the pure Alcohol is thus firſt conſumed, and the Camphire without burning is depreſs'd to the bottom of the Veſſel, where it is collected in a Body by itſelf. But the Alcohol now being all diſſipated by the Fire, you obſerve another Flame ariſing perfectly different from what appeared before, whilſt the Alcohol was burning; for this you ſee is ſtronger, whiter, more lucid, and its Vibrations are greater than the former. At the ſame time too, this Flame produces a black Smoke; and then both the ſmell and taſte of the Camphire aſcend from the Flame, and diſperſe themſelves not only through the cavity of the Bell, but alſo through this whole apartment. This Flame now you perceive laſts as long as there is any Camphire remaining, and when it goes out, leaves no *Fæces* behind it in the bottom of the Veſſel. Hence, therefore, we may learn, that if inflammable ſubſtances of different natures are united together in one compound, they will not burn away at the ſame time; but the moſt ſubtil part will be firſt of all conſumed by the Fire; and the remaining groſſer part will continue defended as it were under the burning Flame, and will then only begin to take fire when the former is diſſipated. In combuſtible Subſtances, is that always firſt, and moſt eaſily ſet on fire, that is the lighteſt of them all? This certainly ſeems to be the caſe univerſally. Is the Flame that is excited in burning Alcohol too weak to ſet Oil on fire? This too ſeems exceeding probable: And hence, as ſoon as ever the Oil, or the Camphire diſſolved by the Fire begins to burn, the Flame immediately you ſee becomes fiercer. Does then Fire by burning combuſtible Bodies, as well as by diſtilling them, ſeparate their differently inflammable Principles, according to their various degrees of ſubtlety, or ſpiſſitude, the Spirits, for inſtance, firſt, then a thin Oil, next an Oil that is a little thicker, and laſtly, a thick, pitchy, tenacious Oil? This plainly appears in this Experiment. Is this then the reaſon, that Charcoal, and the like Subſtances prepared by Fire, and conſiſting of an Earth and Salt covered over with this laſt very thick Oil, yield a ſtronger Fire than can ever be procured from Wood before it is thus burnt? This certainly is found to be univerſally true, that the Fire that is excited by burning Oil, is always ſo much the more violent, as the Oil has a greater ſpiſſitude, and is more ponderous. That this was the caſe juſt now in burning Alcohol, and Camphire, you yourſelves are witneſſes. And all theſe things are confirmed by the moſt common Experiments: As every body knows, that a Fire then gives moſt Heat when the ultimate combuſtible matter comes to be burnt. The burning therefore of combuſtible Bodies muſt not be looked upon as an action, that at once mixes, blends, and conſumes all the different kind of inflammable Elements together; for it appears on the contrary, that this is effected diſtinctly, and ſucceſſively.

EXPERIMENT X.

Of Oil and Alcohol.

Let us now make the ſame trial upon Alcohol of Wine, ſo intimately mixed with fine diſtill'd Oil of Turpentine, that the Mixture appears perfectly homogeneous. This therefore I'll ſet on fire under the Bell in the ſame cylindrical Veſſel, that we may ſee what will be the event. In the firſt place then, we obſerve riſing from this burning Mixture, a beautiful, ſtrong, very bright Flame, which is exceedingly equable, and appears divided at top into two parts. This now, as far as we can diſcern, does not exhibit the leaſt appearance of Smoke, or generate or depoſit any viſible Soot; but yet it has ſo diſcoloured this white Paper that I held over the upper Aperture of the Bell, that you perceive it is grown quite black; whence it evidently appears, that there immediately upon the mixture ariſes ſomething in this pure ſimple Liquor, which is able to diſengage itſelf from the Flame, before it is perfectly conſumed. At the ſame time, however, there is not the leaſt diſagreeable ſmell in the Vapours of this Flame; and it waſtes away ſo quietly, that there is not the leaſt noiſe produced by it whilſt it is burning. But in the ſecond place, the Flame having now conſumed all the Alcohol that was contained in this Mixture, the appearance you ſee is intirely altered: for the Oil of Turpentine is now left burning at the bottom of this Veſſel, and the Flame of it leaps, ſparkles, and makes a noiſe, ſends up a great deal of Smoke, and leaves at the ſame time ſome reſinous *Fæces*, which are not combuſtible by this Fire.

EXPERIMENT XI.

I have again mixed ſome perfectly pure Alcohol, and a very ſtrong alcaline Spirit of *Sal Ammoniac* in equal quantities, and by this means have procured this ſurprizing *Coagulum*, which was long ago known to *Lully*, and was ſo much celebrated by *Van-Helmont*. And I think it worth while to expoſe to your view what I have myſelf obſerved in burning this in the ſame manner as we did the former. What now do you judge will be the conſequence? The unforeſeen events that ſo often deceive our expectation in trials of this nature, make you cautious no doubt how you determine. Let us therefore make the Experiment. You'll now anſwer then, that the Alcohol will be firſt ſet on fire; that this being conſumed, and diſſipated, the Flame goes out; and that then there remains at the bottom the alcaline Spirit of the *Sal-Ammoniac*, almoſt intire. And this is certainly the caſe; for you obſerved, that when this pure *Offa-Helmontiana*, was heated, ſet on fire, and placed under the Bell, it firſt of all exhibited a very weak, equable Flame, ſcarcely viſible, without Smoke, or Soot; tho' the inferiour part of the Bell however, was render'd pretty opake by the exhaling Vapour. You then took notice in the ſecond place, that the Flame grew ſtronger, more lucid, ſparkled, made a hiſſing noiſe, grew unequal, and hover'd about, and ſoon after went out. At laſt there was diffuſed a ſmell of a volatile, alcaline, ſpirituous Salt; tho' the Vapour collected into a Liquor on the ſides of the Bell was almoſt inſipid; and as I ſhew'd you, there remained at the bottom an exceeding ſharp, ſtrong, Spirit of Urine, very volatile, and ſtrong ſcented. In this Experiment now there's one very ſingular *Phænomenon* that well deſerves our obſervation, which you'll conceive in the following manner. The Salt contained in the alcaline Spirit of the *Sal Ammoniac*, is much more volatile than even the Alcohol itſelf; as appears in the ſublimation of this *Offa* of *Van-Helmont*, with a very gentle Heat; for in that Operation, a dry Salt always riſes firſt; and yet whilſt it is burnt in this manner, the Alcohol in this Mixture is firſt of all attracted upwards into the Flame, and ſo conſumed; and altho' this Mixture is heated in the braſs Veſſel, and is at top very forcibly agitated by the Fire, nevertheleſs, this very volatile Salt is forced downwards with its Water, and is ſo confined under the incumbent Flame, that it is not capable of diſengaging itſelf, or breaking through it. And this, Gentlemen, I beg you will conſider in a particular manner, as it will help us to a knowledge of the nature of Flame, and combuſtible matter, which has not hitherto been much taken notice of. But ſince now Camphire is looked upon by many famous Chemiſts, as a ſolid *Sal valatile Oleoſum*, concreted like *Van Helmont*'s *Offa*, from two principles, the one a ſaline, the other an oily one; it will be worth while to try what will be the conſequence of burning

Of the Offa of Helmont.

burning this under the Bell likewise. We find, then, that upon the application of a Flame to it, it very readily takes fire, and then flames in such a particular manner, that one cannot look upon it without admiration. This Flame, as you see, is white, equable, and long; and terminates in a smokey cone, which is of a great length, and very small. But what a copious, dense, black Smoke does it likewise disperse through all the Bell! and at the same time, as you perceive, there are abundance of little black sooty particles, thrown out on all sides by the Flame, which are so heavy, that they fall to the bottom, and in which there remains the smell and taste of the Camphire, though the colour of them is black. In the bottom, now, there are left hardly any *Fæces*, the Camphire having quite done burning. Hence then we may make some judgment of this wonderful Body; and you'll believe with me, that it is a very perfect simple Resin, or an Oil existing in a solid form.

EXPERIMENT XII.

Of Alcohol and Earth.

I have here a very pure Earth, *viz.* *English* Chalk, reduced to powder; with which I'll mix some of the same Alcohol of Wine, as intimately as possible, and set it on fire under the Bell, as in the former Experiment. The Alcohol, then, you perceive, burns away intirely, as in the third Experiment; but the Earth, you see, remains at the bottom, perfectly dry, pure, intire, and without any Alteration.

EXPERIMENT XIII.

Of Alcohol, Oil, Camphire, the *Offa Helmontiana*, and Earth, all mixed together.

But none of these Experiments are more entertaining than that which I am going now to shew you. For this purpose I mixed Alcohol, Camphire, and Oil of Turpentine together, in such a manner, that they were most accurately dissolved one amongst another; and to these I then added the *Offa* of *Van Helmont*, which will bear conveniently enough too, to be united with the former; and I afterwards worked all these, thus mixed together, with some of that fine earth, *English* Chalk, so as to form them into a mass, with which I then mixed some shavings of wood. This, now, I'll set on fire before you, under the same circumstance as in the former Experiments, and beg that you will observe the issue. The Alcohol then you see burns away, in the first place, almost in the same manner as if it had been set on fire by itself. This being consumed, the Oil of Turpentine next takes fire, and sufficiently distinguishes itself by its particular *Phænomena*. In the third place, you see the evident signs of the burning Camphire. And, at last, the alcaline spirit of the Sal-Ammoniac, the shavings of the wood, and the pure Earth, are left at the bottom. You observed here how strong, unequal, and red, the Flame was, and how it crackled and made a noise, whilst it was burning: And what a small quantity of Smoke rose in the beginning; which afterwards increased, by degrees, till it at last became exceeding black, and very thick. Then too there was produced a very black and dense Soot. And towards the end you perceived flakes of Soot flying about within the cavity of the Bell. As for the Wood, you see the Flame has not affected it. From all these things, then, carefully considered, you have, I think, a fair opportunity of discovering the method which nature makes use of in consuming combustible matter by Fire; which certainly is very different from what people generally imagine;

imagine; at the ſame too you have learned, that there is hardly any thing in all natural philoſophy that is more difficult to underſtand, than what corporeal ſubſtance that really is, which is ſolely inflammable, in combuſtible Bodies. It is a very eaſy matter, indeed, to talk of Oils, Sulphurs, and nitrous ſubſtances too, which ſome people have very injudiciouſly added, and to aſſert, that theſe are the bodies that conſtitute inflammable matter: But to diſengage that which is purely inflammable from every thing elſe, and thus to examine it, and diſcover its nature, is a very difficult task; nor could I ever meet with any one who could give any tolerable account of it; much leſs of the alteration that Fire actually induces in it whilſt it conſumes it. But of this enough.

SCHOLIUM I.

1. In the firſt place, then, there is diſcovered in nature, and that produced from Vegetables, by fermentation and diſtillation, a certain Liquor, of all that we are hitherto acquainted with, the ſimpleſt, the moſt limpid, the lighteſt, exceedingly immutable, and capable of being mixed with Water and Oils, which is of ſuch a nature, that if it is heated, and has a Flame applied to it, it will eaſily take Fire, will then totally burn, and feed and ſupport a pure Flame in every point of its ſurface that is contiguous with the Air, and by this means will have its whole ſubſtance gradually conſumed into Flame, as its particles, by degrees, come to be contained in this ſurface: And this will ſucceed in ſuch a manner, that ſo long as there is the leaſt drop of this liquid remaining, the Flame will continue to burn, and the very moment it is intirely burnt away, will totally diſappear, without leaving the leaſt indication of Flame behind it. We are therefore in reality maſters of ſuch a Fluid that properly deſerves the name of Aliment or *Pabulum* of Fire; ſince as far as our ſenſes are capable of diſcerning, it may, by burning with an open pure Flame, be totally and abſolutely converted into the pureſt Fire. For if you pleaſe, Gentlemen, to conſider this affair attentively, what does become of all this Alcohol, when it is thus conſumed? Is it not changed into the pureſt Flame? But is not all the Flame that is excited and ſuſtained by this means, exactly the ſame in every effect as that Fire which we have already deſcribed by its proper phyſical characters? Certainly there is not any one thing taken notice of in our whole hiſtory of true Fire, that does not equally hold good of the Flame that is fed by this Alcohol. Alcohol the one pure inflammable Body.

2. But we obſerve here in the ſecond place, that the Fire thus collected about the Alcohol, perſiſted to be Fire there, ſo long as any of the Alcohol remained, without adding any other Fire to it, or bringing any to it by any means whatever; ſo that when once the Alcohol was ſet on fire, it was conſtantly preſent there, nor needed any other Body, or any other *Pabulum* to continue it, when it was thus excited in the open Air. Which, without any aſſiſtance, ſupports Flame, when once excited.

3. Thirdly, there is this farther remarkable, that as ſoon as ever the Alcohol was conſumed, there was not the leaſt remains left of the Fire or Flame; ſo that it did not continue one moment after that was burnt away. This *Pabulum*, therefore, is the true cauſe that procured at leaſt the preſence Which goes out as ſoon as this is conſumed.

of

of all that Fire, in that particular place; for this never remains when that is diſſipated.

Nor does it produce any Smoke.

4. Fourthly, there is this particularly ſingular in this Aliment of Fire, and the Flame produced by it, that from the firſt moment it began to burn, to the moment of its extinction, it never emitted the leaſt Smoke, which every other kind of fuel is obſerved to do, either at the beginning or the end.

But a Water.

We found, indeed, that a moiſt Vapour did evaporate from the Flame of the Alcohol; but this being a very limpid aqueous fluid, formed only a perfectly pellucid exhalation, which being afterwards collected, produced a pure ſimple Water, in which there was not diſcoverable, the leaſt colour, thickneſs, or oilineſs. This, now, is particularly ſurprizing, as we don't know of any other liquid, or ſolid Body, in the whole compaſs of nature, that will feed and ſuſtain fire, abſolutely without any Smoke at all.

Nor yields any Aſhes.

5. We learn again from theſe Experiments, in the fifth place, that Alcohol does not contain any matter that is fixed and incombuſtible; for if it is perfectly pure, as it muſt always be for this Experiment, when it goes out, it won't leave the leaſt ſpot behind it; nay, it will be totally converted into more Flame, without producing the very ſmalleſt quantity of *Fæces*. This again we obſerve no where elſe but in Alcohol; for all other inflammable ſubſtances leave ſome *Fæces* behind them, which are not combuſtible; though indeed, thoſe that are very pure leave but few. *Naptha*, *Petroleum*, and Camphire, yield a bright, ſtrong Flame, but they depoſite ſomething in the bottom of the veſſel where they are burnt, that is not ſo combuſtible: Alcohol is the only one that leaves nothing.

Nor cauſes any diſagreeable Smell.

6. Sixthly, Alcohol, when it was thus ſet on fire, did not diffuſe any diſagreeable Smell, of a different nature from what naturally belongs to it. But this again is not the caſe with any other combuſtible matter; for every thing elſe ſends forth a rancid, ſooty Smell, or an empyreumatical one, when it is reduced to Flames in the Fire. One would thence, perhaps, be ready to imagine, that all the parts of Alcohol are perfectly homogeneous in their natural ſtate, and that they remain ſo during their burning, and after they are burnt; unleſs thoſe obſervations, of Water's riſing from the Flame of Alcohol were againſt it, and taught us, that even in Alcohol there reſides ſomething that is not combuſtible.

It has no ſolid Subſtance formed from it.

7. In the ſeventh place, we hence learn farther, that in this Body which alone when expoſed to Fire, diſcovers the properties above mentioned, there is not the leaſt appearance of any ſolid ſubſtance; not even to the ſharpeſt eyes, aſſiſted by the moſt perfect Microſcopes: Hence, therefore, a ſolid form is no ways neceſſary to render Bodies a proper *Pabulum* for Fire; but on the contrary, the moſt liquid one that human obſervation has ever yet diſcovered.

But is tenacious of Water.

8. But we perceive yet again, in the eighth place, that this Alcohol is of ſuch a nature, as to attract, take in, and unite to itſelf the pureſt, elementary Water; but that at the ſame time the Flame excited in the Alcohol, will again attract the pure ſimple Spirits of Alcohol out of the Water and Alcohol thus blended together, and having drawn them to the ſurface of the mixture, will then imbibe them, conſume them, turn them into Flame, and by that means ſeparate all the pure Alcohol from the Water that is mixed with it; and at the ſame time refuſing to be united with the Water, will repel this, and depoſite it in the bottom of the veſſel.

9. It's

9. It's ſurprizing now, in the ninth place, that the very ſame Alcohol, perfectly the ſame in every reſpect, may, by fermentation, and a gentle diſtillation, be procured from every kind of known Vegetable, that is naturally diſpoſed to ferment: Whereas, excluding the vegetable Kingdom, and the aſſiſtance of fermentation, examine all the Bodies you are acquainted with in the univerſe, and you will not find one that is poſſeſſed of the properties above deſcribed. And is a true Offſpring of Vegetables.

10. But farther, in the tenth place, from what has been obſerved in theſe Experiments, we are of opinion, that though Alcohol be ever ſo pure, yet there is in reality ſome difference in its conſtituent parts, though not diſcoverable by any other Art than ſetting the Alcohol on fire; for by this means it is ſeparated into a Water, which when alone extinguiſhes Fire, and into an inflammable part, which is truly conſumed in the Flame, and reduced to ſuch a ſubtlety, that it afterwards becomes quite inviſible. *Van Helmet*, indeed, has told us, that by the application of Salt of Tartar to the pureſt Spirit of Wine, he could inſtantly convert it half into Water, the other part being retained and held faſt by the Alcali; but I always doubted, whether he ſhould not be underſtood to ſpeak there only of rectified Spirit of Wine, of which it is ſtrictly true, and not of pure Alcohol, ſkilfully prepared, of which I believe no body has hitherto ever made it appear. If theſe things, now, are really true, as they certainly ſeem to be, then Alcohol would very much reſemble Sulphur, as both of them would be totally conſumed in the Fire; both of them would yield a blue Flame; be reſolved into one inviſible part, that is inflammable; and whilſt they are burning, yield another part that extinguiſhes Flame; which in Alcohol is a mere inactive Water; in Sulphur, an exceeding acid Salt of Vitriol diluted with a portion of Water, whoſe Vapour is hence perfectly ſuffocating. But compounded. Other ſubſtances changed in the Fire like Alcohol.

11. In the eleventh and laſt place, we hence farther infer, that ſolid compound Vegetables, whilſt they are burnt, are changed and agitated in the ſame manner; inaſmuch as their inflammable part alone is conſumed by the Fire, the reſt being diſperſed into a matter, which if it is again collected, becomes viſible, nay and ſometimes combuſtible too; or elſe, being converted into a fixed one, which we then call Aſhes, or *Fæces*.

Scholium II.

1. In the firſt place, then, Alcohol ſeems to have ſomething of the nature of Fire. This appears evident from many of its effects. Both of them coagulate Blood, *Serum* of Blood, and bile, and parch up, as it were, the fleſh, nerves, and *viſcera* of Animals, whites of Eggs, and Bread. Is Acohol, then, a magnet to Fire? It is certain, it has a power of attracting the light that approaches it. Does the mixing Alcohol and Fire together cauſe an efferveſcence, and by this efferveſcence produce Flame? Alcohol agrees with Fire.

2. Secondly, all other inflammable Liquids, let them be ever ſo ſubtil, if they are burnt in the manner propoſed, yield a viſible black Smoke and Soot, and leave ſome *Fæces* behind them, which are not perfectly combuſtible. This incombuſtible matter in the pureſt Oil is at firſt a mere Earth, to which there ſtill adheres ſome portion of Oil, in which reſpect, as it retains the nature of a Coal, there is yet ſomething inflammable remaining in it. But when theſe Oils are often depurated by an artful diſtillation, they always depoſite an Earth, Other *Pabula* produce *Fæces*.

grow conſtantly thinner, become more inflammable, produce leſs Smoke, Soot, and Aſhes; and thus continually come nearer to the nature of Alcohol: Repeat this operation, in the mean time, ever ſo often, yet you'll never reduce them to ſuch a ſubtlety that they'll bear being diluted with Water.

What would be the effect of Alcohol upon Fire if it had no Water mixed with it?

3. Thirdly, that Body, that we have diſcovered to be abſolutely inflammable, ſo that it will totally feed and ſupport Flame, yields not the leaſt Smoke in this Fire, produces no Soot, nor leaves any *Fæces* behind, but as far as our ſenſes are able to penetrate, has its whole ſubſtance converted into Fire; or at leaſt when it is ſet on fire affords us nothing but a pure Water. If it were poſſible then by any Art to ſeparate that part of the Alcohol, which is perfectly combuſtible, and hitherto unknown, from the Water that appears to be collected during its burning, and this afterwards ſhould be applied ſingly to pure Fire or Flame, what would be the conſequence? Would it then burn ſucceſſively, as it does now it has a mixture of Water with it? Or would it like lightning be conſumed in a moment? A cloſe meditation, certainly, ſuggeſts a good many things upon this head; but this pure ſpeculative knowledge, muſt not be too much indulged, but muſt give place to that more ſolid one founded upon Expements.

The true *Pabulum* of Fire vaniſhes in it intirely.

4. From what has been demonſtrated, we may venture to aſſert, in the fourth place, that that part of inflammable Vegetables, Alcohol, or Oils, which in reality is not combuſtible, is either an intimately united Water, a Salt, or an Earth. Theſe, then, if they could be perfectly ſeparated from Oil, or Alcohol, the remainder would be that ſimple pure matter, which is totally convertible into the pureſt Flame, without *Fæces*, Smoke, or Soot. In *Alcohol*, certainly, that very ſubtil limpid Vapour, which is collected in the Bell, whilſt the Alcohol is burning, is produced only from that watery part of the Alcohol that is not inflammable. All Aſhes, Smoke and Soot, therefore, that are mix'd with inflammable ſubſtances, conſiſt ſolely of Water, Salt, or Earth, nor of any thing elſe in nature, that we are acquainted with.

Whence ariſe Smoke and Aſhes?

5. In the fifth place, we learn farther, that the quantity of Smoke, Soot, and viſible Vapours in burning Vegetables, will be always ſo much the greater, as they contain more Water, Salt and Earth, in proportion to their Oil and Alcohol; for this is found to be the caſe univerſally, as well as in the Experiments we have been making. That is to ſay, ſuch Bodies, when they are on fire, yield ſome parts, which though they are attracted into the Flame, and agitated there with a violent rotation, yet will not be converted into that ſubtil evaneſcent matter, but will either be expelled upwards out of the Flame, or elſe will fall to the bottom. If you compare a piece of very green wood laid on the Fire, with another in the ſame circumſtances, that is ſo moderately dried as to retain its Oil, you will eaſily ſee a demonſtration of the truth of what I aſſerted.

What are the leſs combuſtible parts?

6. Sixthly, we find it is poſſible, that the parts of a combuſtible Vegetable that are not inflammable, *viz.* the Water, Salt, and Earth, may ſo far exceed thoſe that are, that the Alcohol, or pureſt Oil, will not be able to flame in the Fire, but only ſend forth a mere Smoke. Alcohol, if it is mixed with an hundred times its quantity of Water, will not take fire, tho' it is heated hotter than Alcohol is when it boils; and if it is thrown upon the Fire it will extinguiſh it. A piece of Wood that is very oily, but at the ſame time very green, and full of Water, yields a large quantity of Smoke, but no Flame.

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In fat clayey Potter's Earth, there is an Oil, which will take fire when alone, though when it is united with the Earth in ſuch a manner, that there is but a very ſmall quantity of Oil to a very great one of Earth, it refuſes to burn. And in every inſtance you examine, you'll conſtantly find this aſſertion hold true.

7. But, in the ſeventh place, I think there is nothing more remarkable in this affair than this, which has been already proved in the former Experiments, *viz.* that if Fire is applied to a combuſtible Vegetable, compoſed of combuſtible and incombuſtible parts, and ſo far exerts its power upon it, as to ſet the combuſtible part on fire, and at the ſame time, and by the ſame action, to minutely divide and agitate the incombuſtible one; then the Flame that is thus excited from the combuſtible and incombuſtible matter agitated together, will be much ſtronger than would have been produced by the combuſtible one, if it had been ſeparated, and ſet on fire by itſelf. For we always find Flame to be ſo much the weaker, as the matter is purer of which it conſiſts. The Flame likewiſe generated from ſuch a mixture, will always be more unequal than that which riſes from a ſimple inflammable Subſtance: and hence, ſuch a fire always makes more noiſe whilſt it is burning, ſo as ſometimes by its crackling and flying about to be very troubleſome. At the ſame time too it produces more Smoke, and a greater quantity of *Fæces*. The more incombuſtible matter now there is in any Body, the more violent will all theſe *Phænomena* appear, if you can but ſet it on fire, and make it burn. The greateſt ſtrength of Fire riſes from the parts that are not combuſtible.

8. But again, eighthly, it is univerſally certain, that the denſer, cloſer, or heavier the incombuſtible matter is, that is united with the Oil, the ſtronger will the Flame and Fire be that are produced by ſuch a Body, if ſet on fire. So that not only the ſolideſt part of any particular Vegetable yields the ſtrongeſt Fire, if compared with the reſt, (for who, that wants a ſtrong Fire, ever prefers the Flowers or Leaves of Trees to their ſolid Wood) but alſo of different Woods compared with one another, we obſerve thoſe afford the greateſt Fire that are moſt ponderous; thoſe the weakeſt, that are lighteſt. Thus, for Inſtance, compare Cedar with Sallow, or *Sideroxylom* with Poplar, and you'll find the ſtrength of the Fires they excite will be in proportion to their weights. And the *Pabulum* that is heavieſt.

9. But, in the ninth place, we muſt here have regard to the doctrine we laid down before, that no Vegetables will burn, 'till they are heated to that degree, which is neceſſary to make Oil begin to boil. Light ones, indeed, will grow hot with the ſame Fire ſooner than heavy ones; and therefore theſe will ſoon take fire, but thoſe more leiſurely: And for this reaſon you ſee that nobody makes Matches with ſolid Oak, but with ſpongy Reeds, or ſomething of that nature. But the ſooner they take fire, the weaker will be the Flame; and on the contrary, the longer they are before they light, the ſtronger and more durable will the Fire be that is raiſed by them: And hence, of conſequence, the heavier the Wood is that is to be burnt, the more pre-exiſtent Fire is always requiſite to ſet it on fire; and without this it will not grow hot, ignite, and kindle. No *Pabulum* of Fire burns of itſelf, but by means of Fire.

10. In the tenth place, theſe things being conſidered, it follows, that in the burning of Vegetables, all the combuſtible parts are not conſumed at once, but gradually, by the ſucceſſive action of the Fire. And here, during the time that the Fire is thus acting, that combuſtible matter, which is purely in- Burns ſucceſſively, and in order.

 flammable,

flammable, and consequently the lightest, always takes fire, is separated and changed first; for this sort grows very soon hot, is first put in motion, and is more easily extricated than any of the other. This being consumed, that matter is next agitated, heated, set on fire, and separated, that possesses the next degree of inflammability to the former. This then being likewise burnt away, that last of all begins to burn, that of all is the least combustible. And it appears by an infinite number of Experiments, that this ultimate combustible matter in Vegetables is a small quantity of Oil, firmly united to a great deal of fixed Earth. Hence, then, we see the reason why this Oil cannot be separated from this Earth, in close vessels, where there is no admission of fresh Air. And hence, likewise, we know that this last combustible matter will never yield a violent Fire; for whilst it is burning away, a small portion of the combustible Oil is gradually distributed through a larger one of the incombustible Earth; and hence it may be made red hot, and lucid, but will very rarely produce Flame.

And most at one certain time.

11. From what has been said, therefore, we perceive, in the eleventh place, that Fire which is raised by compound combustible matter, will be most violent when it is in the middle of its burning, *viz.* when all the elements are flaming in the most vivid manner: Whereas towards the end, if you would keep Fire up brisk, it is necessary to rouse it with a pair of Bellows; for then the earthy, saline, fixed parts, which are interspersed throughout, in the form of Ashes, always begin to damp the force of the Fire, which is now supported by a smaller quantity of Oil.

Weak in Alcohol.

12. In the twelfth place, we are farther certain, that the purest Flame of all, *viz.* that produced from mere combustible matter, without the mixture of any other particles with it, will never yield a very strong Fire; for it appears on the contrary, from former Experiments, that the purest *Pabulum* always produces the weakest.

What the incombustible part does in Fire.

13. Hence, therefore, contrary to the common opinion, we infer, in the thirteenth place, that the strength of Flame depends as much, nay, perhaps more, upon the incombustible elements in the burning matter, than upon those that are in reality truly combustible. And therefore the quantity of Fire in Flame raised from combustible Bodies, is more collected within the compass of this Flame, by the rotation of the immutable corpuscles that are mixed and whirled about with the rest, than by that fine volatile simple oily substance, that is agitated likewise by the Fire, in the same space.

Hence a two-fold matter of Flame.

14. In the fourteenth place, then, why may we not suppose, that there are two causes exerting their united forces in material Fire; the first, elementary Fire, and its proper simple *Pabulum*, *viz.* perfectly pure Alcohol; the second, other kind of particles dispersed through the Fire thus produced, and which one would call pure Fire, which, though they are not able to sustain elementary fire of themselves, yet being agitated in the former pure Flame, excite a violent action by means of their vibratory motions, which is very often much greater than could ever be brought about by this agitating cause alone. That you may thoroughly take my sense, Gentlemen, please to reflect upon half an ounce of Gunpowder set on fire in the open Air; in this case, you know, a Flame will burst forth on all sides, and be over in a moment: But, now, if you put the same into a narrow cylindrical Tube, with some Bullets over it, and so fire it,

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it will then, by its own proper motion, force theſe hard thick Bodies out of the Tube, with an incredible *impetus*, hardly any of which was obſerved before in the Particles of Gunpowder, tho' they were, by being ſet on fire, reduced to their moſt ſubtil Elements. In the ſame manner, therefore, you conceive, that the hard incombuſtible Particles of Vegetables being ſwiftly whirled about, and vibrated in the rapid Flame, muſt of conſequence add a vaſt deal of force to it.

15. In the fifteenth place then it appears, that the greateſt ſtrength of this Fire, may be rendered more intenſe by Water, Salt, and Earth, if they are intimately mixed with the combuſtible Matter, and with one another in this pure burning Fire; provided the force of this Fire is great enough to put theſe Bodies into a violent motion. Whence Fire is increaſed.

16. We obſerve again in the ſixteenth place, that ſome cauſe is abſolutely neceſſary, and that there really is ſome cauſe which continues this Flame, or keeps in this Fire, when it is once kindled. And one effect of this cauſe, muſt be the keeping the *Pabulum* of the Fire whilſt it is burning, cloſely apply'd to the Fire itſelf, ſo that they ſhan't be ſeparated from one another, which otherwiſe would inſtantly happen from the proper power of the Fire. But again, the hard incombuſtible Particles too, that are agitated by the action of the former combuſtible ones, muſt be likewiſe confin'd by the ſame cauſe within the compaſs of the burning Fire; that theſe likewiſe may not fly off too ſoon, but be compell'd to remain in the place where they are mov'd in ſuch a manner, as by this very motion to be continually expelled out of it: For unleſs this was effected likewiſe, all this matter muſt of conſequence be immediately diſperſed by the agitation of the Fire, and thus all the vibratory force of theſe Corpuſcles within the ſphere of the Fire, would be loſt in a moment. Hence, therefore, it appears, that all Fire would be momentaneous, was it not for this uniting, applying, and compreſſing power. It is probable, however, that this cauſe which compreſſes theſe Bodies together, muſt not act with ſo much force, as to unite them into one immoveable Maſs; for by this means the lighted Fire would inſtantly be put out: But ſuch a preſſure only ſeems requiſite, that the groſſer Particles, whether combuſtible, or incombuſtible, as they are agitated in the Fire, may ſucceſſively diſengage themſelves in proportion, as others begin to be put into the ſame agitation. Now for this purpoſe ſuch a cauſe appears vaſtly beſt ſuited, that acts with a reciprocal, oſcillatory compreſſion, and relaxation, itſelf all the while remaining perfectly fluid, and incapable of being conſolidated. Such a one now is our Atmoſphere, which perfectly ſurrounds us, and always compreſſes us. Before we proceed any farther, therefore, it is neceſſary to have a juſt notion what aſſiſtance the Atmoſphere really gives towards the ſupport of Fire; which I ſhall endeavour to explain as evidently as poſſible in the following manner. The cauſe of uniting Fire with its *Pabulum*.

Let us ſuppoſe a Fire kindled upon an iron Plate with the choiceſt Wood, and burning perfectly quite through, upon a Baſe a Rhineland foot ſquare. Upon this Baſe then there preſſes ſuch a weight of the Atmoſphere, as is contained in a priſm of Air, whoſe Baſe is of the ſame magnitude. The weight, however, of this Priſm, appears by the Barometer, to be different at different times; tho' the exceſs of its greateſt weight above its leaſt, is ſcarcely ever more than one tenth part of the whole. Let us imagine then the Atmoſphere at this The Phyſical manner explained in a common Fire.

time to be heavieſt, that is, the Mercury to ſtand at the height of 30 inches in the Barometer. Hence, if we ſuppoſe the ſpecific gravity of Mercury, to be to that of Water, as 14 to 1; and a cubic foot of Water at the ſame ſerene time, to weigh 64 pounds *Troy:* Of conſequence, the preſſure of the incumbent Atmoſphere upon this ſquare Baſe, will be equal to the weight of 2240 pounds *Troy.* This Fire-place, therefore, is preſſed upon by this vaſt weight at this time. But in this very place, by ſuppoſition, there is burning a flaming Fire, which repels from it on every ſide, and elevates with an incredible force all this bulk of the Atmoſphere that is in its way, and at the ſame time expells from the ſpace in which it is burning, all the heavy matter of the Atmoſphere; and hence, of conſequence, muſt increaſe its weight. It appears then, from the doctrine of Hydroſtatics, that the reſiſting Fluid of the repell'd Atmoſphere will preſs upon every point of the burning Surface; which therefore will be as ſtrongly compreſſed by this weight, as if it was confined in a Furnace ſo ſtrong that it would not break with the weight of 2240. All the inflammable Particles, therefore, that are agitated in this Fire-place, by the force of the elementary Fire collected there, and all thoſe Corpuſcles likewiſe that are incombuſtible, but are put in motion by the action of both the former, as they endeavour to diſengage themſelves from the Fire, are repelled towards its center by this vaſt weight, and that conſtantly, and exactly, ſo much the more as the Fire exerts itſelf within more violently. Hence, therefore, you perceive, that the Elements of the Fire itſelf, and the Particles of the combuſtible Matter, muſt be applied to one another, and compreſſed together with this prodigious force, and at the ſame time muſt undergo a very rapid concuſſion, and circumvibration among themſelves from the incredible expanſion, and active power of the Fire. Muſt there not therefore be excited a prodigious attrition in this Fire among theſe ſolid Particles? And will not the compreſſion of theſe to one another, whilſt they are thus agitated, increaſe in proportion to the greater attrition generated by the Fire? But the Fire is continually acting upon the Atmoſphere by unequal concuſſions, which always makes an equal reſiſtance: And hence this collection of Fire is beat upon by the continual return of the Atmoſphere, with as much force, as if it was every moment ſtruck upon with a Hammer of 2240 pounds. But we are farther certain, that the Air boils very violently over Fire, as one may perceive by expoſing a live Coal to the Solar Rays, and then looking upon it towards the Sun, and hence the *ſubſultus's* of this very elaſtic Fluid, boiling thus ſtrongly, muſt be ſtill ſo much the more violent and frequent upon this Fire. If now, in any part of this burning ſpace, the Fire yields leſs reſiſtance than in the reſt, then, the Air being driven thither by the weight of the Atmoſphere, muſt ruſh in with a prodigious violence, and being inſtantly rarefy'd, and repelled again, will produce a continual ſtrong oſcillatory motion round the whole compaſs of the Fire. So long therefore as there remains Fire enough in this Fire-place to excite a Flame with its proper *Pabulum*; ſo long as the other incombuſtible Particles can be forcibly agitated by the action of the Flame; and ſo long as they continue to be preſſed together by the weight of the Atmoſphere, that they are not able to extricate themſelves: So long the attrition excited in this ſpace, will be ſo great, as to collect ſuch a Fire here, as is ſufficient to continue the like Flame. But on the other hand, as ſoon as ever the active elementary Fire, the true inflammable

 Pabulum,

Pabulum, or the other groſſer hard immutable Particles that ſhould be agitated among the other, are wanting, then the Fire preſently grows weaker, and goes out: If the preſſure of the aereal arch too is by any means leſſened, or made leſs ponderous, the Fire immediately likewiſe loſes its ſtrength; and if it happens to be diminiſhed to a very great degree, then the Fire, *Pabulum*, and other Particles, inſtantly fly aſunder, and are diſſipated. Hence in *Boyle*'s *Vacuum*, all Flame, and then ſparkling Fire, ſoon goes out; as there is nothing there to keep the Particles apply'd to one another. And from the ſame principles we ſee the reaſon why a moderate Wind very much increaſes the force of Flame; for it is then affected in the ſame manner, as if it was compreſſed by a heavier Atmoſphere. If the Wind, indeed, blows ſo ſtrong upon the Fire, as to deſtroy this arch of Air that ſurrounds it, the Flame will, then, be extinguiſhed in an inſtant; tho' perhaps the next moment it will be raiſed again by the ſame blaſt that blew it out. Hence, therefore, if you blow a Fire with a pair of Bellows, ſo as not to put it out, by breaking this arch with the too great force of the Wind, the application of the Particles to one another, will by this action be ſtronger, and conſequently the Flame more violent. But if two large pair of Bellows are placed in an oppoſite direction, and blown ſtrongly upon the ſame Fire, then the Flame, excited by this means in the middle of them, will be prodigious intenſe, fit for fuſing of Metals, and other Operations that require a violent Heat. This you may ſee at any time among your Workers in Gold, and other Metals. And from theſe Principles we ſee, laſtly, why Fires burn more fiercely than uſual, when the Air is contracted by a very ſharp Froſt; for then, the aereal Arch ſurrounds the Fire proportionbly cloſer, and confines it more powerfully, and by this means prevents the Corpuſcles, that are flying about and torrified in it, from extricating themſelves, till by the long continued action of the Fire, they are reduced to ſuch a ſubtlety, as to be able to paſs through the Air itſelf, and ſo to make their eſcape. But at the ſame time, likewiſe, the Fire exerts itſelf with the greateſt force in its upper parts, and leſs about the circumference of its Baſe; and hence the Air finding there the leaſt reſiſtance, preſſes both the Flame and Fire upwards; and ſince the Fire is moſt condenſed, and conſequently ſtrongeſt in the middle, hence the Flame will riſe higher in the middle than on the ſides where the force of the Fire grows gradually weaker; and of conſequence will diſpoſe itſelf into a pyramidal figure. But as ſoon as ever now the Surface of Fire is ſurrounded with ſuch a Body as cuts off the communication with the Air, then the Fire of the *Pabulum*, and the agitated Particles, ſoon loſe their motion, the Flame goes out, and the Fire itſelf is ſoon extinguiſhed, except you remove the cover, and let in a free Air; then indeed, it will preſently burſt out into Flame, or at leaſt may be raiſed to a bright, burning Fire.

The *Pabulum* of Fire does not become Fire.

17. But in the ſeventeenth and laſt place, if we carefully conſider every thing that has hitherto been demonſtrated, or delivered, it does not appear, that there is any Body in Nature, which being committed to elementary Fire, will in reality be converted or tranſmuted into Fire: For my own part, I have examined every argument that offers itſelf, and have not been able to find one that proves it. Hence, therefore, I dare not by any means aſſert, that either Alcohol, Oil, or any other Matter, becomes pure Fire by being burnt. I confeſs, indeed, that perfectly combuſtible Bodies are ſo changed in Flame, as to get

get beyond the reach of our preſent perception; but if we would have a proper regard to truth, we muſt not hence abſolutely aſſert, that they are therefore converted into Fire itſelf.

Of the Pabulum *of Fire in the Animal Kingdom.*

Combuſtible Matter from Animals.

Having thus then carefully treated of the combuſtible Matter diſcovered in the Vegetable Kingdom, we come now in the next place to examine that which is contained in the Animal one. But here, as every one knows, that the Bodies of Animals conſiſt of Vegetables reduced by their concoctive powers to proper nouriſhment, hence this head likewiſe is almoſt intirely exhauſted in our Hiſtory of Vegetables. And indeed, if we will credit Hiſtorians, the humours of the animal Body have ſometimes been advanced to that prodigious ſubtil oily nature, as to take fire like Alcohol, and yield a weak pure Flame. We have accounts too of Flames kindling about the exhalations of Men's Bodies; and *Helmont* takes notice, that the Wind of the Bowels being diſcharged upon a Candle, actually burned, and was converted into Flame. Theſe things, however, if they are true, certainly happen very ſeldom. As for the other Oils of Animals, they differ hardly any thing in reſpect of their inflammability from thoſe of Vegetables, and therefore the repetition of the Obſervations already laid before you, will here be needleſs. In theſe likewiſe we diſcover Water, Spirits, Salts, Oils, and Earth: And the nature, preparation, depuration, and effects of them in the Fire, are perfectly the ſame in Animals, as they are in Vegetables. If you'll pleaſe therefore to recollect what we have before delivered of the latter, and apply them to the former, the doctrine of theſe too I think will be ſufficiently evident. You may poſſibly, indeed, ſurmiſe, that the *Phoſphorus* procured from Animals, is an inſtance of ſome other inflammable Matter in Animals, than what is obſerved in Vegetables: But this may likewiſe, by the chemical Art, be extracted from the pinguious Coals of burnt Vegetables; eſpecially if they are of that kind, whoſe Juices very nearly reſemble the Humours of Animals, as has long ago appeared in the Muſtard. Any farther inquiry therefore upon this head, I think, is abſolutely unneceſſary.

Of the Pabulum *of Fire in the Foſſil Kingdom.*

It is particularly remarkable now, that the very ſame law of combuſtibility, which we took notice of in the two former, holds true likewiſe, even in the claſs of Foſſils. For here it is obſerved in the ſame manner, that the Oils alone are inflammable, the other parts not at all; and that all theſe Oils likewiſe yield ſo much leſs Smoke, Soot, and Aſhes, as they are more ſubtil and lighter; and on the other hand ſo much more, as they are thicker, and more ponderous. Poſſibly in theſe too, there may be ſomething that almoſt arrives to the ſubtlety of Alcohol; tho' at preſent, I confeſs, I don't know that ever any body has diſcovered an Oil in them that would bear to be diluted with Water.

Naptha like Alcohol.

I have read, indeed, of Fluids ſometimes diſtilling from rocks, that by the application of a lighted torch to them, would take fire, flame, and burn; and have likewiſe met with accounts of Streams running from Fountains, that in the ſame manner might be raiſed into Flames: But whether the ſame Liquor that would thus take fire, would bear to be mixed with Water too, the perſons

ſons that mention theſe things take no notice. As for the *Naptha* of *Babylon*, Hiſtorians tell us, that that was ſo ſubtil, volatile, and eaſily inflammable, that riſing, and being diſperſed through the Streets, it would take fire from the Torches that were carried about in the night, ſo that it ſeemed as it were to burn ſpontaneouſly, covering all the Surface of the Ground with a blue Flame that was not very ſtrong, and but little pernicious. This Liquor, therefore, on account of its exceeding ſubtlety, ſeems to come very near to the nature of Alcohol; for the ſame thing poſſibly might happen to our Alcohol, if it was diſtributed about in that hot country, in the ſame manner as we ſaw it take fire by the application of a lighted Match to its Vapour, when it exhaled into the cavity of the Bell. As it is hardly poſſible, however, to procure this ſort of *Naptha* genuine, at any price, hence we can ſcarcely come at any certainty about it: As for that which is commonly ſold about under that name, it has never any ſuch degree of inflammability, but is always thicker, and more tenacious.

Petroleum is likwiſe very ſubtil, but no ways comparable, either to the *Naptha* of the Ancients, or the Alcohol of the Moderns. This, however, if it is depurated by proper diſtillations, grows gradually more ſubtil, and ſooner inflammable, tho' it at laſt ſtill remains an Oil, nor ever is reduced to Alcohol. And here again, as we obſerved in Vegetables, the finer, ſubtler, and lighter the oily combuſtible Matter of Foſſils is, they always yield ſo much leſs Smoke, Soot, Stench, and *Fæces*; but at the ſame time the Flame is always in proportion the lighter, purer, and weaker. *Petroleum next to Naptha.*

As for the inflammable Foſſils that have a mixture of a groſs heavy incombuſtible Matter in them, they always take fire with more difficulty, and require a ſtrong blaſt of Wind, or Bellows to make them burn ſtrongly; but then the Flame and Fire that is raiſed from them, is ſo much the more violent, as we ſee evidently in the burning of the foſſil Coal: Such Bodies likewiſe emit an exceeding black, thick Smoke, (which has ſomewhat of a diſagreeable ſmell, and produces a good deal of Soot) and leave behind them a large quantity of Aſhes, which generally have an inſipid taſte, but are very heavy. Foſſil Coal.

Laſtly, amongſt the foſſil Bodies, that afford a *Pabulum* for Fire, there are ſome which conſiſt merely of a perfectly combuſtible Oil, united with an exceeding acrid, acid Salt. By theſe you'll eaſily perceive I mean Sulphur: Whilſt the oily combuſtible part now of this burns away in the Fire, the other very acid ſaline one (which exceedingly reſembles that Liquor which is forced from Vitriol by an intenſe Fire, and is called Oil of Vitriol) is incombuſtible in the Fire, and being collected by itſelf in form of a vaporous Fume, and then ſuffered to cool, goes by the name of Oil of Sulphur *per Campanam*. If this is then accurately freed from the Water that is mixed with it whilſt the Sulphur is burning, and thus rendered pure in its kind, it appears to be the heavieſt of all Fluids next to Mercury, and the moſt acrid we are acquainted with. And hence it happens, that Sulphur will not yield Flame, 'till it is firſt melted, and conſequently, made very hot; but as ſoon as ever the Flame is excited by the inflammable part, the very ponderous, corroſive, ſaline, acrid one, being agitated, attenuated, boiling in the Flame, and being hence driven outwards, produces at firſt in the Flame, a very violent Fire, tho' afterwards, indeed, when by the continued action of the Fire it is ſo divided, as to be able to break Sulphur.

 through

through the Arch ſurrounding the Flame, it floats about freely in the Air, and produces a Vapour that powerfully inflames all the parts of Animals it comes at, and hence, if it is apply'd to their Lungs, quickly ſuffocates them. And as for other Bodies that are expoſed to the Fumes that riſe from burning Sulphur, they are by this means ſurprizingly altered, and that, differently, according to their particular natures, and the relation they bear to the acid, which is the moſt ſo of any we know of in nature. Theſe effects now produced by the Fire of burning Sulphur, are generally aſcribed to the elementary Fire, tho' very wrongly: For theſe ought to be perfectly diſtinguiſhed, and it ſhould be conſtantly remember'd, that theſe effects are partly to be aſcribed to the elementary Fire partly to the combuſtible portion of the Sulphur, and partly to the Acid that is by this means rendered volatile. I don't think it neceſſary now to explain particularly what *Phænomena*, *Bitumens*, *Aſphaltus*, *Piſſaphaltus*, and *Pix Judaicus*, produce in the Fire; or what they ſuffer there. I believe this will be ſo eaſily underſtood, from what we have delivered already, that we need not ſtay upon this head any longer. It is ſufficient to take notice, that in all theſe there is a mixture of pinguious foſſil Oils, generally acid Salts, Earth, and frequently ſomething metalline or rocky; and that in them all, that only is truly inflammable, which is of an oily nature. As for the other parts of the compoſition, they afford a ſort of *Spicula* which fly about in theſe fires, and by their vibrations, ſurprizingly increaſe their violence, or give them ſome ſingular phyſical power upon ſome particular ſort of Bodies. Theſe then being diſpatched, I think we have ſufficiently treated of the nature of the *Pabulum* of Fire, for our preſent purpoſe. And now, therefore, from this whole Hiſtory of Fire, we may fairly deduce the following Corollaries, as truths which have been evidently demonſtrated.

Fire rarefies all Bodies.

1. Simple, pure, elementary Fire, inſinuates itſelf into, and rarefies all Bodies in the univerſe that fall under the obſervation of our ſenſes, whether they are ſolid, fluid, or compounded of both.

When alone always equable.

2. This power is ſo proper to Fire alone, that it is not common to any other Body in nature, that human knowledge is yet acquainted with. The effervesſcences, fermentations, and particular rarefactions of Bodies, do not prove the contrary.

3. This Fire, as diſtinguiſhed by this property, is always preſent in every place, as well in the ſolideſt *Plenum*, as in the moſt perfect *Vacuum*.

4. And this Fire is every where diſtributed in the moſt equable manner, 'till there ariſes ſome cauſe that is able to collect it, thus diſperſed, into one particular place.

Collected by attrition.

5. The firſt of theſe collecting cauſes, and perhaps the principal one, is the attrition of ſome ſort of Bodies with one another.

Expands itſelf.

6. Fire from its own nature is moved equally every way; or at leaſt, is ſpontaneouſly expanded in this manner.

7. It's poſſible, however, that this motion, or expanſion of Fire, may be ſo determined, that it may be directed in parallel, or converging lines; and this is a ſecond very common method, by which Fire is likewiſe collected.

May be determined by the Sun.

8. The principal cauſe that compels Fire, of itſelf thus undetermined, into a parallelliſm, is the Sun; for this Body is found to be of vaſtly the moſt conſequence for this purpoſe.

9. The

9. The cauſe then, that makes theſe Rays of Fire, converge, and unite in a ſmall ſpace called a *Focus*, is either reflection, or refraction.

10. And hence again we have a third manner of collecting Fire.

11. The rapid percuſſion of the coldeſt Steel, againſt the coldeſt Flint, in the coldeſt place, and weather, will in a moment produce the moſt intenſe Fire: This therefore furniſhes us with a fourth.

12. This Fire therefore does not any ways depend upon the Sun, with reſpect to its Matter.

13. It will continue, however, ſome while in Bodies, being united to them during that time.

14. And the time of its continuance, will be proportionable to the denſity of the Body with which it is united.

15. There is not, however, any Body yet known, that is able to retain Fire always, when it is once communicated to it.

16. This Fire now deſcribed in theſe 15 Particulars, is in reality that which every Body calls elementary Fire.

17. There is, beſides this, likewiſe, as people generally imagine, another ſort of Fire, which conſumes combuſtible Bodies into ſomething inviſible, which is ſuppoſed to be fed, and ſupported, and is falſly believed to convert combuſtible Matter into Fire itſelf: This is thought to be produced, when Fire firſt exiſting, is apply'd in the open Air, to a proper *Pabulum*. And by this means we have a fifth manner of collecting Fire; and that, the moſt common of all. Fire ſupported,

18. There is diſcovered, now, but one kind of matter in the Univerſe, which will feed Fire in ſuch a manner, as to be ſo intirely conſumed by it, that nothing will be generated by it, but pure, ſimple Flame, and nothing at all will remain behind, when the *Pabulum* is burnt away, and the Flame goes out: And this is pure Alcohol alone. By Alcohol.

19. Other Bodies, however, being mixed with the true *Pabulum* of Fire, whilſt they are agitated by and in the Fire, together with this *Pabulum*, are capable of conſiderably increaſing its power. And Oil, remains the ſame,

20. Upon the kindling a common Fire, therefore, there is no Fire created, or generated *de novo*; nor is there any deſtroy'd when it is extinguiſhed; nor does it undergo any alteration; nor perhaps has it any weight. The contrary, indeed, to this laſt aſſertion, ſeems to be grounded upon ſo many, and ſuch ſolid arguments, that after Mr. *Boyle* had publiſhed his Treatiſe, *Of the Ponderability of Flame*, it was thought there was hardly any room left to doubt of it; much leſs ſtill, ſince we have been favoured with thoſe Obſervations of Monſieur *Homberg*, concerning the great weight that is added to incombuſtible Bodies, by pure elementary Fire, where there is not the leaſt Mixture of any corporeal *Pabulum*; for by theſe, indeed, it ſeems plainly to appear, that elementary Fire may on a ſudden be ſo abſolutely concreted with Bodies, as to increaſe their weight very conſiderably. Theſe Experiments, therefore, both candour and love of truth, oblige me to lay before you. Firſt, then, Mercury, that was perfectly depurated by the help of Metals, and thus rendered more liquid than the native, being for a convenient time digeſted in a pure Veſſel by the Flame of a Lamp, was converted into a black, white, or red powder, and in the operation was ſomewhat increaſed in its weight. Secondly, the famous *Du Cloſius*, Nor becomes heavy.

demonſtrated before the *Academy* of *Sciences*, that Antimony calcined in the *Focus* of a burning *Speculum*, weighed a ſixteenth part more when it had been thus expoſed to the Fire, than it did before, notwithſtanding ſo much in the mean time was diſſipated in form of Smoke. But the egregious *Homberg* proſecuting the inquiry ſtill more accurately by the aſſiſtance of the *Focus* of *Tſchernhauſen*'s Convex, directed into a hollow Veſſel, ſeems to have made it much more certain, that true Fire may be united with Bodies; that by this union it will be concreted with them; that by this means it will produce with them a new Body perfectly different from the former, and add a very conſiderable increaſe to their weight. For this purpoſe, therefore, four ounces of powdered *Regulus Antimonii Martialis*, where expoſed to the *Focus*, as it was called, of the great dioptrical Glaſs of the *Duke of Orleans*, at a foot and a half diſtance from the true *Focus*, and was there frequently ſtirred about with an iron Spoon, 'till it would not ſmoke any longer; for at the beginning, and for ſome time after, it emitted a large quantity of denſe Fume. This Powder then, was found to weigh four ounces, three drachms, and ſome grains; ſo that it had gained about a tenth part of its whole weight. The ſame afterwards being expoſed to the true *Focus* of the Glaſs, was inſtantly put in fuſion, and by this means loſt three additional drachms, and grains, together with an eighth part of the firſt weight of the *Regulus*. Hence, therefore, it ſhould ſeem probable, that the *Regulus* loſt half an ounce by the Fumes of the firſt calcination, and gained three drachms of Fire, and that this fuſion afterwards took away thoſe three drachms of Fire that were thus ſuperadded. The Preparations of *Minium*, Quicklime, and other ſubſtances in the Fire, ſeem to evince the ſame thing. That this now was really the event of theſe, and ſome other Experiments of Mr. *Boyle*, I make no doubt; nor do I in the leaſt call in queſtion the capacity of theſe great Men for making theſe Experiments, or their integrity in relating them. This, however, in the mean time, is certain, that a Maſs of Iron of eight pounds, being made perfectly red hot quite through, did not acquire any additional weight. The degree of Heat, now, or quantity of Fire in the *Focus*, mentioned in M. *Homberg*'s Experiment, which was a foot and half diſtant from the true one, was by no means ſo great as that of this Iron; and yet I weighed this Iron when it was red hot, and left it in the Scale till it was quite cold, and there was no alteration in the weight. That calcination was performed in an iron Ladle, or an earthen Veſſel, and the matter to be calcined was continually kept ſtirring with an iron Inſtrument: Hence, therefore, the quantity of Powder might be augmented. The true *Focus*, in an inſtant, is ſuppoſed to expell again the Fire that was thought to be united with the Antimony. But who can venture to aſſert, that this was actually Fire? All Bodies thus calcined in the ſame Fire, do not acquire the ſame increaſe of weight, but thoſe only that abound with a corroſive Sulphur, as Antimony, Lead, Tin, Iron, and Orpiment. Hence, therefore, may be, this external, or additional part, is obtained by the Sulphur's corroding, and rubbing of the Particles of the other Bodies, and thus mixing them with the Matter to be calcined. And as for the increaſe of weight that Bodies are found to acquire, when expoſed to the Fire in glaſs Veſſels, ſuppoſed to ariſe from the inſinuation of the Fire into them, this is ſo inconſiderable, that it may poſſibly be aſcribed rather to what may be communicated to them from the Glaſs, than to the Fire itſelf. Theſe

Experiments

Experiments certainly ought to be made on purpose, and with the utmost caution; as nothing is more easy here than being deceived. Lest, however, I should be suspected of being too obstinate, or partial, in my opinion, give me leave to refer you to *M. Du. Hamel*, a Gentleman particularly careful in relating Experiments, in the *Mem. de l'Ac. Roy.* p. 14, 15. where you will see how very prudently he himself raises some difficulties after he has recited his Experiments. And there too you will meet with some other Experiments of the famous *Bouledue*, which almost evince the contrary.

21. It has appeared farther, that this elementary Fire may be increaesd in a particular place, to a prodigious degree; so that by this means, certain physical effects, not easily understood in any other way, may be produced, observed, and reduced to a natural History. This we see evidently in Dioptrics and Catoptrics; but more remarkably still when both their powers conspire in the same action. And of the effect of this Fire we take the more particular notice, because as there is here neither any heterogeneous mixture, nor any material *Pabulum*, hence the purest elementary Fire exerts itself alone, and thus plainly teaches us what is the proper power of simple Fire, when bodies are exposed to it. If we nicely examine, now, the effects of this Fire, we shall find they may be reduced to these two: First, both Liquids and Solids, that are volatile in the Fire, are dissipated by it in a moment; and secondly, almost all fixed Solids, that have hitherto been examined in it, run into Glass. The most intense elementary Fire, therefore, that has ever yet been discovered, either dissipates, or vitrifies. But, as I have often observed before, the utmost that we know of this Fire, is only what we are able to learn from the greatest degree of it, that we can excite, by the assistance of those Arts which we are at present masters of; and therefore, as in the nature of things it may by collection be increased, and rendered more intense through an infinite number of degrees, we must not imagine, that the possible action of Fire is as yet determined. On the contrary, certainly that force of Fire which is with us at present the greatest, is scarce, as one may say, a beginning of what may possibly be generated. Since, then, we see in that small increase of it, which is contained betwixt the greatest Cold and the Heat of that *Focus*, which is produced by the union of *Vilette*'s and *Tschirnhausen*'s together; I say, since we see, even in this small extent of augmented Fire, so many various, singular, and surprizing *Phænomena*, who can so forget himself as to think, that the Doctrine of the power of Fire upon Bodies is as yet exhausted?

May be rendered vastly intense by collection.

22. It is certain farther, that if this elementary Fire is collected in a particular place, let the cause be what it will, it may there be supported, by the help of proper *Pabulum*; which is always either Alcohol, or Oil procured from the animal, vegetable, or fossil kingdom. But again, this Fire being thus collected in this place, and supported by this *Pabulum*, may there likewise be prodigiously increased, by a greater weight of the incumbent Atmosphere, acting freely upon it; by a large supply of oily *Pabulum*, very strongly and intimately united in a proper quantity, with other very heavy Bodies; and by the action of a great many very large Bellows, blown swiftly, and so disposed as to unite their force in the center of the Fire. Now the ultimate effect of the greatest Fire of this kind that we are hitherto acquainted with, is, in Animals, and Vegetables, the production of Phosphorus; in Vegetables, the making

In various manners.

of

† Is not the fusion of Iron greater? See p. 25.

of Glass; in Fossils, the fusion of † Gold, which remains in this Fire, without suffering any alteration.

23. Having thus, then, explained to you the physical methods I am acquainted with, by which Fire may be collected and supported in any place, it remains now that we say something of that other most common and efficacious one, by which the same thing is effected, *viz.* the mixing different Bodies with one another, which affords us abundance of very extraordinary *Phænomena.* Of these, however, as there is an infinite number, it is impossible to mention them all, though it is necessary to touch upon some of them.

Of the Heat arising from the mixture of vegetable Substances.

The Philosophers have long ago observed, that upon mixing certain different Bodies together, there often suddenly arises a very considerable degree of Heat or Cold, evidently depending upon this cause: And this Heat or Cold, they took notice, did not exist in the Bodies before this Mixture, nor continued any longer than till this was perfectly compleated, the Bodies then returning again to the very same temperature they were of before. The history of these the Lord *Verulam*, in particular, began, and *Boyle* and *Hook* carried to greater perfection: A few instances I shall here exhibit before you. Give me leave, however, first to explain to you the instruments that have been contrived on purpose for these Experiments, and which I shall make use of as I proceed. ABCD is a large Thermometer filled according to Art with ting'd Spirit of Wine, which is fixed in such a manner to the board it is let into, that the lower part of it MBA may be free of the Wood, and thus the Vessels, in which the Liquors to be examined are to be mixed, may receive it without any difficulty; and to render the numbers on the side sufficiently visible, the board is painted very black, and these white. The Vessel, then, with the Liquid is to be placed in such a manner under this Instrument, that the whole Thermometer AB may be within the Vessel, and in the Liquor; and then let the other Liquor be poured in, and let them be well stirred about with a glass Pipe, that they may be intimately mixed together; and by this means the Thermometer will immediately indicate the alteration that is produced, with regard to Heat or Cold, from this mixture. By this instrument now, and this method, you will be able to see perfectly the whole Affair at a distance; let us now therefore begin.

Pl. V. Fig. 1.

EXPERIMENT I.

In this vessel are two ounces of rain Water, rendered exceeding pure by distillation in a tall Glass with a gentle Fire. In this other there is the same quantity of common Spirit of Wine. Both these Liquors, you shall see me examine with this small Thermometer; and you observe they have both 44 degrees of Heat. One of these, now, I put under the Thermometer just explained, which stands likewise at the same number 44. I'll now mix these together at once, and stir them about with this cold glass Tube; and you perceive evidently, that they have acquired such a degree of Heat from this mixture as to make the Thermometer rise to the degree 52. Hence then we learn, 1. That this pure Water, and the Spirit of Wine, were in the Air equally hot before the mixture. 2. That the Air, Spirit of Wine, and Water, had before this mixture the same degree of Heat. 3. That if Air and Water, or Air and Spirit of Wine, are mixed together, there will be no alteration produced in their Heat. 4. That upon mixing Spirit of Wine and Water together, they grow hot immediately, but not from the Heat that was in them before, for they were both equally hot or cold. 5. But from some other physical cause, which was latent in them, and which, upon the mixture, produced this Heat. 6. That this Heat, that is thus generated from this mixture, lasts no longer than during the time in which it is performed, and then ceases, tho' you agitate them much more forcibly than you did in mixing them. 7. That the whole physical cause, therefore, of the production of this considerable Heat, is only the first application of the particles of the Spirit of Wine to those of the Water; and that Fire is instantly excited in the very contact, and disappears again presently after it. 8. That the Fire thus generated, or discovered by this mixture, is true elementary Fire; as its effect upon the Thermometer evidently demonstrates. 9. That a good deal of the Heat was destroyed, whilst the Thermometer was heating by the mixture to this degree.

Experiment II.

Observe, again, these two Vessels, one of which contains the same quantity of Water, as in the former Experiment, and heated to the same degree, *viz.* 44; the other the same quantity of pure Alcohol precisely as hot as the Water; the Thermometer likewise, as before, standing at the degree 44. These then being mixed in the same manner as in the preceding Experiment, the Thermometer rises to the degree 62. Hence, then, we infer, 1. Every thing that was taken notice of in the first Experiment. 2. That Water and Alcohol, by being mixed together, grow very hot, much hotter than Water and Spirit of Wine. 3. That the cause, therefore, of this greater Heat depends intirely upon the proportion of the Alcohol, to that of the Water with which it is mixed. 4. That Water, by being poured upon Alcohol, causes a greater quantity of Fire to enter into the Alcohol, than was in it before, though this so much resembles Fire; for Alcohol mixed with Alcohol produces no heat at all; Water mixed with Alcohol does. 5. That the less Alcohol, the Water, which is thus mixed with the Alcohol, has in it, that is, the purer the Water is, the more Heat it will generate in the Alcohol; and the reverse.

Experiment III.

I take now two ounces of alcalisated Alcohol; and the same quantity of pure Water. Before they are mixed they are equally cold, *viz.* 41 degrees; as is likewise the Thermometer: The mixture gives 54 degrees of Heat. Hence we see, 1. The truth of what has been asserted under the first and second Experiment. 2. That Water and alcalisated Alcohol grow hotter upon mixing, than Water and Spirit of Wine; but less so, than Water and pure Alcohol. 3. That the cause therefore of Heat in these mixtures is owing wholly to the Alcohol, and pure Water.

Compare with these the Observations of the famous Mr. *Geoffry*, in the *Mem. de l'Ac. Roy.* 1723. p. 53. These Experiments furnish us with some Bodies, and those pretty remarkable ones too, by which we may bring about this generation of Heat; and in these, besides what has been observed already, I think this deserves to be particularly taken notice of, that in them all the Heat is only generated in the very point of mixing, nor is any greater degree perceived afterwards. And hence, the quicker this is performed, the Heat that is excited by the same quantities will be always the greater; and on the contrary the less, the slower, and more successively. For as soon as ever the mixture is so compleated, that all the particles of the Water are united with all the particles of the Alcohol, in vain will you expect any farther increase of Heat. Nor will a violent agitation of the mixed Liquors be then of any consequence; for the degree of Heat will afterwards not only be no greater, but in those three Experiments, when the mixture is once perfectly finished, it begins immediately to remit, and a succeeding Cold increases every moment, till the Liquor is soon reduced to the common temperature of the Atmosphere: And in the same manner the Experiments I have tried have always succeeded. Hence, therefore, we infer, 1. That at the point of time, in which the Elements of the Water and Alcohol come into contact, there arises some physical cause which attracts the Fire thither. What this cause is, it is not easy to determine. This, however, we observe, that at the time particularly when the mixture is first made, the Liquors, which were before clear, lose their transparency; and that this opakeness continues so long as the Heat is generating, which being quite compleated, they perfectly regain their pellucidity. And again, precisely at the very same time, there is produced a vast number of very small bubbles, which move among the mixed elements of the Liquors, presently burst, disappear, and are again renewed; but when once the Heat is generated, are never observed after. Whether, now, these Bubbles do by their motion produce this Heat, or rather, whether they themselves are generated by the Heat's rarifying the aereal particles interspersed through the Liquors, is hitherto matter of doubt. 2. This, however, we learn certainly from those Experiments, that this Heat does not depend upon the united substance of both Liquors, but upon some other cause, which exerts itself only in the very first union of the elements together. On this Account, therefore, it seems very probable, that all the Heat thus generated exists there but the least instant of time; which certainly is very remarkable. Nor does Gunpowder, perhaps, burst sooner into Flame, by the application of a spark to it, than this Heat arises upon the mixing of these Liquors. 3. The more accurately, and intently, therefore, we examine this affair, are we not so much the more at a loss to find out what this in reality is, which thus collects this Fire? Is it the reciprocal attractive power of these elements, by which, when they approach one another, they rush into contact, and by this Collision excite little Fires? Or does an alternate attraction, and repulsion between these elements, produce a very swift attrition among them, and by this means generate Heat, the attrition ceasing again, when the particles are equally distributed among one another, are at rest? 4. Since this Heat arises in Water and Alcohol, upon their being mixed together, whether they had this or that particular degree of Heat, when they were separate, and the new degree is so much greater than that before the mixture; hence, therefore, Alcohol, by being mixed with the Water of our Blood, may, to a certain degree, and for a certain time, heat it very ſuddenly, tho' afterwards, however, it will in this reſpect have no farther effect upon it. 5. For this reaſon, therefore, Bodies that are cold from a watery dampneſs upon them, may be warmed by being rubb'd with Alcohol; and on theſe principles the effects of Baths and Fomentations made with Alcohol may be underſtood.

EXPERIMENT IV.

If the pureſt Water, and the moſt generous Wine are perfectly united together in the ſame manner, they don't diſcover the leaſt ſenſible increaſe or decreaſe of Heat; there is ſomething of Warmth, indeed, but it is ſo exceeding ſmall, that it can ſcarcely be perceived. Hence it appears, 1. That Water and Wine are equally warm in themſelves, and that they ſtill continue of the ſame Warmth after they are mixed together. 2. That the application of Wine, therefore, does not heat any thing conſiderably more than Water. 3. That the Heat, of Conſequence, that is perceived in a human Body from drinking of Wine, does not ariſe from any Heat that pre-exiſted in the Wine, and is then communicated to the Fluids, but is owing to its *ſtimulus*, by which the velocity of the Blood being increaſed, and a greater attrition excited between the Veſſels and the Fluids, Fire of courſe is attracted thither.

EXPERIMENT V.

From this quick mixture of Water with the diſtilled Vinegar of the ſtrongeſt Wine, which were perfectly of the ſame warmth, you don't perceive the leaſt degree of Heat produced, but they remain exactly as they were before. Hence, therefore, 1. The Heat of Water and Vinegar is the ſame, nor does there ariſe any alteration in it, by mixing them together. 2. The refrigerating power, therefore, of Vinegar in the human Body, ſo extolled by the Phyſicians, muſt depend intirely upon ſome other cauſes than a Cold that is natural to the Vinegar.

EXPERIMENT VI.

Theſe two Veſſels contain equal quantities of Oil of Tartar *per Deliquium*, and pure Water, which are both exactly as warm as the external Air; and you perceive evidently, now I have perfectly mixed them together, they retain preciſely the ſame degree of Heat. Hence, 1. That Liquor, which of all Fluids appears to us the moſt fiery, is in reality no hotter in itſelf than pure Water; nor is Water any ways cooler than that very heating Liquor. This aſſertion, to a perſon unacquainted with this Experiment, would ſeem an extraordinary paradox; but the Truth of it, however, is undeniable. 2. This Liquor, which is eſteemed ſo igneous, if it is mixed with Water, don't at all leſſen its Coldneſs. 3. When a fixed fiery alcali is once diſſolved in ſuch a quantity of Water as is ſufficient to dilute it, it will not afterwards generate Heat in any other Water. 4. Neither, therefore, can this liquid Alcali excite any Heat in this reſpect, by being mixed with the Water of our Blood.

EXPERIMENT VII.

I have here Water, and diſtilled Oil of Turpentine, which now they are ſeparate, are juſt as warm as the Air at this time; and though I now mix them together as intimately as poſſible, yet they don't generate the leaſt degree of Heat. Hence again, 1. Diſtilled eſſential Oil, which heats the human Body to ſuch a degree, and defends it ſo happily againſt the ill effects of Cold, has in reality no more Heat in it than ſimple cold Water. 2. This Liquor, though in a great many of its properties it comes ſo near to Alcohol, yet communicates no Heat to the Water it is mixed with, though Alcohol, by being mixed with Water, excites a very conſiderable degree; which extraordinary *Phænomenon* makes probable the doctrine we before laid down, when we aſſigned the firſt contact of the elements of the Water and the Alcohol, as the principal cauſe of the Heat that is thus generated. 3. This Oil, therefore, again, cannot add any Heat to the Water of our Blood, by being mixed with it.

EXPERIMENT VIII.

The moſt certain mark, perhaps, of Alcohol's being perfectly pure, is its ſuffering itſelf to be intimately mixed with diſtilled Oils, by ſimple concuſſion; for if it contains but the ſmalleſt quantity of Water, ſuch a perfect mixture will not be poſſible. Some ſuch Alcohol I have here, which is equally warm with this very pure ætherial Oil of Turpentine, and the Air at this time. Theſe, now, I'll mix together, and what do you imagine will be the conſequence? You ſee they unite intimately with one another, juſt as Alcohol does with Alcohol; and that there is not the leaſt variation from the Heat which both the Liquors had before the mixture. This, certainly, perſons generally would not have expected: Nay, even thoſe who were acquainted with the former Experiments would imagine, that ſome degree of Heat muſt ariſe from the intimate contact of the Oil and Alcohol. We here ſee, then, that the particles of Alcohol will bear to be as perfectly and equably diſperſed through the Oil, as they will through Water; but that no Heat, however, is generated by this means. Alcohol, therefore, will not excite any Heat by being mixed with our Oils, though it will if it is mixed with the Water of our Blood. What new and unexpected diſcoveries do we make in natural Philoſophy, when we deſignedly apply Bodies to one another! Let us, therefore, proſecute this method as much as poſſible.

EXPERIMENT IX.

Diſtilled Vinegar, and Oil of Turpentine, which now they are ſeparate, are equally hot with the Air, and one another, *viz.* * 44 degrees, I thus gently and gradually mix together; and by a ſucceſſive augmentation, they increaſe the heat to the degree 45. Here therefore, 1. The Vinegar and the Oil are of themſelves equally hot. 2. Some Heat ariſes from their being mixed together. 3. Hence the power that Acids have of generating Heat with oily Bodies begins to diſcover itſelf, tho' they are ſo but in the ſmalleſt degree, for as *Monſ. Homberg* has demonſtrated the ſtrongeſt Vinegar don't contain above one eightieth part of pure acid. *Mem. de l'Ac. Roy, des Sc.* T. 1. p. 52. 4. Vinegar,

* Should not this be 42? See the next Experiment.

Vinegar, therefore, will generate ſome Heat with our Oils by being mixed with them. 5. And in this reſpect Vinegar differs from Water.

EXPERIMENT X.

The ſame Vinegar and Alcohol, which I made uſe of before, and which are qually hot with the Air, I now mix together; and you perceive what a remarkable Heat immediately ariſes: For from the degree 42, in which they were before the mixture, they now raiſe the Thermometer to 52. Hence, therefore, 1. Alcohol and Vinegar are ſeparately equally hot. 2. A very conſiderable Heat is generated by their being mixed together. 3. Alcohol grows hot with Vinegar, ſo much more than it does with Oil.

EXPERIMENT XI.

Oil of Tartar *per Deliquim*, and Oil of Turpentine, ſeparately equally hot, *viz.* 45 degrees, upon mixing, raiſe the Thermometer to the degree 48. Hence, 1. Theſe Liquors of themſelves have the ſame degree of Heat. 2. In mixing, they grow conſiderably hotter than they were before.

EXPERIMENT XII.

The ſame Vinegar and Oil of Tartar *per Deliquium*, which ſeparate were eqally hot, *viz.* 46 degrees, being expeditiouſly and accurately mixed together, continued exactly in the ſame degree of Heat: But in this Experiment I made uſe of 3 parts of Vinegar, and 1 of Oil. Hence, therefore, it appears, that Fire is not collected by the Union of oppoſite Salts.

EXPERIMENT XIII.

Alcohol, and Oil of Tartar *per Deliquium*, that were as hot as the common Air, by being intimately mixed together, increaſed their Heat from 64 degrees to 68.

EXPERIMENT XIV.

I have in this Phial ſome of the ſame Alcohol, equally hot with the Air at this preſent time, *viz.* 47 degrees. Into this, now, I pour ſome pure, dry, fixed alcaline Salt of Tartar; upon which the Liquor in the Thermometer riſes to the degree 51.

EXPERIMENT XV.

With this pure Water, I mix one third part of the ſame Salt of Tartar; and the Thermometer riſes from the degree 47 to 57.

EXPERIMENT XVI.

I now put one part of the ſame Salt of Tartar, to three of the Vinegar we made uſe of before; and the Thermometer riſes from 43 to 49.

EXPERIMENT XVII.

With three parts of Oil of Turpentine, I mix one of the ſame Salt of Tartar; and the Thermometer riſes from 43 to 48.

From what has been hitherto laid down, then, we learn, 1. That the ſimple Bodies, which are chemically extracted from Vegetables, have really the very ſame degree of Heat in them, *viz.* that of the common Air, at the time they are examined. 2. That ſome of theſe acquire a greater Heat by being mixed together; which generation of Heat, however, continues no longer than during the time of the mixture, which being perfectly compleated, the new degree of Heat does not remain, but they gradually return again to the temperature of the common Air. 3. That this production of Heat, therefore, does not depend upon the Subſtance of the united Bodies, but only upon the union of them at that time. 4. That Alcohol and Water are the principal of the vegetable Fluids, which have that power of generating Heat, which has been deſcribed. 5. That Salt of Tartar and Water are the chief among the Solids and Fluids, which, by being mixed together, produce the greateſt degree of Heat. 6. And that next to theſe, Alcohol and Salt of Tartar, are the moſt efficacious. Theſe, then, being thus diſpatched, let us, with the ſame care proceed to examine the parts of Animals.

Of the Heat ariſing from the Mixture of animal and vegetable Subſtances.

EXPERIMENT I.

Freſh Urine, well concocted in a healthy Body, being expoſed to the Air, ſoon acquires the ſame temperature with that at that time; and if it then, as you ſee, is mixed with an equal quantity of Water, it makes no alteration at all in the Thermometer.

If it is mixed with Alcohol, the Heat increaſes from 38 degrees to 49.
With Oil of Turpentine it ſuffers no alteration.
With Salt of Tartar the Thermometer riſes from the degree 38 to 39.
With the ſtrongeſt Vinegar no alteration.
Nor with Spirit of Urine.
With Salt of Urine it deſcends two degrees.
With Spirit of Nitre it riſes from 38 to 43.
With Spirit of Salt, from 39 to 43.
With Oil of Vitriol, from 39 to 54.

EXPERIMENT II. *After various manners.*

The Urine of a healthy man being kept a good while in a cloſe Veſſel, and by this means being very much putrified, will have the ſame temperature as the Air at that time; and if it is then mixed with Water in equal quantity, will cauſe a ſmall deſcent in the Liquor of the Thermometer.

Being mixed with Alcohol in the ſame manner, the Heat increaſes from the degree 38 to 45.
With Oil of Turpentine, no alteration.
With Salt of Tartar, the Thermometer deſcends from 38 to 36.
With the ſtrongeſt Vinegar, aſcends from 37 to 38.
With Spirit of Urine, deſcends from 38 to 36.
With Salt of Urine, from 38 to 32.
With Spirit of Nitre, aſcends from 38 to 40.

With

With Spirit of Sea Salt, from 38 to 41.
With Oil of Vitriol, from 38 to 45.

EXPERIMENT III. *After various manners.*

Salt of Urine procured from fresh Urine by distillation, without the addition of any thing but Sand, being mixed with Water in the manner often described, made the Thermometer descend from 40 to 38.

With Alcohol, it ascends from 40 to 41.

With Salt of Tartar, from 40 to 45.

With the strongest Vinegar, it descends from 43 to 41; but with the same inspissated to the consumption of one half, ascended from 42 to 44.

With Spirit of Nitre, from 43 to 60.

EXPERIMENT IV. *After various manners.*

With a pretty strong, volatile, alcaline Spirit, prepared from equal quantities of *Sal-Ammoniac*, and Salt of Tartar, I mixed an equal quantity of Spirit of the strongest Vinegar, when they were both equally hot with the Air; and the Liquor in the Thermometer rose from the degree 44 to 48.

With the strongest Vinegar, inspissated to one half, from 46 to 47 $\frac{1}{2}$.

With spirit of Salt distilled with Bole, and afterwards rectified, from 46 to 64.

With Spirit of Nitre, distilled with Bole, from 46 to 82.

Of the Heat generated by the mixture of fossil Substances.

EXPERIMENT I. *After various manners.*

I here take 3 ounces of clean Water, 47 degrees hot, and put to it 1 ounce of pure Nitre reduced to powder; and the Liquor in the Thermometer descends to the degree 36.

I mix 1 ounce of pure Borax with 3 ounces of Water, 48 degrees hot; and the Thermometer falls to 45 $\frac{1}{2}$.

With 3 ounces of Water, 46 degrees hot, I mix 1 ounce of Sea Salt; and it falls to the degree 43.

To 3 ounces of Water, 47 degrees hot, I put 1 ounce of *Sal-Ammoniac*; and it falls to the degree 28.

With 3 ounces of Water, 45 degrees hot, I mix 1 ounce of Oil of Vitriol not rectified; and it rises to the degree 60.

To 2 ounces of the purest Alcohol, 47 degrees hot, I add 1 ounce of Oil of Vitriol not rectified; and it rises to the degree 60.

With 3 ounces of distilled Vinegar, 46 degrees hot, I mix 1 ounce of Oil of Vitriol not rectified; and it rises to the degree 60.

Ceruss, by causing an ebullition with weak *Aqua Fortis*, makes it rise from the degree 44 to 57.

Tin, by causing an ebullition with weak *Aq. Regia*, makes it rise from the degree 44 to 56.

Filings of Iron, by causing an ebullution with *Aq. Regia*, make it rise from the degree 44 to 160.

A great many other Experiments I have made of the like nature, but am afraid I ſhall tire your patience. Give me leave, however, to obſerve, that if all the ſimple Bodies in the animal, vegetable, and foſſil kingdoms were examined in this manner, beginning firſt with theſe of the ſame claſs, and carefully noting all the *Phænomena* that ariſe from the mixture of theſe; and afterwards proceeding to make the ſame trials upon the ſimples of different claſſes; we then ſhould ſoon have a compleat and certain hiſtory of the Heat that is generated by the ſole mixture of various Bodies with one another. But here let me caution you, that the Experiments thus performed before you, are not made with that care and accuracy, as they might and ought to have been, if we would have ſettled this affair nicely; but this the ſtraitneſs of our time, and the fear of being tedious, would not admit of. And beſides, as ſo large a number of you do me the honour of attending to theſe lectures, and I am willing you ſhould all fairly perceive the event of the Experiments, I thought it proper to make uſe of ſuch large Thermometers. But theſe, as you know, by having their large Bulbs immerſed in ſo ſmall a quantity of Liquor, muſt, by being affected themſelves, make an alteration in the Heat or Cold produced in the mixture, and thus make ſome variation in the viſible effect. Theſe Experiments, therefore, for this reaſon, you muſt not look upon as very exact. If your own ingenuity ſhould put you upon proſecuting theſe inquiries with greater accuracy, I would adviſe you to make uſe of thoſe beautiful Thermometers of *Fahrenheit*, that are made with Mercury; which is the ſort I made uſe of in producing the Cold with *Sal-Ammoniac*, which I ſome time ago gave you an account of. Theſe have this great advantage, that they are exceeding ſenſible of Heat and Cold, and at the ſame time are ſo ſmall, that they make very little alteration in the Heat of the Liquors to be examined.

Of true Fire generated in a cold Body, by the ſole acceſs of the Air.

The indefatigable induſtry of the Chemiſts is continually finding out ſomething which former Ages were not acquainted with. Now among theſe diſcoveries, Gunpowder excepted, there is nothing more ſurprizing than thoſe Bodies, which, whilſt they are kept from any communication with the common Air, are as cold as others, but as ſoon as ever this has a free admiſſion to their ſurface, preſently take fire and flame of themſelves, purely from this cauſe, without the acceſſion of any other Body, any mechanical attrition, or the application of any Fire. Theſe Bodies have obtained the name of *Phoſphori*: Thoſe alone I mean, here, by which Fire is really generated; not regarding the other, which only ſhine in the dark, and do not at the ſame time excite any Fire.

The *Phoſphorus* of *Crafftius.*

If the Juices of Animals, when they have firſt undergone a great degree of putrefication, are by the action of the Fire deprived of all their volatile Salt, and Oil, they leave behind them a kind of a Coal: If you mix this with three times its quantity of Sand, or powder'd Charcoal, or with two parts of Charcoal, and half a one of Alum; and then put it into a coated Retort made of crucible earth, and urge it with a reverberatory Fire, gradually increaſed to the greateſt degree, and equably continued for a conſiderable time; and if at the ſame time you take care to diſpoſe the Retort in ſuch a manner, that the

the mouth of it ſhall touch ſome Water contained in the Receiver, which muſt be accurately luted; if you proceed, I ſay, in this manner, you will then with your laſt degree of Fire, after ſome Fumes, have a heavy, greyiſh matter, which will fall in grains to the bottom of the Water, will not diſſolve in it, melts with Heat, and may by the aſſiſtance of it be formed into maſſes under the Water. This, which is called the *Phoſphorus* of *Crafftius*, *Kunkelius*, and *Boyle*, if it is kept cool under Water, may be preſerved a great while without alteration; tho' if the Air by any means grows very hot, it will ſhine in the dark, even through the Water it lies in; but if it is openly expoſed to but a warm Air, it then becomes lucid, and if the heat is pretty conſiderable, upon examination with a Microſcrope, you may perceive a conſtant ebullition in the internal parts, ſoon after which, it burſts into Flames, conſumes, and leaves behind it an Oil of Vitriol, or a Liquor exceedingly like it in acidity and weight. This, therefore, is a new method of generating Fire, perfectly diſtinct from all the former. Does the Air, then, when it is pretty warm, at which time it is probable it is in a conſtant ebullition; I ſay, does the Air then, by its concuſſions, cauſe an attrition in the parts of the *Phoſphorus*, and, by this means, excite in this very Mobile, but at the ſame time pretty fixed matter, ſome degree of Heat, then Light, and afterwards Flame? Certainly, if it is expoſed to the Air in the greateſt Cold, it ſcarcely ſhines, does not grow hot, and is far from being ſet on fire: But as ſoon as ever it begins to flame out, it can ſcarcely be extinguiſhed. In almoſt every quality, and the *Analyſis* of it by deflagration, it comes very near to the pureſt common Sulphur, but is of a ſofter conſiſtence, more eaſily melted, and on that account is rather of the nature of Wax. In this reſpect, however, there is this difference between them, that *Phoſphorus* boils and takes fire with a ſmall degree of Heat. See *Boyle. Noctiluc. Aer. Slare. Philoſ. Tranſ.* 1683. p. 1457. *Homberg. Mem. de Mathem. & Phyſ.* Ann. 1692. p. 74 to 80. *Nieuwentyt.* p. 520. *Hoffman. Diſſert. Chem. Phyſic.* p. 336.

But there has been another and much more beautiful method diſcovered of making a Matter, which upon contact with the Air, whether hot or cold, immediately generates Fire, and burns. This was firſt communicated to me by Letter, by the egregious *Homberg* of *Paris*, the 16th day of *April*, 1712, which was delivered me by the ingenious *Haſberg*, who at the ſame time added ſome conſiderable remarks of his own. Afterwards, when the method was rendered more eaſy, and leſs diſagreeable, it was publiſhed in the *Journal des Scavans*, *An.* 1716. p. 60. And here give me leave to obſerve, that as the *Phoſphorus* juſt now mentioned, owed its diſcovery to a crazy headed Alchemiſt, that was hunting after the *Philoſopher's Stone* in Urine; ſo this which I am going to deſcribe, was the invention of one of the ſame Sect, who was madly purſuing this occult Stone in human *Fæces*. The Operation is as follows. Take the Fleſh of a tender Animal chopp'd very ſmall, or any of its Juices, or even its Excrements; put this Matter into an iron Frying-pan over a moderate Fire, and with an iron *Spatula*, keep ſtirring it about 'till it is reduced to a dry black Powder: Or inſtead of this, you may treat in the ſame manner any ſoft Vegetables, any ſort of Meal for inſtance, it ſignifying very little, which of theſe you make uſe of. Take 1 part then of this black torrified Powder, and rub it with 4 parts of crude Alum, 'till it is brought to a very fine Powder. Put

Igneous *Phoſphorus.*

this into an iron Frying-pan, and roaſt it over the Fire, all the while ſtirring and rubbing it with a *Spatula* almoſt red hot to keep it in form of a Powder; and whenever the Alum is melted, and with the Powder runs into lumps, theſe muſt be immediately rubbed to pieces, and the whole muſt be thus kept in motion, till the matter will emit no more Fumes, but is totally converted into a fine, dry, fix'd Powder, that is perfectly black. Take then this dry black Powder, and put it into a clean dry glaſs Bolt-head, with a ſlender Neck, filling the Body two thirds full; and let the mouth of the Glaſs be covered with a Paper, ſo that the Air may paſs in and out freely; and that the Fumes may get readily out of the neck of the Glaſs. Put this Bolt-head into a Crucible, and ſo guard it with Sand, that the ſides and bottom of the Crucible may be well ſecured from touching the Glaſs; and let there be left ſo much room above the Sand, that you may eaſily look into the Body, and ſee whether the Matter contained in it, is red hot. Round the crucible then, with the Sand, and Bolt-head, diſpoſe ſome burning Coals in ſuch a manner, that it may be heated gently and by degrees, 'till it grows all over thoroughly hot; and then increaſe the Fire, 'till the Crucible, Sand, Bolt-head, and Matter contained in it, are perfectly red. When you obſerve this to be the caſe, keep up the Fire in the ſame degree for the ſpace of an hour; and then, whilſt the force of the Fire continues, cloſe the Orifice of the Glaſs ſo accurately with Wax, that no Air can poſſibly get into it. This being done, let them all cool of themſelves; and in the Bolt-head you will have a black powdery Coal, compoſed of the Powder and the Alum. If any of the Matter then thus prepared is thrown out of the Glaſs into the cold Air, it inſtantly takes fire and burns; but if it has once been expoſed to it, it loſes intirely this vertue. And this method of generating Fire ſeems the moſt ſurprizing of any we are acquainted with, as this matter will retain its power of exciting Fire for the ſpace of three whole months, if it is kept from any communication with the external Air. In this Experiment, now, we have a true animal, or vegetable Coal produced by the calcining force of the Fire, and that an exceeding ſubtil one too, and conſequently intirely fit to feed and ſupport a ſpark of Fire when once it has received it; as appeared formerly in our Hiſtory of Coal. This Coal too is rendered as dry as it is poſſible to make it; as appeared through the whole proceſs: For if the leaſt Moiſture, nay even that which is diſperſed in the Air, comes at the Powder, the ſucceſs of the Experiment is intirely fruſtrated. And here we muſt obſerve, that all the Air, likewiſe, muſt be expelled by this exceſſive Heat: For at that time, the mouth of the Glaſs muſt be carefully ſtopped, when the greateſt degree of Fire which the Glaſs can bear without melting, has forced all the Air out of its Cavity, and out of the Matter contained in it; for if by any means the Air can inſinuate itſelf in afterwards, the Experiment will never ſucceed. In the mean time, by this protracted calcination, the Air, Water, and volatile acid Spirit muſt be expelled from the Alum likewiſe, (which ſeems to be a Lime-ſtone prey'd upon by Oil of Vitriol, and converted into a Salt) nothing at all remaining but a very ſtrong Oil of Vitriol, fixed in the exceeding dry Earth. Theſe Bodies now, which are vaſtly attractive of Moiſture, grow hot upon the admiſſion of Air, and this ruſhing into their empty Pores with the *Impetus* formerly computed, p. 130, will in an inſtant cauſe a moſt vivid attrition of its parts, and thus, perhaps, generate Fire, which being received on that very fine Coal, will be easily sustained and supported. But whether this, or something else, is the cause of this wonderful *Phænomenon*, this at least we are now a-days certain of, that, without any assistance of Fire, it is possible for the common Air, by simple contact only, to set fire to a cold Body in such a manner, that it shall by this means be totally consumed to Ashes, as certainly, as by any other Fire that we are acquainted with. But to the best of my knowledge, this last Experiment is the only one by which we can always effect it. Who then can pretend to set bounds to the power of Fire? Who, five and twenty years, would have thought such a thing possible? Or who can foretell those things that will be reveal'd to future ages? should the Glass which contains this cold Powder be broke, and it should fall amongst Gun-powder, what would be the consequence?

Of Fire produced from cold Fossils by the help of Water.

Fire produced by mixing Iron, Sulphur, and Water.

If the fresh Filings of Iron, not yet rusty, are mixed with an equal quantity of very pure Sulphur, and they are strongly rubbed together for a considerable time, till they are reduced to a very fine Powder; then, this Powder, keep it ever so long in a dry Air, will continue cold, if you carefully secure it from all Moisture: But if you work this Powder with such a quantity of pure Water, as to reduce it to a stiff Paste; then, after some time, the Mass will grow warm, fume, puff up, grow hot, emit a black, hot, sulphureous Smoke, take fire, and flame: And after the Operation is over, there will be left a brown, black, fine *Calx*, by pouring Water on which, you may extract a kind of Vitriol from the Iron, exceedingly like the *Vitriolum Martis*, which in the common Method is prepared with Oil of Vitriol. If you take, now, a large quantity of each of these Fossils, for instance, 25 pound of Iron, and as much of Sulphur, and make them into a Paste, and bury it a foot under ground, after 8 hours, the Earth that is over it will begin to heave, send forth hot sulphureous Vapours, and burst out into Flames, and thus produces a true subterraneous Fire. *Hist. de l' Acad. Roy.* 1700. p. 52. *Mem.* p. 101. And the reason seems to be this; the Sulphur being an inflammable Oil, concreted with the exceeding acid Oil of Vitriol; and Iron being a Metal, which will always dissolve in the Acid of Vitriol, and by this means generate a very great degree of Heat; hence, it seems probable, that when the very small Particles of these two Bodies are rubbed together, and thus brought into very close contact, and by the addition of the Water, are held still much more strongly together; I say, when this is the case, it is probable, that the Acid of the Sulphur begins to corrode the Iron, and thus produces the usual Heat; and by the effect of this continually augmented Heat, this solution being every moment more efficaciously carried on, of consequence the Mass grows hotter and hotter; so that at last, a Flame breaks out, partly from the Oil of the Sulphur which is freed from the Acid that is now gone into the Iron; and partly from the Vapour, that arises from the Iron now dissolved by the acid Oil of Sulphur, which is easily inflammable. That this is the Case appears from another beautiful Experiment mentioned in the place above cited, and in *Hoffman*'s *Diss. Physi. Ch.* 169, which is as follows. Take a glass Bolt-head of a middling size, with the neck of it cut off, and mix in it 3 ounces of Oil of

Vitriol, with 12 ounces of Water; ſet the Glaſs then in a moderate Heat, and throw into it at different times, half an ounce or an ounce of Filings of Iron, and there will by this means ariſe a white Vapour, which iſſuing out of the neck of the Glaſs, cauſes a ſulphureous ſtench like Garlick, and upon the application of a Candle, takes fire like Lightning, ruſhes with a vaſt *impetus* into the Glaſs, and being there violently agitated, produces very ſurprizing *Phænomena*; ſo that the Matter which conſtitutes theſe Fumes, ſeems perfectly like Alcohol, when it is raiſed by Fire into a Vapour. And thus there is diſcovered a new method of generating Fire in a cold Matter no ways inflammable, purely by the aſſiſtance of Water. And, indeed, we are moſt firmly perſuaded, that there are in Nature, an infinite number of other methods, by which the ſame ſurprizing effect may be produced; and which poſſibly hereafter may come to light. Damp Hay laid together in a heap will do the ſame thing.

Of the Production of Fire by the mixture of cold Liquors.

Fulminating Fire from Liquids.

Take half a pound of very pure dry Nitre reduced to Powder, put it into a clean dry Retort, and mix with it an equal quantity of Oil of Vitriol very pure likewiſe, and perfectly freed from all its Phlegm: Diſtill this Mixture with a gentle ſand Heat, continued for a conſiderable time, and then a Spirit will ariſe in form of a yellowiſh Vapour, which collected in the Receiver, will be *Glauber*'s Spirit of Nitre. If in a glaſs Veſſel, now, you put a Drachm of diſtill'd Oil of Cloves, Saſſafraſs, Turpentine, or Carraways, and then pour upon it an equal quantity, or half as much again of this Spirit of Nitre of *Glauber*, a violent Flame will be excited by theſe Liquors, which were cold before the Mixture. Here again, then, is a moſt ſurprizing Experiment, and of infinite uſe in Chemiſtry, in which we ſee a moſt rapid Flame inſtantly produced by two cold Liquors, which almoſt conſumes them both, leaving behind it only a ſmall quantity of a kind of reſinous Aſhes. And by this Experiment, we perceive again likewiſe, that very acid Liquors mixed with oily ones, which are pregnant with a *Spiritus Rector*, compoſe a matter very much reſembling Sulphur, and that very eaſily takes fire. See *Borrich. Act. Hafn.* 167. *Hoffman. Obſ. Phyſ. Chem.* 38, 42, 123, 127. *Slare. Phil. Tranſ.* N. 150. p. 291.

Of the nature of elementary Fire, which is corporeal. 1. As is extended.

If we examine now carefully what has been hitherto laid down, we may, poſſibly, be able to aſſert ſome things with ſufficient certainty, concerning the nature of Fire. Firſt, then, it is evident, that true elementary Fire is really corporeal. For as by this we mean ſomething, that may be meaſured geometrically by three Lines drawn perpendicularly to one another from the ſame center, or, as we expreſs ourſelves now a-days, ſomething extended; ſo, that Being, which we have conſidered in our former inquiries, under the notion of Fire, has appeared to be always extended. If, for inſtance, a ſolid ſilver Sphere almoſt red hot, is ſuſpended by a Thread, and let very gently down into cold Water, ſo that it ſhall put the Water hardly at all in motion; will not the Fire then of this Sphere diſperſe itſelf gradually through the meaſurable ſpaces of this Water, of which that which is neareſt the Sphere will be hotteſt, and the reſt will be heated proportionably, and thus the Fire will be really extended? For Thermometers placed in the Water at different diſtances from the heating Sphere, will indicate the different degrees of Fire diffuſed through the Body and Spaces, and demonſtrate a true Mixture

of

of the Fire with the Body, or Space, and of conſequence, a real extenſion of it. And, certainly, our whole Hiſtory of Fire proves as evidently, that Fire is truly extended, as ſpace is, or the Bodies contained in it.

2. As it is movable, or capable of reſt.

A ſecond general property that belongs to every known Body, is, that it may ſucceſſively exiſt in the place which is next to that which it took up before, and thus may be really moved: And that, whether, firſt, it continues in the ſame ſpace, but is turned upon its own *Axis*, and ſo all the parts conſidered together poſſeſs the ſame Space, though every particular part is changing its place every moment; or, ſecondly, the whole maſs leaves the place it took up before, and enters upon a new one, and continues ſucceſſively to do ſo; or, laſtly, both theſe motions conſpire together. But it appears, by every Experiment, that Fire is thus moved likewiſe; nor, indeed, was there one of them which did not demonſtrate a true phyſical motion; and therefore this needs no farther proof. But this mobility, now, is ſo cloſely connected in Bodies with a power of being at reſt, that no one can deny, but that that Body which one moment exiſts in any particular ſpace, may be conceived to remain for two moments in the ſame; which is in reality being at reſt: Since, therefore, all the actions of Fire, which are conſtantly performed by motion, may be always increaſed; or diminiſhed; hence it is no ways abſurd to ſuppoſe, that Fire may be abſolutely at reſt in a determined ſpace; certainly not more ſo, than to ſuppoſe the ſame of any other Body.

3. As it reſiſts Body.

A third Affection of Body, and which is peculiar to that alone, is this, that a ſolid Body, as ſuch, exiſting in any particular ſpace, infinitely reſiſts any other ſimilar Body's poſſeſſing the ſame ſpace, at the ſame time. To this ſome perſons have given the name of Reſiſtance and Impenetrability; *Democritus*, by a moſt expreſſive term, called it ἀντιτυπία, or Repercuſſion. Nor indeed do I apprehend, we conceive any thing elſe by the word Impenetrability of Body, than this Repercuſſion of a Body, that endeavours to enter upon any part of ſpace which was poſſeſſed by another before. But if this Repercuſſion, now, does really obtain in any Body, it does certainly in Fire in particular: For this puts in motion, and changes the figures of the very ſolideſt Bodies we are acquainted with, ſo that there never was yet diſcovered any one that does not actually ſuffer ſome alteration from it in its true ſolid part, and receives a motion from it, by which it is carried into other parts of ſpace with this *impetus* communicated to it by the Fire. But again, if we conſider, that true, pure, elementary Fire, when it is directed upon certain Bodies, is driven back again, or reflected in ſuch a manner, as to return from thoſe Bodies, on which it fell, with a vaſt *impetus*, nay ſuch a one as puts in motion every thing that is oppoſed to it; I ſay, if we rightly conſider this, we certainly obſerve in Fire the moſt perfect ἀντιτυπία; and by this means diſcover its real corporeal nature. For if, for inſtance, the igneous rays determined by the Sun, fall upon *Vilette's ſpeculum*, when it is exceeding cold, and conſequently, when it is moſt elaſtic, and reflects moſt powerfully, they will then be reflected into the *Focus* in a quantity that may be pretty nearly computed, with reſpect to the magnitude of the aperture of the *ſpeculum*, and will there exert a moſt vehement corporeal force; which evidently demonſtrates, that this Fire is moved with reſiſtance. And this conſideration confirms the argument ſtill more ſtrongly, that if the *ſpeculum* is very much heated, and conſequently dilated, looſer, leſs elaſtic, and leſs powerful, with regard to its reflecting vertue, then the igneous rays, when they are returned back by it into the *Focus*, will act precisely with so much less force, as the hardness of the substance of the *speculum* was diminished. Hence, then, I think it appears certainly evident, that Fire itself is corporeal, and has a resisting power, inasmuch as it is reflected from the Body it strikes upon. Bnt here again we observe, that if these igneous rays are vasty united together, and hence have their strength greatly increased, and become so powerful as to be able to melt the metalline substance of the *speculum*, then there will be no reflection produced, but the Fire being superiour to the *speculum*, will destroy it; a very evident proof, that this reflection arises from the mere repercussion of Body upon Body. But we may consider farther, that if this very pure elementary Fire is determined by the Sun through *Tschirnhausen*'s Glasses upon the iron Needle of a Compass, it will then, in the very point where the *Focus* falls upon it, turn it round, and thus by a true corporeal percussion put in motion the substance of the Iron. This percussion now being made upon an impenetrable Body, demonstrates, that that, likewise, which moved against it, was not penetrable, but yielded some resistance. Elementary Fire, therefore, is truly corporeal. And every one of its elements or atoms, will consist of particles united together; which it is very probable are not capable of farther division by any natural powers. And hence the figures, likewise, proper to these elements, in all appearance, suffer no alterations by any force these powers are able to exert upon them. This wonderful element, therefore, is immutable itself, though it induces a change upon every thing else. But whether now Fire has likewise that property, which the great men of this age judge common to all Bodies, *viz.* that it gravitates in proportion to its solidity, does not yet appear so evident as persons generally imagine. For upon examination of the whole History of Fire, I am almost induced to believe, that it does not tend towards the center of the earth, more than any other point, but that it is perfectly free from any natural determination, or tendency to any particular place, or Body: That it may be determined every way, without resistance: That it exists in every place: That if there is no other cause to disturb it, it is dispersed throughout the whole universe: Nay, that naturally it exists every where, in the same quantity, and with the same power. All which positions, if I am not much mistaken, are plainly demonstrated by the former Experiments.

The Corpuscles of Fire the least of all we are acquainted with.

But in the second place, the elements of Fire, which by their first property appear to be corporeal, seem to be the least of all the Bodies that we are hitherto acquainted with. For if they are truly corporeal, they must, of consequence, be exceedingly subtil, since they are able to insinuate themselves with so much ease into the very densest Bodies, and passing through their whole thickness, exert their proper effects in the inmost penetrable parts of 'em. If a very large sphere of solid Gold, for instance, should be exposed to a proper Fire, for a sufficient time, it might be so penetrated by the Fire, as to be red hot to its very center: And if then it should be divided into two Hemispheres, there would appear Light, Heat, and every known property of Fire, in every point of their internal Surface. But again, the Subtlety of these particles is so exceeding great, that amongst all the Bodies that fall under our observation, there is not any one so compact, and free from pores, or of so large a size, but that it may be forced to transmit Fire through it. Every thing else, of what kind ſoever, we can prevent entring into the *meatus's* of certain Bodies: Air, for inſtance, Water, Spirits, Salts, Oils, and all other Subſtances, we can exclude a Glaſs Bolthead, by hermetically ſealing it, and by the ſame means include them ſo that they ſhall not poſſibly get out: Fire alone procures itſelf a free paſſage, both in and out, without any difficulty: Fire alone, both when it enters the Glaſs, and quits it again, exerts thoſe effects which are proper and peculiar to it. I confeſs, indeed, that the cauſes of Gravity, and Magnetiſm, in like manner pervade all Bodies, without having their proper activity diminiſhed: But then, whether theſe depend upon the emanations of Corpuſcles, or act in ſome other way, that we are not acquainted with, is not yet ſo certain. Nay, and we muſt farther acknowledge, likewiſe, that both Gravity and Magnetiſm, in an inſtant, and almoſt without any retardation, penetrate through all Bodies, in their full force and efficacy; whilſt Fire requires ſome length of time before it can pervade thoſe that are very thick: But hence, certainly, the corporeal nature of Fire appears ſo much the more evident, which is not ſo manifeſt in the two former. For theſe reaſons, therefore, I aſſerted only, that the elements of Fire are the ſmalleſt of all the Bodies that are univerſally acknowledged to be true Bodies. Far be it from me to deny, that the Divine Being has in the material World created Corpuſcles that are actually more ſubtil than the Elements of Fire: This only I affirm, that it does not appear to the human ſenſes, by any phyſical effect, that any ſuch Corpuſcles do really exiſt. But this infinite Subtlety of the Elements of Fire appears yet again, if we conſider, that the Solidity of Gold is ſo great, that if you gild a piece of Silver with a grain of it, in ſuch a manner, that the thickneſs of the golden foliage ſhall be only $\frac{1}{1050000}$ of a line (*Ac. Roy. des Sc.* 1713. 10), yet even then, when it is ſo vaſtly thin, you will not be able to diſcover the leaſt pore in it, by the aſſiſtance of the niceſt Microſcope. Nay, if you take a bit of Leaf Gold, ever ſo fine, and oppoſe it to the Sun, ſhining through a hole into a dark room, it will not ſo much as freely tranſmit the Light, but you will ſee only a greeniſh kind of caſt through it. And yet now a very large Sphere made of ſolid Gold, may be penetrated through its great bulk, and this prodigious denſity, by the ſmalleſt, as well as the greateſt Fire. For if, in a very cold ſeaſon, this great Sphere is expoſed a conſiderable time to the cold Air; it will acquire the very ſame temperature, that is, it will receive the Fire that is at that time in the Air: But if it is then committed to a ſtrong Fire, ſo that it may be perfectly red hot, and juſt ready to melt, it will then have a moſt intenſe Fire in every part of it; and yet if it is then in this condition removed into the Air, all this Fire will ſoon quit it again, and it will return to the common warmth of the Atmoſphere. Hence, therefore, it evidently appears, that the ſmall portion of Fire contained in liquid Air, can as eaſily inſinuate itſelf into all the pores of Gold, as the moſt intenſe Fire of a Furnace. But if in ſuch an exceeding fine leaf of Gold, now, the *meatus's* were ſo very ſmall; what muſt we think of them in this caſe, when ſuch a large Body of Gold is penetrated by Fire through all its Subſtance? Certainly, growing hot and cold, is nothing elſe but admitting Fire in a greater or leſs quantity. Theſe arguments, then, ſufficiently demonſtrate the very great Subtlety of Fire. This, however, would appear yet infinitely greater, if this opinion was true, that the Matter of Light and Colours is the very ſame with that of Fire.

Fire. For if a chamber is perfectly darkened all but one very ſmall hole, and an eye that has been ſome time in the dark, is placed directly againſt it, it will then ſee all the external objects very exactly, by means of certain diſtinct igneous Rays, ariſing, and propagated from every viſible point of ſo many different Bodies, and tranſmitted through this very ſmall aperture, without any confuſion. If we conſider, now, what an infinite number of viſible points are ſeen in ſuch a Hemiſphere; and that every one of theſe appears only by its own particular Rays; the idea that ariſes hence of the ſubtlety of theſe particles confounds the human underſtanding. But again, if you place a Sheet of white Paper in this dark room, at a proper diſtance from the Hole, and by means of a convex Glaſs, throw the Rays upon it, then all the objects will appear upon this paper, of a pretty large ſize, and very dictinctly; and conſequently all theſe Rays, and therefore, upon our preſent ſuppoſition, all this Fire which from ſo many objects muſt be infinitely great, may be contracted together within the ſmall ſpace of this aperture. From theſe conſiderations, therefore, it evidently appears, that the Elements of Fire, with reſpect to our comprehenſion, are infinitely ſubtil.

And vaſtly ſolid.

In the third place, theſe very ſmall Corpuſcles, the ultimate Elements of Fire, appear to be of ſuch a nature, as to be the moſt ſolid, perhaps, of all Bodies. The ſignification of the term I make uſe of is eaſily underſtood: For by a Solid, I mean only that extended Being, which makes an infinite reſiſtance; by Space, that Extenſion which admits and tranſmits Solids. An abſolute Solid, therefore, is ſuch an extended Being, where there is not the leaſt ſuch penetrable Space, but which through its whole Extenſion, and in every point of it, is perfectly impenetrable. If any Body, now, is compoſed of particles thus perfectly ſolid, but at the ſame time ſo united together, that there are left little ſpaces between them that contain nothing ſolid; then it appears evidently, that ſuch an extended Bulk is partly Body, and partly Space. And it is hence evident, likewiſe, that the ſmalleſt Elements of all Bodies will be moſt ſolid; and that when theſe are afterwards compounded into one Maſs, then, betwixt theſe Elements thus united together, but not touching one another in every point, there will be formed ſuch Spaces within that Body. The compound Maſs, therefore, will be always full of pores, and conſequently leſs ſolid than the ultimate Elements of which it conſiſts; and hence, in this reſpect, the parts may be more eaſily ſeparated from one another, or are capable of a more eaſy diviſion. But again, in theſe ultimate Elements, it is probable, that there are not any pores, and that hence they are perfectly ſolid, and conſequently not to be divided by any other Bodies, but remain immutably the ſame. As Fire, therefore, has been demonſtrated to conſiſt of prodigious fine Corpuſcles, if theſe have any pores, they muſt certainly be exceeding few, and conſequently theſe *Moleculæ* will be vaſtly ſolid. But ſince impenetrable Subſtance is real corporeal ſubſtance itſelf, it is poſſible, that all true corporeal Subſtance, as ſuch, may cohere with an infinite force not to be diſſolved; but that the Maſſes that are made up of this Subſtance, with intercepted Vacuities, may be ſo far diviſible as they contain theſe Pores within them. Fire, therefore, according to this doctrine, will be totally corporeal, immutable, incapable of having its figure changed, nor liable to any concretion with itſelf, or other Bodies. In the mean time, however, it will poſſeſs a

power

power of vaſtly dividing others; ſince it can always enter the Pores of the Bodies to be divided, exert its force there, ſeparate the concreted Filaments and Particles, and thus reſolve the Compounds into their ſimple Elements, or at leaſt diſpoſe the elementary *Moleculæ* in ſuch a manner, that it may paſs equably through the *Meatus's* in every direction; as we ſuppoſe may be the caſe in Gold, when it is put in fuſion, which afterwards ſuffers very little alteration from the Fire. But if this vaſtly ſubtil and ſolid Fire, now, is applied to the perfectly ſolid Elements of other Bodies, it then ſeems probable, that it can induce no change in them, but only put them in motion by a mechanical propulſion, or by attraction; which again is confirmed by every kind of Experiment. Fire, therefore, in reſpect of this property, effects the moſt powerful changes in the Univerſe, whilſt of all Bodies it remains itſelf the moſt immutable.

In the fourth place, we conceive, that theſe corporeal, exceeding ſmall, and ſolid elements of Fire, have the moſt equably ſmooth, or poliſhed Surface. By this we mean ſuch a one, that has nothing in any one point of its circumference, which ſtands out, or is depreſs'd more than any other part. For if the Surface was rough, or unequal, then thoſe points which were higheſt, would ſtrike with a greater force againſt the Bodies they met with than any other part of the Maſs; and conſequently, in every action of Fire, either upon its own Elements, or other Bodies, thoſe Particles would receive the greateſt *impetus* which had the weakeſt coheſion with the whole Corpuſcle; whence, it ſeems probable, that theſe Particles would be continually abraded from the reſt of the Maſs, and of courſe the Elements of Fire, and therefore Fire itſelf, would undergo perpetual Alterations; which is contrary to what has been already delivered: Beſides, the vaſt ſolidity of Fire ſeems moſt conſiſtent with that Figure, in which all the Particles are diſpoſed in their ſeveral Orbs moſt equably with reſpect to their common center; ſince by this means they acquire the moſt immutable form, and moſt powerfully reſiſt every tranſpoſition of their parts. But farther, if we conſider with what eaſe Fire penetrates into the Pores of every kind of Body, let it be applied in what direction you will, then certainly, we ſhall ſee that the moſt ſmooth Surface is requiſite that it may paſs on without any impediment; which it does not at all ſeem likely would be the caſe, were it covered with little Hooks, Points, or any thing reſembling Down or Wool. For ſince ſuch a vaſt number of little Fires may be tranſmitted perfectly diſtinct through a very ſmall hole into a dark Chamber, and that without the leaſt difficulty; it is eaſy to conceive how vaſtly ſmooth the Surfaces of theſe Elements muſt be in the points of contact, not to intangle, and obſtruct one another: And laſtly, the exceeding quick reflection, and refraction, which are conſtantly obſerved in the Particles of Light, and which anſwer ſo exactly to the effects of a perfectly ſpherical Figure, induce us to believe, that the Elements of pure Fire do in reality poſſeſs this figure. Hence therefore, we may almoſt venture to infer, that the ultimate Particles of pure Fire are exceeding ſmooth poliſhed little Spheres. And the ſmootheſt.

In the fifth place, from our whole Hiſtory of Fire, we infer its exceeding great ſimplicity. By this we mean that condition of Bodies, where every ſingle Particle is perfectly of the ſame nature with the whole: This, therefore, in Fire, would denote it to be of ſuch a Nature, that every ſingle Element of And moſt ſimple.

it, ſhould be a perfect corporeal Maſs, without the leaſt intercepted Pore, ſo that every component Particle ſhould be abſolutely alike; and hence, perhaps, be a little ſolid Sphere. And then if we conſider a *congeries* of theſe Elements together, all theſe Spherules would be perfectly the ſame. In theſe, therefore, would conſiſt the ſimplicity of Fire, depending particularly upon this circumſtance, that as there are no Corpuſcles in nature ſmaller than theſe of Fire, it is impoſſible it ſhould be compounded of leſs, heterogeneous Particles. And certainly, the ultimate ſmallneſs, abſolute ſolidity, and ſpherical figure of the Elements of Fire, very evidently denote this ſimplicity. Fire, therefore, we conceive to be the ſimpleſt of all Bodies. It muſt be acknowledged, however, that an abſolute ſimplicity of Fire is repugnant to the doctrine of the great *Newton*, whoſe uncommon genius ſeems to have penetrated almoſt beyond the limits of human underſtanding. For this noble Author, by an artificial ſeparation of one Ray of Fire, has divided it into ſeven different ones, not only perfectly diſtinct with regard to their Colours, but intirely different in reſpect of their Reflection and Refraction; and conſequently, in theſe three properties, of a quite different nature. And yet, if we nicely contemplate ſuch a Ray as this, how fine is it, and how ſimple? If the nature of Fire, and Light, now, has been examined by ingenious Men for ſo many ages, and with ſo much diligence, and the great *Newton* alone of our age has made theſe Diſcoveries; who will pretend to determine the farther Improvements that future ages may be able to make in Natural Hiſtory? Who knows what additions may hereafter be made to the *Newtonian* Doctrine? Certainly, it is not above half a Century, ſince all the Philoſophers imagined a ſingle Ray of Light to be ſo infinitely fine, that they unanimouſly aſſerted, that with regard to its thickneſs it was indiviſible: And yet that incomparable Geometrician, by undeniable Experiments and Arguments, has evidently demonſtrated, that ſuch a ſingle Ray, is, in reality, a collection of ſeven Rays, which are perfectly diſtinct, and which, it appears, may be applied to one another through their whole length, and again be ſo ſeparated from one another, as to be always capable of a longitudinal diviſion into ſeven exceeding ſubtil Filaments, or Rays of ſeven different Colours. If, hereafter, now, this Science ſhould be more ſubtly cultivated, and dioptrical Inſtruments ſhould be carried to greater perfection, who will pretend to aſſert, that even in theſe ſimple *Newtonian* Rays, ſome penetrating genius may not be able to diſcover a ſtill farther compoſition? Theſe inſtances, in the mean time, are ſufficient to raiſe our higheſt admiration, when we conſider the noble faculties with which the Alwiſe Creator has endued the human mind, which being rightly employ'd, will conduct us to a diſcovery of thoſe laws which were eſtabliſhed for the formation of the Univerſe. And certainly, infinite reverence, and eternal thanks, are juſtly due to that gracious Being, who by impreſſing his own Image upon us, has made us capable of diſtinguiſhing truth, and diſpoſed us to be delighted with it, and to uſe the utmoſt of our endeavours to attain it. But this, however, is not all the variety that has been obſerved in the moſt ſimple Particles of Fire; for even in ſuch a ſingle Ray, the ſame *Newton* has diſcovered another diverſity in the nature of its oppoſite ſides; as he found by accurately viewing the refraction in Iſland Chryſtal, where he perceived the Ray to have a Power on one ſide, different from what it had on the other. And as in one Loadſtone, with reſpect to another, the Pole is either attracting, or repelling; ſo likewiſe in one and the ſame Ray, there is a ſimilar

lar Power with regard to its tranſparent ſubſtance. In Fire, therefore, tho' ſo exceeding ſimple, there is diſcovered a three-fold variety. 1. With reſpect to its ſeven different elementary Colours. 2. On account of the very different action of the Rays of different Colours, with regard to reflecting, and refracting Bodies. 3. In regard of the ſame diverſity in the oppoſite ſides of the ſame Rays, with reſpect to this Iſland Chryſtal. In this ſo vaſtly ſimple Being, therefore, we ſee there ſtill remains this manifold variety: What diverſity, therefore, have we reaſon to expect in Compounds? In the ſmalleſt Bodies, we every where obſerve a reſemblance of the greater. Had this diſcovery, which was reſerved for the great *Newton* alone, ſtill lain in obſcurity, I don't doubt but we ſhould all even at this time, have firmly believed, that in a Ray of Light there was ſomewhat ultimately ſmall, and infinitely ſimple: But convinced by his Doctrine, we are now obliged to confeſs, that, tho' Fire is of all known Bodies the moſt ſimple, yet even in this, there is found to be a various multiplicity.

The ſixth property of this Fire is its mobility, which is diſcovered to be ſo great, that we are almoſt certain, let it be where it will, it is never abſolutely at reſt. And here, I don't only mean that motion, which is conſtantly obſerved in all Bodies in general; for in this ſenſe it is certain, that there is not one Body in the Univerſe, that ever for one moment enjoys a perfect quiet. The Sun, certainly, the Planets, and Comets, and their Atmoſpheres that gravitate with them, are all whirled about with very rapid motions: But theſe are the only Bodies that come under our obſervation. Nothing therefore is ever at reſt, but the whole Univerſe is thus conſtantly kept in a ſwift rotation, as the Creator of all things has appointed it. But there is yet another motion which I aſcribe to Fire, and which is the conſtant effect of its proper agility; and this is moſt evidently demonſtrated by undeniable obſervations. Let us, for inſtance, conſider Water, when it is 33 degrees cold, and it will then be in its coldeſt ſtate, that is, it will contain as ſmall a portion of Fire, as in the nature of things can poſſibly reſide in pure Water; for if this ſimple Water is affected by a greater degree of Cold, it will not continue Water any longer, but will be converted into a Subſtance very much reſembling Glaſs, in all the properties of hardneſs, brittleneſs, and pellucidity, tho' reducible again to Water by a Heat of 33 degrees, whereas Glaſs, to make it run like Water, requires a great deal more than ſix hundred. Hence, therefore, it appears evident, that Water is Water only by reaſon of the motion of the Fire reſiding in it, and that it is not Water from its own nature conſidered ſeparately and alone. The ſame is true of Glaſs, Foſſils, Sulphurs, Semi-metals, Metals, and perhaps, of all other Bodies; which appear in a conſiſtent form in a ſmaller degree of Heat, as we obſerved juſt now in Ice, but are put in fuſion, and converted into a kind of Water, if the ſame is increaſed to a certain degree, which will be different, according to the various natures of the Subſtance under examination. Since, therefore, by *Fahrenheit*'s Thermometers, the natural Heat has been obſerved 32 degrees below the freezing point, hence, we ſee evidently, that through all this difference of 32 degrees, the Fire was agitated with a motion, that grew gradually leſs, and leſs, but was never totally deſtroy'd; and therefore, even at that time, when all Animals and Vegetables periſhed through the exceſs of the cold, the Fire was not abſolutely at reſt. We may ſafely aſſert, therefore, that the Fire was even then in motion. But, as it has appear-

And always in motion.

ed ſince by the ſame Experiment, that this Fire may be artificially diminiſhed ſtill 40 degrees more; hence we are now certain, that Fire in the greateſt poſſible natural Cold, is agitated 40 degrees more than it is in this artificial one, and that again through every intermediate degree, it is continually diſſolving ſome Bodies, which a little after, in a ſmaller degree of Heat, appear of a ſolid conſiſtence: Theſe things the Experiments referr'd to abundantly demonſtrate. Fire, therefore, is perpetually agitated in the greateſt Cold, and ſtill gradually more and more in every increaſe of Heat; and hence it is always in motion. The famous *Romer*, from a great number of certain aſtronomical Obſervations carried on for the ſpace of ten years, very ingeniouſly inferred the vaſt ſwiftneſs of the Fire derived from the Sun to the *Satellites* of *Jupiter*, and thence reflected to our Earth; for from theſe *data* Mr. *Hugens*, to whom this was communicated by *Romer*, evidently demonſtrates, that the propagation of it is ſo ſwift, that it moves more than 1,100,000,000 feet, in the ſpace of a Second. See *Hugens, de Lum.* p. 8, 9. This velocity, therefore, of Fire, or Light propagated from the Sun, which is looked upon to be true elementary Fire, would be vaſtly great, if we ſuppoſe it to proceed from the Sun, and fall upon the *Satellites* of *Jupiter*, and to be thence derived to our Earth, which ſeems agreeable to the *Newtonian* Doctrine. And if we ſuppoſe, as others will have it, that theſe Spaces are perfectly full, yet ſtill, the action of luminous Fire, be it what it will, muſt be communicated with the ſame celerity. Afterwards, however, the great *Caſſini*, and *Maraldus*, Men of infinite induſtry, and perfect Maſters of Aſtronomy, carefully examined this affair by the moſt accurate Obſervations of a great many years, and diſcovered, that the opinion of Meſſieurs *Romer* and *Hugens* was very far from the truth. *Mem. de l' Ac. Roy.* 1707. *Hiſt.* p. 77. *ibid. Mem.* p. 25. On this account, therefore, we don't pretend to determine any thing farther concerning the celerity of Light from theſe very ſubtle diſputations: This, however, we are certain of, that the communication of it will be always ſo much the ſwifter, as it is found to be leſs ſucceſſive.

Do not generate Fire.

In the ſeventh place, from what has been laid down, we may certainly conclude, that tho' this elementary Fire induces an infinite number of changes upon all other Bodies, yet, it never has appeared by any Experiment, that any of them have ever been converted by it into true elementary Fire. And hence, it is not confirmed by any Obſervation, that Fire is able to multiply itſelf, by changing its own *Pabulum*, or any Bodies into true Fire, by aſſimilating them to its own nature. Certainly, the more carefully we conſider all the effects of true Fire, the leſs concluſive thoſe Arguments appear, which are brought to prove ſuch a power in Fire, or ſuch an aptitude in other Bodies to this tranſmutation. Hence, therefore, it will be evidently certain, that if Fire itſelf cannot from any other Matter generate Fire, it cannot poſſibly be generated by any other Matter For what cauſe can by any action produce Fire from a Body that is not Fire, if this cannot be effected by Fire itſelf? In the whole compaſs of Nature, certainly, we diſcover nothing, that, with regard to ſuch a Power, can any ways be compared with it. This ſeems to be the grand univerſal Mover, from which every thing elſe receives its motion, all Fluids at leaſt, and perhaps a great number of Solids; which is itſelf never begotten *de novo*, renewed, or reſuſcitated, but is only rendered diſcernible where it did not appear before.

Or are generated by any other means.

Since,

Since, therefore, we are undoubtedly sure of these things, we may now freely assert, that this elementary Fire is always, and every where the same in every Body that is heated by Fire, whatever way it is excited, whatever *Pabulum* it is fed with, or by what contrivance soever it is supported. Unjustly therefore do the Chemists complain, that in their most subtle Operations, they cannot have the advantage of pure Fire; for in these, they imagine the most pure, astral, celestial, solar, elementary, incorruptible Fire, to be intirely necessary. But had they rightly considered what has been already laid down, they would never have embarrassed themselves with this needless solicitude: For the Heat that is generated in the Bodies of Animals, Vegetables, and Fossils, owes its Being intirely to the very same Fire; and when it passes through a glass Vessel into its cavity, is as pure, as if the Vessel had been exposed to the most lucid Rays of the brighest Sun. The Heat of burning Alcohol too, and fossil Coals, when it acts upon any Matter included in a clean glass Vessel hermetically sealed, if it is reduced to the same degree with that of the Sun, and is applied in the same manner, will appear perfectly the same by every effect. Nay, I add farther, that the Fire which is generated by the fetid putrefaction of the most putrid Bodies, when it has pass'd through dense Glass, is as pure, simple, and sincere, as if it had been propagated thither by the clearest Sun. The Heat, therefore, generated by putrefaction, fermentation, and the putrifying Dung of Animals, is the very same as that from pure Fire. And hence, I see no difference betwixt the Heat of Horse Dung for chemical Operations, and any other whatsoever, that is of the same degree, and is applied in the same manner. In Nature, therefore, we meet but with one sort of Fire; for both the elementary, and artificial, are always the same.

Nor have any diversity.

What I have here said, however, must not be understood of common Fires; for in these all sorts of Bodies float about with the pure Fire, and being mixed with it, according to their different Natures, and the alteration induced upon them by the Fire, affect the Bodies exposed openly to them in a very different manner from what they would have been affected, had they been acted upon by a solar catoptrical, or dioptrical *Focus:* Nay, and very differently too, with respect to their own proper Nature. But then, in this case, this various action of Fire does not depend upon Fire, as Fire, but upon Fire, and the other Corpuscles, that at the same time are agitated with it, which certainly makes a vast deal of difference, falsly ascribed to a diversity in Fire itself, which in reality appears to be always the same. The effect, however, of this Fire upon other Bodies, is very different, whilst it is supported in the manner above explained, by various sorts of Fuel; for by this means it acts with more or less violence, and even mixes with them the Particles of its *Pabulum*, which is agitated, vibrated, and often united with it.

The Fire of common Fires the same, but mix'd with other Bodies.

In this respect, therefore, the Fire that is excited and supported by burning Alcohol, is the purest of all, and least of all affects the Bodies exposed to it with any impurities from the combustible Particles.

With Alcohol.

The next pure to this, is that which is fed with Oil often distilled, especially from a fixed alcaline Salt, and hence rendered exceeding fine, simple, subtil, and limpid, like Alcohol. Under this head come the native *Naptha* and *Petroleum*, which are endued with the same property.

With the purest Oils.

Next to this follows the Fire of well prepared Charcoal. Then that of

 pure

With Charcoal, Wood, Turfs, pure Wood; which is succeeded in purity by that from Bituminous Turfs. And these are of two sorts, the one found in Heaths, where the upper Surface being pared off, affords a pure Fuel; the other which is made from a wet, black, fat Mud, which being dug out of proper Pits, and then dried in the Sun, is divided into Parallelipipeds: These yield a noble, wholesome, steady Fire, which the illustrious *Boyle* was formerly so mightily pleased with.

With Coal made from Turf, When this Turf is burnt 'till it is perfectly red hot quite through, and no longer emits any visible Smoke, if you then extinguish it, it affords a Coal, which when it is dry, takes fire with a vast deal of ease, and is exceeding fit for a great many purposes; for it produces no Smoke or disagreeable Smell, continues to burn a long while of itself when once it is kindled, and yields the most equable Fire of any thing we know of.

With Fossil-Coal, To these more compound Fuels belong likewise the Fossil Coals, which consist of an Oil like the Fossil Oil of *Naptha* or *Petroleum*, and another Matter that will vitrify.

And Dung. And lastly, the dry'd Dung of some sorts of Animals. The vast variety therefore that is observed to happen so often from the action of Fire in its physical effects, must be ascribed intirely to the different nature of the *Pabulum* it is fed with: This may be confirmed by abundance of Examples, but one or two will make it sufficiently evident. Wood, for instance, or Turf, when they burn in the open Air, emit a Smoke that is not very pernicious, only making the Eyes smart, and affecting the Lungs in such a manner as to provoke a Cough; and yet, if you convert either of these into Coal in the manner abovementioned, and then dry it thoroughly, and set it on fire and let it burn 'till it is perfectly red hot, there will arise from these Coals a very fine invisible Fume, which in a close place is very quickly fatal to all sorts of Animals. And in this affair there is something very remarkable; for it appears by Experiment, that if you take an Animal, and put it under a large Glass, and draw some of the Air out, but not so much but that the Animal might live in it for some time; then, if by the help of a Pipe you convey the external Air into the Glass, in such a manner as to make it pass through smoaking Coals, it will not destroy the Animal; and yet if the same passes through Coals that are perfectly red quite through, it will be instantly suffocated. And very often too, there is some very extraordinary power communicated to Fire by the Air, as we see evidently in an Experiment related by that famous Writer of *America*, *á Costa*. For he tells us, that the native Silver that is dug out of the richest Mines of *Peru*, cannot, so long as it adheres to its Ore, be melted by the strongest Fire that can be raised by the largest Bellows; and yet if this Fire is blown up by an artificial Wind procured by the fall of cold Water, and convey'd, and forcibly directed upon it by proper Instruments, the fusion of the Silver is soon obtain'd without any difficulty: These, therefore, and many other instances, sufficiently point out to us, how very circumspect we ought to be, if we would rightly understand the action of Fire upon other Bodies, since the minutest circumstances very often make a great deal of difference with regard to the event. There are a few things in our History of Fire still remaining to be considered, which will hereafter be of very great service in our chemical inquiries.

In

In the first place then, don't let us be led away by that vulgar opinion, that Fire is a universal solvent of all Bodies: That it dissolves a great many, indeed, we readily allow; but at the same time we must deny, that it has this effect upon all. Nay, upon the very same object, in different degrees of it, we see it acts in a quite different manner. If you put some Mercury, for instance, into a Bolthead, and apply a gentle Fire to it at first, and afterwards gradually increase it, it will, in length of time, be converted into a various-colour'd Powder, something of a fixed nature, and scarcely miscible with any Liquor; and yet, if you apply as strong a Fire to it at first, as you did at last, it will all immediately evaporate. And farther, if the Mercury thus fixed by a gentle, and gradually increased Heat, is at once exposed to a strong Fire, it will again become totally volatile; so that we see plainly, what the Fire effects in one degree, it destroys in another.

Fire is not a universal Solvent,

In the second place, Fire is not so pure a dissolvent, as to extract from Bodies only those parts that existed in them before; for at the very same time that it separates some parts, it mixes others together. Nothing can be more evident than this in many instances. Antimony, if it is exposed to a strong dioptrical, or catoptrical *Focus*, emits a vast quantity of Fumes, and yet, at the same time, has so large a number of other Corpuscles united and fixed with its *Calx*, that it considerably increases in its bulk. If Lead, by the same method, is converted into *Minium*, there rises likewise from this abundance of noxious Vapours, and yet the *Calx* acquires a considerable addition to its weight. In Corals too, calcined by a strong and long continued Fire, their weight is in the same manner augmented. And lastly, if Mercury, that is by a particular Art purified by the help of Metals, is digested for a long time in a glass Bolthead, it will be converted into a fixed Powder, and a very small portion of good Metal, with an increase of its original weight.

Nor divides Bodies into their real constituent Parts,

Thirdly, from some sorts of Bodies it produces nothing new, but leaves them without any considerable alteration. Gold, for instance, Silver, *Osteocolla*, *Glass*, the *Selenitis*, *Talc*, and *Virgin* Sand, are not separated, either into their Elements, or other Substances, by the simple application of Fire. Consult *Van Helmont* in various places, and *Boyle* in his *Sceptical Chemist*, from p. 10. to 33.

Nor efficaciously dissolves all Bodies,

In the fourth place, there are every where to be met with, great numbers of Bodies, from which it is impossible, by the help of Fire alone, apply it in what manner you will, to separate different Substances, though we certainly know, that Bodies of quite different natures enter into their composition; nay, and can readily, by the assistance of other Instruments, resolve them into their constituent Parts. A great many such Bodies we find taken notice of among the learned; our present Subject leads us to mention a few of them. Gold, Silver, and Copper being melted together, and thus intermixed with one another, produce a Mass, from which the power of Fire will not easily separate again these three simple Metals. If, with twenty times the quantity of good Lead, you manage this Mixture according to Art, in an Assaying Furnace, you will soon very accurately separate the Copper, and there will remain a pure Mass of Gold and Silver. Apply, now, to this whatsoever Fire you please, the Silver will constantly remain united with the Gold; nay, and in such a manner, that the very least Particle of this Mixture will always contain the same Proportion of Gold and Silver, as was in the whole piece. But if you then throw this Mass into

Tho' they are separable by other means.

pure Spirit of Nitre, the Spirit will intirely diſſolve every Particle of the Silver without the leaſt remainder, and the Gold will lie at the bottom of the Veſſel, in form of a black Powder. The Silver, then, which is thus ſeparated from the Gold, and reſides in the Spirit of Nitre, you will not be able to ſeparate again totally from the Spirit, without a good deal of difficulty; for if you call in Fire to your aſſiſtance, the Maſs will, by the application of this, at laſt grow dry, and become the *Lapis infernalis*, in which the Acid of the Nitre very tenaciouſly adheres to the Silver, and runs with it in the Fire without any Fumes, in the ſame manner as if it was one ſimple melted Metal; but now, if into this Solution of Silver by the Spirit of Nitre, you immerge ſome thin Plates of Copper, then the whole Subſtance of the Silver, without any remainder, will be diſengaged from the Spirit of Nitre, and every thing elſe, and lightly adhere to the copper, from which being ſhook off to the bottom of the Veſſel, and then waſhed with Water, you will obtain your Silver again, in the greateſt purity: So that here we ſee, likewiſe, what the Power of Fire was not able to effect, is brought about by ſome other means. It's needleſs to make mention of the Sulphurs that are mixed among the metalline Glebes, which adhere to them in ſuch a manner, that they either keep melted with them in the Fire, or elſe carry 'em off with them into the Air. How unſucceſsful, and with what diſadvantage, have the Metallurgiſts endeavoured, by the help of Fire, to diſſipate the volatile Sulphur, that the Metal might remain pure at the bottom of the Cupel? And yet if with theſe you mix ſome fixed alcalious Salt, or Iron, which in the Fire greedily unites with Sulphur, or any abſorbent Powders made of theſe or the like materials, as ſoon as ever the Sulphur has abſorbed theſe additional Subſtances, and united them with itſelf, it produces ſome ſulphureous *Scoriæ*, and gives you the pure metalline Glebe at the bottom. Examine Antimony, and whenever it is pure, it appears to be homogeneous. Manage it by Fire, in what manner you pleaſe, and it will either be intirely carried up in Fumes, or, if the Fire is gentle, will totally remain in it. But if you mix with it, now, Tartar and Nitre, or Iron and Nitre, and then ſet it on fire, the external, ſulphureous Part will be immediately ſeparated, and the metalline Maſs will be left behind, intire, ponderous, and homogeneous. If you put the ſame Antimony into *Aqua Regia*, the Sulphur will be caſt out unaffected by the Acid, whilſt the *Aqua Regia* ſiezes upon the metalline part, and unites it with itſelf. *Sal Ammoniac*, which is truly a compound Subſtance, in a greater degree of Heat, riſes totally, and without ſeparation; in a leſs too, continues undivided; and yet, by an addition of a fixed alcaline Salt, it is very readily reſolved into a fixed Sea Salt, and a volatile animal one. *Mercurius Sublimatus Corroſivus*, if it is for a long time expoſed to the Fire, continues compounded of the acid Spirit of Salt, and Mercury; but is freed from its Acid by mixing with it Iron or *Alcali's*. Chemiſtry every where furniſhes us with numberleſs Inſtances of the ſame kind.

Nor divides them into ſimple Elements.

In the fifth place, it deſerves our notice, that thoſe parts, which are ſeparated by Fire from compound Bodies, how carefully ſoever you apply it, are not in reality ſimple Subſtances, but are variouſly intermixed with one another. If you examine, for inſtance, the ſimple Waters, that are drawn by Fire, does not the odour at firſt drawing, and the Turbidneſs, putrid Smell, and ſlimyneſs they naturally acquire in keeping, make it evident, how much they are ſtill compounded, ſince none of theſe things are ever obſerved in pure Water? Conſider the

2 Spirits,

Spirits, and you will find that they consist of a Water and Salt, so intimately united together, that it is not possible to separate them by any Art, except by the joint assistance of fixed Salts and Fire. But what shall we say of the Oils? The common Chemists look upon these, as most simple, pure, sulphureous Elements; but the top masters in the Art make it evident, that these too are remarkably compounded of various Substances. For in these there is that inflammable Element, of which we have so particularly treated above, a great deal of Water, and some quantity both of Salt and Earth, intimately united together. And lastly, as for the Earth that is extracted by Fire from compounded Bodies, what a vast deal of trouble is required before it can be obtained perfectly pure? Certainly it is always tenacious of some fixed Salts, even till it begins to be converted into Glass.

Nay, and it compounds Bodies.

In the sixth place, it appears by abundance of Experiments, that the composition of Bodies is as much affected by the action of Fire as their separation; for it unites the most different Bodies so intimately together, that the new formed Substance appears perfectly simple, and is not liable to any alteration from its power afterwards. For Sand, we know, by being calcined, melted, and intimately mixed with a fixed Alcali, by the force of an intense Fire, produces Glass, which is then so simple in the whole, and every part, that we scarce know any thing more so, or harder to be dissolved, since it can be separated into its simple parts by no other means, than by melting it with a great quantity of fixed Salt, that it may become of a saline nature, and then pouring an Acid upon it, by which means an exceeding subtil powder of Sand will be precipitated from it. The various kinds of Soap demonstrate the same thing. The distillations of *Aq. Regia* evidently confirm it likewise; as well as the artificial mixing of Metals. But what need is there of more instances? Does not universal nature make use of Fire, as its principal instrument in the production of its compound Bodies? What Compound is generated, either in the animal, vegetable, or fossil Kingdom, that does not owe its origin to a soft, digesting, disposing, compounding Fire? Certainly, the gentle and steady action of that grand mover, Fire, seems to be the principal cause that every where brings about the most strict and intimate union; nay, even so much, that it may be doubted, whether Fire is most efficacious in the composition of Bodies, or in their dissolution. Without dispute, it hath a vast effect in both.

And again, separates the Compounds.

In the seventh place, it ought particularly to be taken notice of, that the very same Fire, if it is applied in different degrees, will in one, compound those Bodies, which it will again resolve in another. This the Chemists have frequently learned to their cost, for when they have spent years in fixing Mercury by a gentle Heat, successively increased through various degrees, and by this means have obtained a red powder, which remained a good while fixed in the Fire, they have found that at last, when the Fire was rendered intense by the assistance of Bellows, it has been dissipated into the Air; and thus being disappointed of their expectations, have experienced, that Fire separates in one degree, what it before united in another.

Acts variously, with regard to the Air.

But eighthly, the very same degree of Fire applied to the same Bodies in different circumstances, produces effects that are surprizingly different, and that particularly, according to the various admission of the Air in the operation. The famous *Hook* took a Coal, and by means of a Cover that screwed on,

perfectly

perfectly inclosed it in an iron box. In this manner he exposed it to a very strong Fire, for a considerable time, and yet when he took it out, the Coal, by such a violent action of the Fire, was not burnt up. See *his Life in his Posthumous Works*, p. 21. Hence this ingenious Philosopher inferr'd, that the Air is a *menstruum*, which, being agitated by Fire, will dissolve all sulphureous Bodies, since Fire, without the assistance of the Air, is not able to effect it. The same thing *Van Helmont*, in his Distillations, had formerly observed in his fixed Coal. And *Rapin*, *Receuil des Machines*, p. 25, 26. And when, before you here, I put some Shavings of *Guaiacum* into a Retort, and urged them with a very strong Fire for a long while together, there remained at last, as I told you, some black *Fæces*, that still retained an Oil, which the utmost force of the Fire was not able to force out of the Retort. But when this powdered Coal was laid in a large Dish, and examined, by dropping a spark of Fire into it, then the black Oil was immediately consumed with an aromatick Smoke, that smelled like Cedar, and the Shavings were turned into insipid white Ashes. Camphire, if it is set on fire in the Air, will intirely consume, though it swims in Water; and yet if you expose it to the Fire in a clean glass vessel, with an Alembic over it, it will melt and rise into the Alembic, and there harden into the same Camphire again without any alteration. And though you repeat this a good many times, the event will be still the same. May not Sulphur be sublimed a hundred times in a close Vessel, and still remain the same Sulphur? And yet if during the sublimation, there happens to be a crack any where, so that the Air can have a communication with the melted Sulphur, it immediately takes fire, and is instantly resolved into a blue Flame and an acid Fume. Amber, if you set it on fire in the open Air, almost totally burns away, and supports Flame and Fire; but if you urge it in a Retort with the strongest degree of Fire, but gradually increased, you will force into the Receiver a Water, Spirit, a volatile acid Salt, an Oil of various sorts, and with the last degree will make the whole substance of the Amber come over the neck of the Retort; as I have frequently myself experienced. Fire, therefore, when it acts upon inflammable substances, without Air, or with Air that stagnates, and is without motion, produces very different effects from what it does in other circumstances.

And variously in various degrees. Ninthly, and lastly, the same Fire applied to the very same Object, but in different degrees, is very various in its Operation; as appears, likewise, by Experiments. Take, for instance, the fresh White of an Egg, put it into a clean Vessel, to which there is a free admission of the Air, and let it be exposed to 92 degrees of Heat, in *Fahrenheit*'s Thermometer, and it will in a little time be resolved into a Liquid, that grows continually thinner and thinner, becomes sanious, fetid, and putrid, and at last runs just like Water, nor will be coagulated by the Heat that makes Water boil; and thus it is converted into a most putrid, volatile Alcali: But now, if the same White of Egg is exposed to 200 degrees of Heat, in the same Thermometer, it is immediately changed into a white, solid, scissile, insipid Mass, exhales a large quantity of inodorous, insipid Water, and at last there remains at the bottom an exceeding hard, brittle, pellucid, insipid, inodorous Substance, that may be kept for years without any alteration: And again, the same White being urged by a Fire of 400 degrees, in a glass Retort, yields a Phlegm, Spirits,

fetid

fetid Oils, an oily, fetid, alcaline, volatile Salt, and an exceeding black Coal that is ſurprizingly puffed up by the Fire. But there would be no end, Gentlemen, ſhould I go about fully to explain the nature of the power of Fire. Let it ſuffice at preſent, that I refreſh your memories with a ſhort abſtract of this Doctrine, as it has been already delivered, *viz.* that the action of Fire, as it may be varied under all the circumſtances above mentioned, is capable, as a concurring cauſe, of producing the greateſt part of the phyſical effects that fall under our obſervation. It can alter Concretes in their Figures, and Coheſions; but in ſuch a manner, however, that a difference in the Concretes produces a variety, with regard to this power; for Fire is never able to produce the ſame thing from different Bodies, but ſome certain things from particular ones; and then, beſides, there will be yet a farther difference, according to the various order, degrees, and application.

Our Diſſertation of Fire, Gentlemen, is thus then at length ſo far advanced, that we are now able to treat of that knowledge of Fire, conſidered as preſent, and operating in a particular place, which an Artiſt ought to be acquainted with, in order to know how to direct and keep up ſuch a Fire, in a given place, as is proper for the inducing ſuch and ſuch changes in certain Bodies. This doctrine was laid down by the ancient Chemiſts, and is at preſent almoſt brought to its greateſt perfection by means of thoſe beautiful Thermometers of the ingenious *Fahrenheit.* It was their opinion, that the power of Fire might be conveniently enough reduced to four degrees, and that this diſtinction was ſufficient for the exerciſe of their Art: Of this matter, however, they gave us but a very obſcure Account: Nor have the moderns made any conſiderable additions. Let us, therefore, Gentlemen, undertake this point, and call in Art to our aſſiſtance, but Art that is formed upon Nature.

Of diſtinguiſhing and managing Fire.

The firſt degree, then, of Chemical Fire, I call that, within the compaſs of which Nature brings about the work of Vegetation in Plants, and by which the Chemical Art imitates the ſame. This begins from the greateſt degree of Cold, *viz.* Number 1. in *Fahrenheit*'s Thermometer, and ends at the degree 80: For through all the degrees contained betwixt theſe limits, Vegetables of one kind or other give plain indications of Life and Vigour. Don't you, in the moſt piercing cold, ſee the bitter moſſes growing upon the barks of Trees, and indeed ſcarcely at any other time? Don't the Fir, the Juniper, the oriental Larch-tree, the Cedar, the Pine, the Savine, the Yew, and the *Arbor vitæ*, retain their verdure in the ſharpeſt Winter? Not to mention the Sea Moſſes, the Land Moſſes, the Black Hellebore, the *Hepatica Nobilis*, the Snow-drop, the Winter Wolf-bane, the Baſtard Hellebore, and others; which in the hardeſt Winters put out Leaves, flower, generate, conceive, and bring forth, notwithſtanding the check one would imagine they ſhould receive from the intenſeneſs of the Cold. In ſhort, if you carefully examine all the Plants that we are at preſent acquainted with, by the degrees of Heat contained within the bounds here deſcribed, you will find ſome Plant or other that comes to its maturity in almoſt every one of theſe intermediate degrees.

The firſt degree of Chemical Fire.

Hence it appears very probable, that the Chemiſt, by a well managed degree of Heat, may in his artificial Stoves imitate that power of Fire, which Nature makes uſe of in the generating of Vegetables, ſo as by gentle degrees to

The remarkable uſe of this.

proceed to cherish the Plants, and not to destroy them. If you desire to excite such a Heat as this, upon a proper furnace place a vessel full of Water, in which dispose a Thermometer, and then you may, by increasing or lessening the Fire, easily reduce the Water to that temperature which is for your purpose. When the Water is thus found to be sufficiently warm, put the Body you would make the Experiment upon in a glass Vessel, and set it in the Water, which by this means will communicate to it a proper degree of Heat. Is it not very probable now, Gentlemen, that this degree of Heat is the best suited to impregnate Oils with the choice Spirit of some Vegetables, without dissipating the most precious Part? If one wanted, for instance, to impregnate an Oil with the most fragrant Spirit of Roses, what method is more likely to succeed, than the taking some Roses, gathered in the morning, and digesting them with some pure, inodorous, and almost insipid Oil of Olives, in a tall Bolthead, in 56 degrees of Heat? Such a Heat certainly will so unite and intangle the Spirit of the Roses in the viscidity of the Oil, that it will not be easily disengaged again, but will produce a most fragrant Balsam. And if you would inrich the most liquid Alcohol with the choicest Spirit of Saffron, make use of the very same degree; for with a less you will scarcely extract it from the Substance of the Saffron; with a greater, you will dissipate those particles which are most volatile. There are but few who have a right notion of this Affair; those, however, who are best acquainted with these things, know it to be true. By this caution in the management of the Fire, it is certain, there are incomparable Medicines prepared, which become good for nothing, if you increase it beyond its proper bounds.

The second degree.

The second degree of Fire may, I think, be most conveniently measured by the Heat that is at some time or other observed in healthy Bodies. This, in its lowest State, is supposed to begin at the 40th degree, in *Fahrenheit*'s Thermometer, and in its greatest height, to rise to about 94. Within this compass Animals seem to be capable of subsisting, if their humours have any degree of Heat in them, that is contained between these Limits. There are some kinds of Insects that live with a very small degree of Heat in their vital Juices, and nothing seems to me more surprizing, than that the *Embryo's* in the Eggs of Caterpillars (which they lodge, when they are impregnated, in a viscid matter circularly disposed round small twigs) should remain secure in their little Nests, during all the severe Winter of the Year 1709, and the very sharp one of the present 1729: For notwithstanding every body would be ready to imagine, that they must have perished through the extremity of the Frost, yet by the kindly influence of the warmth of the approaching Spring, we saw the Worms able to disengage themselves from their Eggs, and thus make it appear, that they had stood out against the great severity of the weather. Fishes too, belonging both to Seas and Rivers, that have Gills instead of Lungs, live and keep moving continually in Water that is 34 degrees warm; and if the Heat of it is increased from hence as far as 60 degrees, and better, they are still in some measure able to bear it. But Fishes that are furnished with Lungs, like other respiring Animals, in the time of health, communicate to their humours a warmth of 92 degrees, a little more or less; and hence they will subsist in any degree, betwixt 33 and 94. Within the compass of this Heat are included the vital actions of Animals, the fermentation of Vegetables, and the putrefaction both of

The use of this.

of Vegetables and Animals; as likewise the generation, breeding, hatching, birth, and nutrition of Animals. This degree of Heat the most experienced Chemists make use of to prepare their Elixirs, volatile alcaline Salts, both simple and oily, and their Tinctures; and employ the same in concocting their Mercury to the first preparation of the Philosopher's Stone.

The third degree of Heat begins at the degree 94, and reaches as far as 212, in which Water generally begins to boil. Through this whole intermediate space, the Water and native Spirits are separated from all kinds of Animals and Vegetables; and the *Residuum* grows dry, becomes durable, and almost immutable. The essential Oils of Plants in this Heat become volatile. The Salts and Oils, in the fresh Juices of Animals, are scarcely raised, but the Juices are dried into a thick, hard, brittle, insipid, inodorous Substance, which will keep for years without any considerable alteration. And hence it appears, with how little reason some persons imagine, that volatile, alcaline, oily Salts, are generated and retained in a healthy Body. This degree of Heat serves for the distillation of the distilled Oils, and medicinal Waters of Vegetables. The sanguineous serous Juices of Animals coagulate in boiling Water into a Mass that will bear to be cut asunder; whilst all their Solids are destroyed by it, and reduced to a thick, tenacious Liquid. And hence it is absolutely destructive to all Animals.

The third degree.

The efficacy of this degree.

The fourth degree may be reckoned from the degree 212 to 600; within which limits, all Oils, Saline *Lixivia*, Mercury, and Oil of Vitriol, recede from the Fire, are carried upwards, and by this means distilled. In this too, Lead and Tin are put in fusion, and may be mixed together. The Oils, Salts, and saponaceous Juices of Animals and Vegetables are rendered volatile and acrid, and become more or less alcalescent: The solid parts of them are dried, and if they are calcined, are changed into a very black Coal, are all absolutely destroyed, quite altered in their qualities, and lose intirely their proper Virtues. Within this Heat too are sublimed Fossil Sulphur, and *Sal-Ammoniac*.

The fourth degree.

The fifth degree of Fire may contain that latitude, in which the rest of the Metals are put in fusion. This will begin at the degree 600, and reach as far as that which is capable of melting Iron. This degree, Glass, Gold, Silver, Copper and Iron, bear a considerable time, whilst it destroys every thing else. In this degree all other fixed Bodies grow white with Heat, the fixed Salts of Vegetables and Fossils are put in fusion, are deprived of almost all their Oils, acquire a greater and greater alcalious acrimony, and with Sand or Flints are converted into Glass; Lime-stones are calcined; all other things either vitrify, or become volatile, and are dissipated into the Air.

The fifth degree.

The sixth and last degree comprehends the whole compass of the dioptrical and catoptrical Fire above describ'd; which hardly any Body is able to resist: By this even Gold itself suffers very surprizing alterations. Concerning this Fire, consult the Observations of *Mess. Homberg*, *Hartsocker*, and *Vilette*, and what we formerly delivered upon this Subject. The principal effect that this Fire commonly has upon almost all Bodies, is the turning them to Glass. The ultimate effect, therefore, of the Fire that we are at present acquainted with upon fixed Bodies, is their Vitrification. This the most ancient *Magi* of the East seem to have understood, when they prophesied, that the whole World would at length be destroyed by Fire, and that it would then be con-

The sixth degree.

verted into pellucid Glaſs. Thus far, then, at leaſt, our doctine of the degrees of Fire ſtands upon a ſure Foundation; as for the ultimate power of it, the human mind will never be able to fix its limits.

A certain direction for theſe degrees. In the next place, now, it is of great conſequence for us to be acquainted by what means we may know how to raiſe and keep up a Fire to any degree that we have occaſion for; on this principally depends all the operations of the whole art of Chemiſtry.

First, the nature of the *Pabulum.* And here it is much more difficult to preſerve a great degree of Cold, for a conſiderable time, than it is to keep up a very great Heat; as the metal and Glaſs Works, where ſuch intenſe Fires are requiſite, moſt evidently demonſtrate. The firſt way, then, by which we may keep a Fire moderate, is by chooſing ſuch kind of *Pabulum*, afore deſcribed, as is proper to produce ſuch a ſtrength of Fire as is fit for our purpoſe. Alcohol of Wine yields a weak, and equable Flame, that may be eaſily increaſed or diminiſhed by a greater or leſs number of wicks. When you are determin'd, therefore, about the degree of Heat, that you deſign to make uſe of, it is a very eaſiy matter to light a Lamp with ſo many Wicks as appear by the Thermometer to be neceſſary to excite the degree deſired. After Alcohol, follow the lighter, porous, ſpongy kinds of *Pabulum*, as Ruſhes, Straw, dry Leaves, Hair, Feathers, Shavings, dried Stalks of Buck-wheat, Chaff, and Bran. Next in order, Oils, Tallow, Wax, Camphire, Pitch, Roſin, Sulphur, and other Compounds. Then thick, heavy, hard, ſound Wood, not too dry, and the Coals that are made from it. And, laſtly, red hot Metals; and foſſil Coals.

Secondly, the quantity. Again, various degrees of Fire, even to the greateſt, may be raiſed by the quantity of combuſtible matter thrown on; for if a vaſt quantity of Fuel is ſet on fire all at once, then the Fire that is produced by it will be always proportionably ſtronger, the force of it all being united together.

Thirdly, the diſtance. But farther, there will be a vaſt deal of difference in the Heat, with reſpect to the Object it acts upon, according to the diſtances in which the Body is expoſed to the Fire, the Heat always decreaſing, as it is removed farther off. A great many famous Philoſophers have been of opinion, that this difference might be determined by one ſimple rule, *viz.* that the forces of corporeal qualities always decreaſe in a reciprocal proportion of the ſquares of the diſtances from the center that generates theſe qualities; and hence that Fire too acting at double diſtance, has only one fourth part of the force. But before we can be certain of the truth of this, we muſt firſt be ſure, that the Fire itſelf, when it is contracted into a narrower compaſs, does not acquire ſome new power, not depending upon the number of the Elements alone, but upon ſome efficacy which they acquire by being brought nearer to one another. And indeed, if we carefully examine this Affair, we ſhall find, that though it is true, indeed, that the farther we recede from Fire, the leſs Heat we are always ſenſible of; yet the law in which it decreaſes is very different from the general one, juſt now mentioned. For Experiments cautiouſly made for this purpoſe, plainly evince, that at a ſmall diſtance from the heating point, the Heat on a ſudden decreaſes prodigiouſly, but that at a greater, the proportion of the decreaſe is not ſo remarkable. Hence it appears very probable, that beſides the power they have of acting upon other Bodies, the particles of Fire acquire another power, depending upon the relative motion which arises from their approaching very near to one another. For since those famous Philosophers, *Grimaldus* and *Newton*, have observed, that the Elements of Fire, as they tend towards opake reflecting Bodies acquire new motions, as they come near their Surfaces, why may not the very particles of Fire be effected in the same manner by one another? But here I refer you to what has been already delivered upon this subject.

Fourthly, by agitation and compression.

In the last place, the agitation, concussion, and compression of Fire, when it is excited by its *Pabulum*, and included within its aereal Arch, must enter likewise into the consideration: For by these the violence of it is very much increased, and indeed, always the more so, the stronger they are, supposing the Arch not destroy'd, as we took notice of before. And here, as we cannot by any means procure this agitation and compression of Fire, more conveniently, and more efficaciously, than by blowing, or driving the Air forcibly upon the Body of the Fire; hence Bellows are the Instruments in particular by which we direct this pressure of the Air upon the Surface of the Fire, and thus agitate the parts of it with a great deal of violence: But of this too we have treated already, when we was considering the aereal Arch that surrounds a burning Fire. And there likewise we saw, that if the Wind of a great many strong Bellows is directed from opposite parts upon the center of the same Fire, then the Fire will act with so much more strength upon the Body that is placed in that center, and consequently the changes it induces upon it will be so much more considerable. And hence the Assayers make use of this method in particular, when they want the greatest strength of Fire. In short, therefore, if the four methods abovementioned are called in to our assistance, and made to conspire in their efficacy, we shall by this means procure the most intense common Fire.

These are the things, Gentlemen, which I thought principally necessary to lay before you, and to explain to you, in the natural History of Fire, particularly, as it is of use in the chemical Art. The disposing them in a proper manner, and setting them in an advantageous Light, has cost me a great deal of pains: Whether it has answered any valuable purpose, I leave you to judge. I think, however, that this is evidently certain from what has been said, that a chemical Fire, supported by the same *Pabulum*, and apply'd in the same manner, and the same degree, will always have exactly the same effect upon the same Bodies, either of adunation, or separation: And again, that unless these circumstances are first accurately determin'd, it is impossible to describe the action of Fire upon Bodies with any certainty. In giving an account therefore of any chemical operations, we must have a very careful regard to every thing that has been any where proposed in our Treatise of Fire: And thus at length the Art of Chemistry may be reduced to as certain and regular a Science as any other. Besure, therefore, always to take notice of the degree of Fire; the succession of the degrees; the weight, and heat of the Atmosphere, and its action upon the Fire, either by draught, or artificial, or natural Wind; and then give an account of the Object: And a description formed upon this plan, will never lead a person, that would work after you, into mistakes. Give me leave now to add a few things that regard the nature of Fire. First, then, Fire, for its existence, does not stand in need of Air, Nitre, Fuel, Sulphur, or any other

Body. True *Naptha*, among Bodies we are acquainted with, is ſet on fire the eaſieſt, and that, at a conſiderable diſtance from the Flame; as is likewiſe the pureſt *Petroleum*. *Journ. des Sc.* 1675. 53. Bodies that are rubb'd over with *Naptha*, and then ſet on fire, continue to burn, tho' they are immerged under Water. *Journ. des Sc.* 1683. 104. *Naptha* takes fire by the flame of a Candle placed within a Lanthorn, and thus prevented from coming into contact with it. *Phil. Tranſ.* N. 100. p. 188. Some Gunpowder was diſpoſed in a machine into which Water could not penetrate, and with it was included a piece of Clockwork, which at a certain time, by ſtriking a Flint againſt a Steel, ſhould ſet the Powder on fire; it was then let down to the bottom of the Sea, and when, at the time expected, the Gunpowder took fire, they heard a very great rumbling noiſe, and ſaw a very thick Smoke, but there was not the leaſt appearance of any Flame, *Sinclair. de arte Gravitationis*; which Experiment certainly deſerves the moſt careful Obſervation, as it affords a good many *Phænomena* pretty remarkable. Sir *Thomas Sibbald*, in his *Scotia Illuſtrata*, gives us a very extraordinary account of the Lake *Strath-Erith* in *Scotland*, whoſe Water, he tells us, let the Cold be ever ſo ſharp, never freezes before the month of *February*, and yet after that time, in the ſpace of one Night, is often covered with a ſtrong Ice; which *Phænomenon* ſeems to indicate that Heat increaſed in one place, produces a greater degree of Cold in another. And this again, which indeed was formerly taken notice of, ſeems more evidently deducible from another ſurprizing Obſervation of a little Rivulet that never freezes at all, let the Cold be ever ſo ſevere. *Phil. Tranſ.* N. 56. 1139. The ſame abridg'd, T. II. 335. But this opinion ſeems moſt of all confirm'd by the accounts we have from the Abbot *Boiſotte*, in the *Journ. des Sc.* 1686. p. 336; and *Du Hamel.* in the *Hiſt. de l' Ac. Roy. des Sc.* p. 257. viz. that at about 5 leagues from *Bicanſon* in *France*, there is a Cave 300 paces deep, which in the ſpace of one day, when the Weather is exceſſive hot, furniſhes ſo much Ice, that the Waggons and Mules are ſcarce able to carry it away in eight; ſo that it riſes almoſt to the thickneſs of four feet: And on the contrary, in the Winter time, it is full of denſe Vapours, and a River runs in the middle of it, which is always frozen in the Summer. When any Vapours are ſeen in this Cave, they certainly prognoſticate immediate rain. In Green-houſes, likewiſe, and Stoves made to preſerve Plants in the Winter, the greater the Heat is in any particular places, the more Cold there is in all the others. And the ſame is true of the places ſurrounding the Furnaces uſed for melting of Iron, and all the works with large Fires, eſpecially, when the Heat within is moſt intenſe.

Thus, Gentlemen, I have endeavoured to explain to you the nature of that wonderful cauſe, which the great Creator has placed in the Univerſe, with a power of exciting thoſe motions in natural Bodies, which are neceſſary for bringing about the extraordinary changes that are continually effected. As far as I have been able to get any knowledge of it by a laborious inquiry, I ſubmit it to your examination. Its abſtruſe and myſterious nature affords us ſtill matter for an infinite number of Diſcoveries. Let me excite your diligence therefore, to continue the proſecution of theſe inquiries, and afterwards to communicate them to mankind, that thus, by a more perfect knowledge of the Works of the Alwiſe Creator, we may better underſtand, and more juſtly reverence that immenſe Power and Wiſdom, which infinitely ſurpaſs all human comprehenſion.

Of Air.

Air next to be treated of.

Order requires, that in the next place we ſhould treat of Air; ſince both Nature and Art, by its concurrence and vertue, perform almoſt all their Operations. It is neceſſary, therefore, that we ſhould be thoroughly acquainted with its nature and properties, if we would rightly underſtand the manner in which phyſical changes are effected. But as Air is more compound than even Fire itſelf, and conſequently more difficult to be underſtood, hence the better to ſearch out its hidden genius, we muſt here again proceed, as if we were intirely unacquainted with it, and obſerve the very ſame ſteps that we took in order to diſcover the nature of Fire. By the name Air then, we would have you underſtand that Fluid, which is hardly to be perceived by our Senſes, but that manifeſts itſelf by its reſiſtance to Bodies moved in it, and by its ſtrong motion againſt other Bodies, at which time it is called Wind. By theſe Obſervations we know, that the Air reſts every where upon the Surface of our Earth. All Men live in it, we enjoy it, and are perpetually nouriſhed by it. The manner of our exiſtence, and inevitable neceſſity conſtrain us, to breath in this Air, be it what it will; inſomuch, that all the aids of Art are vain, and all that Nature can do for us, is fruitleſs, if we are deprived of it.

A ſecond univerſal Inſtrument,

If we will but examine into the manner, in which Nature operates according to the Laws which the great Creator has appointed, we ſhall plainly perceive, that this very Air is that grand, efficacious, and neceſſary Inſtrument, which univerſal Nature principally makes uſe of, in almoſt all the Operations ſhe is perpetually engaged in. For in this, all *Species* of Bodies are placed; in this they move; and in this they perform all their actions; as well thoſe ſingular ones which proceed from their proper and particular Natures; as thoſe which are produced from their mutual, or as it is called, relative, diſpoſition. Nay, there is ſcarcely any Liquid, as will hereafter appear by Experiments, which has not Air intermixed with its parts; ſcarcely any Solid, out of which Air may not be extracted by ſome Art or other. So that in ſhort, it is very difficult to mention any known Operation of Nature, which happens without the aſſiſtance of Air, or utterly excluſive of it. The Operations of Fire, the Loadſtone, Gravity, and the particular attraction, and repulſion of Corpuſcles, may perhaps be alone excepted, as capable of being performed without it: To all others it is abſolutely neceſſary. Whatever the chemical Art performs, it executes in the Air without any exception that I know of; unleſs, perhaps, the Alchemiſts will have it, that the Matter of the *Philoſopher's Stone*, rightly prepared, and carefully lock'd up in the philoſophical Egg, is intirely deprived of all crude Air, and is brought to its maturity, rather in *vacuo*, than in Air; for indeed, they all declare to a Man, that nothing is ſo great an obſtacle to the maturation of this moſt beautiful Fruit, as the crude Air: But this may be ought rather to be underſtood, of the other Particles that are intermixt with the Air, than of the pure Element itſelf.

Becauſe it excites even Fire itſelf.

We know with the greateſt certainty, that Fire which puts all things in motion, can ſcarcely be either collected, preſerved, directed, increaſed, or moderated, without Air. Hence, then, if Fire requires Air, of conſequence, all

all its Operations will require the ſame; ſo that without it, Fire would ceaſe to operate, nor could be applied to other Bodies. But let me caution you, that I am here talking of that Fire which is excited and fed with inflammable Fuel, by the means of which, both Art and Nature execute their principal deſigns, and which, as has been proved by many Arguments above, ſtands in ſo much need of this Element.

It acts upon Animals, Vegetables, and Foſſils.

Whoever has leiſure and inclination to take a view of the more general *Claſſes* of natural Bodies, will find, that Air is every where required to their vitality, growth, vigour, and action. For if their vitality conſiſts in their propelling their humours through proper veſſels, and by a peculiar power, converting the foreign Juices they receive into their own nature, or at leaſt by a ſingular vertue applying them to their Subſtance, and thus increaſing in their magnitude; I cannot help thinking it utterly impoſſible, that any one of theſe functions can be performed without the perpetual aſſiſtance of Air; but that its preſence and aid is abſolutely neceſſary to them all.

Air, how far concerned in the life of Foſſils.

The chemical Tribe, in particular, I am aware, will be ſurprized, when they hear me calling in the Air, in order to ſet forth the œconomy of Foſſils; ſince their excluding ſimple matter ſeems to have occaſion for the efficacy of Fire alone, to be capable both to act and undergo whatever is brought about in the *Species* of Bodies. But certainly, thoſe who have duly conſidered the nature of things, have long ago underſtood that Foſſils are brought forth, and multiplied, in the deepeſt receſſes of the mines, and are thence protruded upwards, and that all this is accompliſhed by the exquiſite power of the ſubterraneous Fire. And as this is certain, ſo likewiſe it muſt be allowed, that this ſubterraneous, veſtal, and perpetual Fire, is there retained, collected and apply'd, by the Air alone. This, Gentlemen, is what I am particularly deſirous to ſet before you in a proper light, as it is a point which has hardly been clearly handled any where elſe. Air then is a heavy, elaſtic, Fluid; denſe, in proportion to the weights that compreſs it, acts more powerfully upon the ſame Fire, in proportion to its acquired denſity; expands itſelf in the ſame *Ratio*, as it is freed from compreſſion; rarefies proportionably to the intenſeneſs of the Fire that acts upon it; and inſinuates itſelf into all things; and exerts chiefly all its properties, in thoſe parts which are deep, and towards the center of the Earth. Hence, therefore, it always operates the more violently, the deeper and denſer it is, and being agitated by the Fire, which by this very attrition of the Air is collected there in greater quantity, becomes the phyſical cauſe of the moſt violent compreſſion, attrition, compaction, depuration, and union of homogeneous Particles: And hence, the Foſſils which are generated there, are of a nature ſuitable to ſuch a cauſe. Without this Air, none of theſe would be produced. And, perhaps, this is the ſole reaſon, why they are only formed in thoſe places. But more of this hereafter. What I have here ſaid is ſufficient, as it ſerves to let you ſee, that the preſence and active vertue of the Air is requiſite to all the Operations of Nature.

In Animals and Vegetables.

Nor will it be any ways neceſſary, that I ſhould explain to you the power of this Air upon Animals, and Plants; for ſome late very accurate Experiments have fully inſtructed us, that no Eggs of Animals, or Seeds of Plants, be they ever ſo ripe, pregnant, and the beſt of the kind, and cheriſhed with ever ſo kindly a warmth, will ever bring forth the Embryo's contained in them, but will

will remain intirely unactive, if they are either deprived of Air, or are inclosed in stagnating Air in Glasses hermetically sealed. All small Plants, likewise, even the most minute Mosses, or aquatick Vegetables, when they are kept in a place void of Air, or when it is not renewed, presently wither and die. That the same also happens to all Animals, even to the smallest Insect, is true, beyond all contradiction. Thus then you clearly perceive the mighty influence of Air over all things.

An accurate knowledge, therefore, of the Air, by which its actuating properties may be understood, is absolutely necessary for the Chemist, Physician, and natural Philosopher; for by this means alone, we shall be able to comprehend a great many Operations, which are performed by Art, or Nature itself, their principal cause very often being some innate power of the Air, that exists no where else. The knowledge of the Air therefore, very necessary.

In the mean time, there is not, perhaps, any natural Body, the perfect knowledge of which, is a matter of greater difficulty; because spontaneously, and of itself, it scarcely affects the organs of our Senses. This one may justly attribute to its exceeding subtilty, to which the dulness of our Nerves renders us insensible; inasmuch, as, even by the assistance of the most perfect Microscopes, we are not able to discover any thing in it. But there is yet somewhat else in the Air, which is still a greater obstacle to our rightly understanding its Nature, and that is, its containing so many various kinds of Corpuscles, that in the whole Universe, there is not found a Fluid compounded of a greater variety. Nay, when you have heard what I am going to deliver concerning this Element, it will clearly appear, that there is hardly any *Species* of Bodies that we are acquainted with, of which something doth not float about in the Air; Gold itself, the least volatile of all Substances, not excepted. Though difficult.

It is highly necessary therefore, that we first of all take most distinctly into consideration, every single property of the Air, carefully avoiding all confusion: This done, and each being separately examined with due application, we shall by making an aggregate of the whole, obtain as true a knowledge of it, as the nature of the thing will admit of. Method necessary.

The first property then of Air, which offers itself to our consideration, is its fluidity. This is so natural to it, that I do not remember ever to have heard of any Experiment, by which Air could be deprived of it. It is evident to every one's observation, that even in the sharpest Frost, when every thing, almost, is congealed, the Air still remains liquid; nay, in an artificial Cold, 40 degrees greater than ever Nature has been observed to produce, the Air still retained its fluidity, notwithstanding it was acted upon by such a prodigious excess of Cold. If you compress the Air with ever so great weight and force, too, into the utmost density, yet it does not then become solid by concretion, but remains equally fluid as before, and as soon as ever the compression is removed, it resumes its former liquidity: Nay, among the various coagulations I have discovered in the mixing of different Liquids together, which certainly have been a very great number, I have never yet met with one single Experiment, by which it appeared, that Air was coagulated into a solid Mass. I confess, indeed, one Noon, in frosty Weather, when the Air was very serene, I observed some very small Corpuscles floating about in it, glissening in the Sun, and by the variations of their little Surfaces sparkling with wonderful In the first place Air is fluid.

coruſcations; but after a careful inquiry, I diſcovered, that theſe were nothing but little Glebules, conſiſting of Particles of Water, which before were diſperſed about in the Air, but were now united and congealed, and thus appeared in form of a very ſubtil Hoar-froſt. Were it poſſible, therefore, that Fire could admit of concretion with other Bodies, concerning which you may remember, I have treated already; Air ſurely would appear to retain its fluidity much more obſtinately than Fire itſelf. But, indeed, it rather ſeems probable to me, that there are in Nature two Fluids, the Elements of which will never unite with each other, nor will ever harden with any other Bodies into one homogeneous Maſs: And theſe two are Air, and Fire. In the mean time, however, while I am talking in this manner, I would not have you think, Gentlemen, that I have forgot, that this very Air grows together, and unites with every kind of known Bodies, and ſo ſerves as a kind of Element in the compoſition of concretes: For this is ſufficiently evident from the large quantity of Air, which of itſelf makes its way out of almoſt every Body, whilſt it is reducing into its Principles, and is now-a-days, perhaps not ſo properly, called factitious. But you, Gentlemen, who have examined this Air with me, know very well, that it is contained in all known Liquors whatſoever; that it penetrates together with them into all the receſſes of concreted Bodies; that thus at length, after a coalition of the whole, it remains lock'd up in the *Meatus's* of the Bodies, as it were, in very minute Veſſels; and afterwards, the Liquor in which it was convey'd thither, being diſſipated, it is left there alone. Hence, then, you ſee very clearly, that this Air was not concreted there; but only lay concealed, being retained by the including Body. As ſoon as ever, therefore, it can diſengage itſelf from this confinement, it ruſhes forth intirely unchanged, and returns with all ſwiftneſs to its proper Nature. But this ſtill appears more evident, if we conſider common Water whilſt it is freezing. Is there not hid in it a great quantity of inviſible Air? What becomes of it? Why, as ſoon as ever the Water begins to form itſelf into Ice, and its Particles are preſs'd nearer, and united together, as they are now deprived of that degree of Fire, which is neceſſary to keep them aſunder, and prevent their running into their natural union; then, I ſay, the Particles of Air intercepted between the Corpuſcles of Water, cannot congeal, but are preſſed out of theſe interſtices, are united with other Particles, are ſeparated from the Water, collected in Bubbles, become again a moſt fluid Air, and thus evidently evince, that this Air was intercepted indeed, but not concreted, coagulated, or altered. The ſame thing being ſuppoſed to happen in the like manner in all other Bodies, the firſt property of Air, namely, its fluidity, is ſufficiently made out.

The fineneſs of the parts of Air.

In the firſt place, now, the fineneſs or ſmallneſs of every Particle of Air, conduces to this its fluidity; for they are ſo exceeding minute, that no one of them can be preſented to the Eye by any Microſcope whatever. And yet they are far greater than thoſe of Fire; for they can neither make their way through Metals, Glaſs, Stone, or thick Wood, nor even through good Paper. And hence Air may be excluded or ſhut out from many places: Nay, it cannot ſo much as paſs through thoſe inviſible Pores of Bodies, through which Wine, Oils, Water, Brine, *Lixiviums*, alcalious and acid Spirits, are able to inſinuate themſelves. Theſe Obſervations are all evidently confirmed by the Air-pump. For if you put a leathern Ring on the braſs Plate on which you fix the Receiver out

out of which you exhauſt the Air, and place the rim of the Receiver on the ſaid Ring, then the weight of the Atmoſphere, when the Air is exhauſted from the cavity of the Bell, will preſs the rim of the Bell with ſo much force upon the Ring, that the external Air will not paſs into the cavity through the ducts of the porous Leather, but will be intirely kept off; and yet, if you pour any one of the beforementioned Liquors upon the outſide of the Leather, it will be immediately imbib'd, and it will inſtantly inſinuate itſelf under the Glaſs into the *vacuum*; a manifeſt proof, that other Fluids, tho' ſomewhat thick and tenacious, can eaſily paſs through the Pores of Bodies, that repel and keep off the Air. And the ſame thing is likewiſe eaſily made evident by an infinite number of other Experiments.

In the ſecond place, theſe ultimate aereal Particles are ſo eaſily ſeparated from one another, that this divulſion may be procured by a force ſo ſmall, as does not fall under the notice of any of our Senſes. Nor does it ſignify at all on which ſide, or which way you attempt this ſeparation, it being always equally eaſy. This exceeding ready diviſibility every one may obſerve, who conſiders the motion of a ſmall poliſhed Body through the ſtill Air. Can you not move a Steel Needle with great facility in the circumambient Air, which way ſoever you pleaſe? And it is the ſame with all other Bodies. This property, therefore, you will give me leave for the future to call the lubricity or ſlipperineſs of the Air. The lubricity of the parts of Air.

However, when we carefully examine this lubricity on all ſides, we diſcover, methinks, ſome tendency towards a union between theſe Particles, by means of which they readily run together into a mutual aſſociation; a ſlight one, I confeſs, indeed, and that may be eaſily deſtroy'd; but that is ſtill a proper aſſociation. For upon examination, does it not appear, that whenever one ſingle Particle of Air lies hid in any Liquid, nothing of it is any ways perceived; but as ſoon as ever a like Particle is united with it, there preſently ariſes a Bubble from this union, which by a certain tenacity oppoſes its own diſſipation? And if afterwards, another and another like Bubble meets with the former, is it not obvious to every one, that there ſucceeds, in proportion, a ſtill greater Bubble, tenacious, as the former, of its magnitude and ſpherical figure? You will think, perhaps, that this is rather owing to the compreſſive force of the ambient Liquid; nor do I deny, that it may poſſibly happen by that means: But yet, the effort at leaſt of the aerial Particles towards an union with one another, will be ſtill greater than that between the Particles of Water and the very minute Particles of Air. The attraction, indeed, between theſe Particles, I acknowledge to be very ſmall: Nay, but you will be apt to ſay, there is a repulſion between them, as the great *Newton* has plainly demonſtrated: Nor do I deny it, and ſhall myſelf profeſſedly treat of it by and by. In the mean time, however, it remains certain, that there is a power in theſe Particles, by which, when they are united in a ſpherical figure, they long maintain themſelves in that figure againſt the force of the Bodies that ſurround them. Their mutual attrition

For if we examine this inclination to coheſion more cloſely, we ſhall preſently ſee, that the aerial Particles ſingly and ſeparately conſidered, very eaſily ſuffer themſelves to be mixed with any other Liquid void of Air, and that they obſtinately abide in it, quietly reſting in its interſtices, in the ſame manner as Air eaſily mingles with other Bodies.

any Salts are diſſolved in Water. Beſides it will appear hereafter, that a large aerial bubble, that is compoſed of many united Particles of Air, and placed on the ſurface of a Liquor intirely deprived of it, will reſolve itſelf into its elementary Particles, and that theſe, when they are thus ſeparated, will be carried into the empty pores of the liquid, and never gather themſelves into a bubble again, unleſs by the additional force of a greater cauſe.

The imperceptibility of the Air, what? And hence, in the third place, we account for the Air's imperceptibility, already mentioned, to our ſenſes. Nor would ever any one have thought of this Air which we now treat of, had not ſome great Bodies, and chiefly ſuch as contain but a ſmall quantity of matter under a large ſurface, been moved with their broadeſt ſurfaces through it. But in this caſe, the Air reſiſting the motion with a remarkable repulſive force, immediately manifeſts itſelf to be a hard body. And as theſe reſiſtances, which are in reality actual repulſes, vaſtly increaſe according to the augmented velocities with which the Bodies are moved, *viz.* as the Mathematicians compute in a duplicate proportion; hence it may happen, that this imperceptible ſoftneſs of the liquid Air, may become as hard as a Stone. For if a perſon ſhould take a very thin braſs plate an hundred feet ſquare, and with its ſurface directly forwards, try to carry it erect through the Air when it was ſtill, with ſo great a ſwiftneſs, that it ſhould move the ſpace of two and twenty feet in a ſecond of time, he would then find in this Air an incredible reſiſtance or hardneſs, eaſily to be computed by *Mariott's* method. And if with this plate erect and quieſcent, any one ſhould receive the ſhock of a Wind ruſhing with the greateſt rapidity, he would then likewiſe experience, with what hardneſs the Air is capable of ſtriking, when it is hurried along ſo fleetly.

All this now is to be underſtood of the whole Air, as a compound, in which very great and heavy Bodies are capable of ſwimming, as appears by Birds and things of ſome weight carried away by the Wind, not to mention thoſe of a lighter nature, as Duſt, *&c.*

The Gravity of the Air. The next property of this Air, conſidered in the ſame manner as before, is the ſingular weight of its whole bulk; for in this reſpect all the parts together which in the aggregate conſtitute this Air, preſs with ſo gravitating a force towards the Center of the Earth, that by their fluidity, they form a Sphere around its ſurface, which we may properly enough call the Air-ſphere, and which, on account of the very large quantity of Vapours exhaled into it, has hitherto by Philoſophers been called the Atmoſphere.

The Gravity of the Air, formerly diſcovered, *Torricellius*, that great *Florentine* Geometrician, ventured in the year 1643, to determine ſtatically. After him, the famous *Otto Guerick* proved this Gravity by ſeveral experimental appeals to the ſenſes, in the year 1655. That very ingenious Philoſopher Monſ. *Paſchal* afterwards cleared it farther up; and the great Mr. *Boyle* rendered it more compleat. It was *Mariott*, however, who gave the beautiful finiſhing to it by the moſt curious Experiments of all; inſomuch that now-a-days no part of natural Philoſophy ſtands upon ſurer principles than this of the Gravity of the Air; for by the aſſiſtance of what theſe Gentlemen have done for us, the weight of the whole gravitating Air-ſphere may be obtained to the greateſt nicety, and expreſſed under the denomination of common weights.

It

It has hitherto, however, remained impoſſible to determine the weight of the aerial Body, comparatively with other Bodies, the weight of which is known. For upon inquiry, it very ſoon appeared, that no two equal portions of Air taken at the ſame time, but at different heights, were ever of equal weight; but that on the contrary the lower Air always outweighed the higher. And this holds ſo univerſally true, that the very ſame thing is obſerved from the ſurface of the Earth to the tops of the higheſt Mountains. Nay in the very ſame place you will hardly ever find, that an equal quantity of Air, at different times, will be of the ſame Weight; but even in this caſe there is obſerved a great variety, it ſometimes weighing more, ſometimes leſs. How far diſcovered.

The Air-ſphere in our climate, wherever it has hitherto been obſerved, is very conſiderably, and almoſt always wonderfully changing with reſpect to its weight, which never continues long the ſame. This variation is chiefly apparent whenever there is any Alteration in the Meteors in the Air, which is pretty frequent: For Rain, ſudden great Showers, Fogs, Hail, Snow, Lightning, Thunder, Winds from various quarters, Storms, Whirlwinds, Drought, and the Changes of the planetary Aſpects, are certain indications of the Atmoſphere's becoming very ſoon of a new or different Weight. In this Affair the different Seaſons of the Year likewiſe produce an incredible variation. By means therefore of this ſucceſſive and inceſſant mutability, depending on ſuch a number of cauſes which are continually reviving, it comes to paſs, that the weight of the Atmoſphere never continues long the ſame. And hence an infinite number of effects about the Earth, which almoſt all depend upon the action of the gravitating Air, are in a perpetual viciſſitude and inconſtancy: So that this ſingle Variation of the Air alone in point of Weight, is the ſource of a great many cauſes which produce different events. In the mean time however, by the help of very accurate Obſervations, continued for the ſpace of above 86 years, we are now come to the knowledge of the greateſt and leaſt Gravity of the Air that happens in *Europe*. For upon examining, it has been found, that the greateſt Weight of the Atmoſphere is in *equilibrio* with $30\frac{1}{2}$ inches of Quickſilver in the Barometer, but that the leaſt would raiſe it only to $27\frac{1}{2}$: So that the difference appears to be almoſt a tenth part of its greateſt Weight, within which compaſs the perpetual variation of the gravitation of the Atmoſphere is included. Found to vary exceedingly.

This daily alteration now is owing to many peculiar, and perfectly different cauſes, but yet, however, ſuch as are intirely certain, and may be come at by diligent Obſervations. And whenever this ſhall be accompliſhed, then we ſhall be able to form a regular notion of this Fluctuation, which at preſent is looked upon as intirely uncertain. From whom now ſhould we ſo juſtly expect this, as from the famous *Nicholas Kruquius*, whoſe genius, learning, and indefatigable induſtry, highly qualify him for the cultivation of theſe ſtudies, and whoſe aforementioned Meteorological Tables compoſed with infinite diligence and accuracy, ſhew us at one view all the cauſes concurring to every degree of the increaſed Weight of the Atmoſphere. It were to be wiſhed, that theſe ſo uſeful inquiries of this great maſter in Natural Knowledge, might meet with encouragement equal to their merit; leſt when he is gone, we ſhould look in vain for another that is equally qualified for the ſame diſcoveries. To be brought under certain Laws.

Laſtly,

And compared.

Laſtly, it has been likewiſe obſerved, that the Weight of the common Air, about our Earth, at the time of the middle Weight of the Air-ſphere, and in the moſt temperate ſeaſon of the year, is to that of Water, as 1 to 850: But then this muſt be underſtood according to theſe conditions, otherwiſe it would be impoſible to affirm any thing certain about it.

The effects of the weight of the Atmoſphere.

In the firſt place, then, the Air reſting with its whole weight upon our Earth, preſſes its ſurface with a perpetual force. And this preſſure upon any particular Body is equal to that power which at the ſame time keeps up a perpendicular column of Mercury to the height it then obtains in the Barometer; the Baſe of which Column will be a horizontal Plane cutting a Pyramid whoſe *vertex* is in the center of the Earth, whilſt its Sides touch the horizontal boundaries of the Body thus preſſed by Air. Thus then may this power be every where exactly computed, by conſidering the height of the Quick-ſilver in the Barometer, at the time the computation is made, and the magnitude of the ſurface of the Body, the preſſure upon which is required. And hence it is inferred, in the ſecond place, that Bodies diſperſed in the Earth, are ſo much the more preſſed by the incumbent Air, the nearer they are to its center; for it is evidently demonſtrated in hydroſtaticks, that the preſſures of liquids upon their baſes are in proportion to their perpendicular Altitudes. Hence, therefore, if we conſider the Air as a Liquid, every where homogeneous, and incompreſſible; then the proportion in which Bodies are compreſſed in every part of the perpendicular from the ſurface of the Earth to its center, might be eaſily diſcovered: But as the elaſtick power of the Air brings a great many very different conſiderations into the ſubject, we ſhall ſpeak particularly of that matter by and by. In the third place, it appears on the other hand that all Bodies, the farther they are raiſed above the center of the Earth, the leſs in proportion they are affected by the preſſure of the Air. But it muſt be obſerved farther too, in the fourth place, that Bodies in the very ſame ſituation, will be more cloſely compreſſed together, as the weight of the Air is augmented, according to the abovementioned obſervations. And fifthly, as ſoon as ever the ſame Air decreaſes again in its weight, the preſſure upon theſe Bodies will be proportionably diminiſhed. Sixthly, all thoſe Bodies, therefore, that are expoſed to the Air are never long compreſſed with the ſame external force; but the compreſſion they ſuffer is varying continually; with this limitation, however, that the difference of the preſſure is never found in the ſame place to exceed one tenth of the whole; within which tenth is included the whole compaſs of this variation. Seventhly, therefore, the Air itſelf, while by reſting on all Bodies it thus compreſſes them with various forces, muſt likewiſe in proportion be repreſſed by them, provided they are elaſtic, or ſuch as have in them an innate effort to expand themſelves, or to recover that ſize which is the proper effect of their natural energy. And hence, therefore, it appears likewiſe, in the eighth place, that in all Bodies which are ſituated in the Air there is a perpetual oſcillation of their Particles correſponding to the reciprocal augmentation or diminution of the Weight of the Air. This oſcillation is but ſmall indeed, as being confined within the length above mentioned, for the compaſs of its variation; but ſtill it is a proper oſcillation, and is almoſt continual. But we have before, in the Hiſtory of Fire, taken notice of another tremulous vibration in the Particles of Bodies, produced by the various viciſſitudes of

 Heat

Heat and Cold, which, therefore, in conjunction with this of the Air, must bring about very considerable and continual effects. We acknowledge, therefore, two perpetual causes of the constant, internal motion of all the Particles of elastic Bodies, *viz.* Fire, and the Air-sphere. In the ninth place, however, it must be remarked, that upon Bodies, which are absolutely soft, if any such there are, that is, that are intirely destitute of a power to recover their former figure, when the force that presses them is removed; and upon Bodies, such as Water, which cannot by any external Weights be reduced into a smaller space; upon such, I say, the compressive force of the Air-sphere, with regard to its increase or diminution, has no effect; and consequently, upon such Bodies, the reciprocal Oscillation we have mentioned, will be of no efficacy. Seeing then that Fire acts equally, nay more upon these very Bodies, than on all others, it plainly appears, that the power of Fire, on this account, is to be regarded as far more universal than that of Air, and consequently of any other Body.

The effects of Air considered as a Fluid and gravitating Body together.

It will now be of service to us, if with an eye to Chemistry, we take a view of those effects which the external Air produces, considered as a fluid and gravitating Body together; for in this light it evidently appears, that it must rest with some force upon the outward surfaces of all Bodies, as has been just now explained. Hence therefore, in the first place, it will insinuate itself between the surfaces of all Bodies, the distances of which from one another leave interstices so wide for the admission of the external Air, that by its subtlety, or the loose texture of its parts, it may be able to enter into these little spaces. Hence, likewise, it is evident, that all the little invisible *Meatus's* of Bodies, which are qualified in the manner just mentioned, though they appear to our senses to be perfectly empty, are in reality full of common Air. And since this Air must certainly in those Interstices perform all the effects which are proper to it; hence an infinite number of the operations of Nature will of consequence depend upon it. Secondly, it is a curious observation in Hydrostaticks, that the heavy and fluid Air presses upon every side of Bodies with an equal force, whither the horizontal, vertical, superiour, inferiour, or oblique. This is demonstrated in that Science: But as Chemists are often unacquainted with those studies, I have thought it proper to give an ocular demonstration of a truth which is of such importance in the Chemical art. I take then three glass vessels; one cylindrical, A; another conical, B; the third, C, running, like a bolthead, from a spherical bottom, into a long, cylindrical neck. Under these three you easily conceive, all sorts of simple vessels may be comprehended, as is easily demonstrated by Geometry. Be pleased to observe, then, in the first place, I fill the Cylinder A with fair Water exactly up to the brim. Upon the surface of the Water then I put a piece of single clean paper, D, just big enough to cover the mouth of the Vessel, and this with the palm of my left hand I press equally on the surface of the Water, so that between that surface and the paper no Air can be retained. Then with my right hand I invert the vessel, as you see, in such manner, that the palm of my left hand remains close upon the paper. Having in this manner turned the vessel upside-down, so that the mouth of it, which is covered with paper, is at the bottom, I gently remove my left hand, and with my right I hold the Glass as it were freely suspended in the Air: And you see, that not the least drop of Water

runs

runs out of the Veſſel, but that the Paper remains as cloſely preſſed to it, as if the Palm of my Hand was ſtill apply'd to it. Obſerve farther, I gently turn the Veſſel from this vertical to an horizontal poſition; and does not the Water ſtill remain in the Veſſel, and the little Paper ſtill cloſely adhere to the mouth of it? Theſe things you plainly ſee. Do you not therefore acknowledge, that the preſſing power of the heavy and fluid Air, has the ſame effect upwards, laterally, and downwards, and that it preſſes a Body placed in it with the moſt exact equality in every point of its ſurrounding Surface? And therefore, that the Air which is perpendicularly under the mouth of the Veſſel, has the ſame force in its effort upwards upon the Paper, as the Air which horizontally preſſes upon the Paper, and even as that which bears upon it vertically? This effect of every heavy Liquid, the great *Archimedes* obſerved very nicely, as he did every thing elſe, and raiſed a great many very curious demonſtrations upon it. There is in reality no end of the truths, which may be hence deduced. But theſe we leave to be explained by proper Maſters, whilſt we Chemiſts thus enjoy the benefit of them. The ſame thing again you ſee now in this conical Veſſel. The Baſe of this glaſs Cone B being open, and its vertex E cloſe, I fill the Veſſel compleatly up with Water, apply with the Palm of the Hand the Paper D, and turn the Veſſel till the Baſe is undermoſt. I now take off my left Hand, and ſuſpend the Cone with my right. The Paper you ſee does not drop off; nor does the Veſſel loſe one drop of Water. I gradually change the vertical into an horizontal poſition, and ſtill nothing runs out, but the Paper remains as cloſely fixed as ever. Now, if the *vertex* of this conical Veſſel was open, and the *Baſis* cloſed up, and the like inverſion were made of the Veſſel, the very ſame effects would follow. This then you likewiſe ſee the truth of. Laſtly, then, I proceed exactly in the ſame manner with the other Veſſel, and you are Witneſſes, that the Experiment ſucceeds exactly as the preceding. Since this then is the caſe, you conceive, Gentlemen, with me, that the Air, therefore, preſſing equally upon every point of the Surface, enters likewiſe equally into all the Pores and Ducts to which it is applied, whether they are in the upper, lower, or lateral Surface, or in any oblique poſition whatſoever; and that it preſſes likewiſe with an equal force in all thoſe different parts, with this variation only, that that part of the Air that is loweſt, always preſſes more forcibly upwards, the lower it is, that is, the nearer it is to the center of the Earth. In the third place, the Air by theſe its properties, compreſſes all Bodies on every ſide, fills up their cavities, and forms upon them a Surface, which has a very ſtrong coercive power. Hence, in the fourth place, it comes to paſs, that this Air, whether external or internal, which from its fluidity is ſuppoſed to be continually in motion, and by its gravity is applied to the external parts of fluid Bodies, cauſes a continual attrition, concuſſion, and agitation of their Surfaces, by this means mixes different Fluids together in a wonderful manner, applies and excites their reciprocal powers, and thus produces continually a great number of effects. Fifthly, however, it alters not the figure or ſhape of the Bodies which are expoſed to it, excepting only ſo far as there are empty ſpaces in them, in which there is no Air. For if in ſuch a caſe they are not able to reſiſt this force of the Air, they will, by the preſſure of it, be reduced into ſmaller ſpaces, the corporeal parts will run together into a cloſer union, the whole Maſs become more ſolid, and the former bulk will appear diminiſhed. But this caſe excepted, the Air, with all its force, is not able to break the weakeſt and moſt brittle Body that is fill'd with it, and placed in it; for as much as it preſſes on one part, ſo much exactly it ſuſtains on the other, and thus preſerves all Bodies *in equilibrio*. In the mean time we know, that the motion of the Air is always conſiderably ſwift; which is particularly evident from an Obſervation made in a Room that is darkened, when the Air is very ſtill, and then illuminated only by a ſingle Ray let in at a very ſmall Hole: For if then any one ſtanding on one ſide of the lucid aerial Cone, turns his Eye upon that luminous part, he will really be ſurprized at the motion of the Atoms, which with a conſiderable and perpetual rotation, are carried about hither and thither, and moſt rapidly confounded with one another. Hence, then, we are the more induced, with great probability, to conclude, that all thoſe in the external open Air are conſtantly in a greater agitation, and conſequently, that the motion and attrition among themſelves, and upon the Surfaces of other Bodies, is very conſiderable, inaſmuch as the motion is continual, and the gravitating force equal to the preſſure of a column of Water 33 feet high. And hence we may eaſily conceive in the ſixth place, how ſtrong muſt be the attrition and motion of the Atmoſphere upon the Surfaces of all Bodies; eſpecially, as often as it is agitated by Fire, or Storms. Let us ſuppoſe, that in an *Area* of one foot ſquare, there gravitates the weight of 2080 pounds; what a mighty piſtil is this? Let this now, in a great ſtorm, be mov'd with ſuch a rapidity, as that in a ſecond of time it ſhall run the ſpace of two and twenty feet, will not the force of this weighty piſtil, in the attrition of Bodies that are under it, be incredibly great? Thus, therefore, an infinite number of very powerful phyſical changes are effected by theſe cauſes, which not being regarded by the Chemiſts, they have, in order to account for theſe effects, in vain invented, I know not what very abſtruſe, and plainly fictitious ones; whilſt in reality, the whole matter depended intirely upon theſe ſimple ones we have juſt mentioned, nor required ſuch very extraordinary ones, aſſumed without any foundation. In the ſeventh place, it ſhould be particularly remarked, that the ultimate Particles of the Air cohere together in ſuch a manner, that they are not very readily to be divided into their minuteſt parts, ſo as to inſinuate themſelves eaſily into the ſmalleſt paſſages, but theſe are required conſiderable large, before this penetration happens. This I clearly demonſtrate to you by the following Experiment. I have here in my Hand a glaſs Thermometer, filled up to the brim with Water. 'Tis four feet long, and the neck of it is ſo narrow, that the diameter of the Tube is only the eighth part of an inch. This, now, I invert ſo that the mouth of the Tube is downwards, and yet you ſee that not one drop of Water comes out, but on the contrary, it remains as unmoved in it, as if it had been very carefully ſtop'd. But again, the Barometer of *Torricellius*, with the ſuſpended Mercury, does not tranſmit any Air into the *Vacuum* which is left at the upper part of the Tube, tho' the Air exerts ſuch a mighty force upon the Surface of the Mercury, in order to fill up this empty ſpace: For here the Air cannot be divided into ſo minute parts, as to enter the interſtices of the Mercury, but remains excluded. If the ſame Experiment is made with Water, or even with Spirit of Wine, the event will be always exactly the ſame. From all theſe Obſervations, therefore, it is clear, that the Air is not eaſily to be divided into its minuteſt parts; for

 other-

otherwiſe thoſe parts would paſs through the Pores of theſe Liquors, within which the Particles of Air may be diſpoſed, and lie concealed, as will appear manifeſtly hereafter, when we ſhall profeſſedly illuſtrate by Experiments, how the Air may be extracted from the inner Cells of Bodies, in which it is lodged. But in the eighth place, I ſhall endeavour to ſhew you, the magnitude of thoſe Bubbles by which the Air aſcends through Water contained in Tubes. You ſee, I hold here a glaſs Thermometer which has a neck pretty long, and ſo wide, that the diameter of the mouth is a quarter of an inch. This being full of Water, I turn upſide down. What is the conſequence? Why you ſee the Air aſcending through the Water in the neck of this Veſſel, riſes only in large Bubbles, nor does by any means divide itſelf into little ones; and beſides, theſe Bubbles, which are of a very diſcernible ſize, ſtop here and there in the neck of the Veſſel. There muſt therefore either be a power of aſſociation in the Air, or elſe a repulſive power in other Liquors, with reſpect to the Air, by which they drive the aerial Particles into mutual contact. To make this ſtill plainer, I will exhibit to you another Experiment: You ſee here a glaſs Veſſel, open at the top, in which there is pure Alcohol. This very ſmall glaſs Veſſel, formed like a Bolt-head, with a Bulb and narrow Neck, is full of fair Water. This now, into which the Air does not preſently enter, whilſt I turn it up, I thus invert and immerge the mouth of the neck which is now downwards into the Alcohol: And don't you evidently perceive the Alcohol aſcending through the Water into the belly of the Glaſs in ſlow oily ſpirals, and the Water deſcending into the Veſſel which is now abandoned by the riſing Alcohol? The Alcohol now reſts in the upper part of the Vial, whilſt the inſipid Water taking the place which is quitted by by the former, deſcends from that into the Veſſel. Hence, therefore, I look upon it as certain, that the Particles of the Alcohol and the Water, are, by vertue purely of their fluidity and gravity, moſt eaſily admitted into, and tranſmitted through thoſe interſtices, which are left between the Elements of both; but that the admiſſion and tranſmiſſion of the Air is exceeding difficult. But this will be made ſtill more evident by this other Experiment: Inſtead of Alcohol, I have poured Oil into this Veſſel; and the Vial being quite full of Water, and turned bottom upwards, as before, I put the neck of it into the Oil. Could you now have expected what you ſee? How prettily do the Globules of Oil aſcend through the Water from the lowermoſt to the uppermoſt parts, till all the Oil, after much ſtruggling, has riſen out of the lower Veſſel to the top of the belly of the inverted Glaſs. The event will be exactly the ſame, if I fill the Glaſs with ſtrong ſaline *Lixiviums*, and immerge it after the ſame manner in Alcohol, fair Water, or Oil. Of this property of the Air, therefore, which we particularly recommend to the conſideration of the Chemiſts, we are likewiſe aſſured, by comparing it with other Fluids, *viz.* that the Particles of Air collected together in any quanty, are not by far ſo eaſily ſeparated from one another, as the Elements of any other Fluids that we are acquainted with. And hence, it is likewiſe evident, that the minute Particles of Air cannot eaſily be intermingled with other Liquids, but rather run together within them, and thus diſcover themſelves by diſtinct Bubbles, or a collection of them which then becomes froth: Notwithſtanding which, however, when the ſingle Elements of Air have lodged themſelves, ſeparately, in the Pores left between the ultimate Particles of other Liquids,

quids, it is a very hard matter to ſet them free again. This we are very certain of, who have ſeen how difficult it is wholly to fetch out the Air which lies in this manner concealed in Mercury, and are ſenſible of the wonderful effects, with which this ſeparation is attended; for *Hugens* long ago obſerved, that Mercury freed intirely from Air, has kept ſuſpended in the Barometer to upwards of 50 inches. But of this property of the Air, I ſhall profeſſedly diſcourſe to you hereafter. Thus, then, I have faithfully laid before you thoſe properties of the Air which it has in common with all other Bodies; and at the ſame time have carefully explained to you its efficacy, conſidered in this view, upon thoſe Bodies which uſually fall under a chemical Examination; having only added ſome Obſervations, which I could not avoid, concerning its miſcibility with other Fluids. Let us now chearfully proceed to the conſideration of thoſe peculiar properties which are poſſeſſed by the Air alone.

The elaſticity of the Air

The firſt then that here offers itſelf to our obſervation, is the elaſticity which Phyſics has diſcovered in it. This is that ſingular quality, by which all known Air, poſſeſſing a certain ſpace, and being confined there in ſuch manner that it cannot eſcape, will, if it is preſs'd together by a determined weight, reduce itſelf into a leſs ſpace, which will be always in a reciprocal proportion to the quantity of the weight that acts upon it; with this circumſtance, however, always attending it, that it will conſtantly, by a ſpontaneous expanſion, recover again the ſpace it hath loſt, in proportion, as the compreſſive force is diminiſhed: And when this force comes to be the ſame as it was in the beginning of the Experiment, then the aerial Maſs will always infallibly expand itſelf throughout the whole ſpace, that it before filled up, provided, that no other cauſe, in the mean time, ſhall intervene to hinder it. If the preſſure is leſſened, Air extends itſelf to a larger ſpace; if it is increaſed, it reduces itſelf into a leſs.

Is peculiar to it

Now ſuch a diſpoſition as this, Gentlemen, yielding ſo readily to ſuch a compreſſion, and yet recovering itſelf with ſuch a ſpring, I don't remember to have been obſerved in any other Liquid hitherto examined. 'Tis certain, no ſuch thing is diſcovered in Alcohol, Oil, Water, Spirits, or any *Lixiviums*. For tho' all theſe are eaſily contracted by Cold, and dilated by Fire, yet they yield not to weight by proportional retreats into cloſer and cloſer ſpaces; nor being freed from their preſſure, do they expand themſelves perpetually. This, therefore, is the peculiar property of Air alone. And hence it merits an exact explication, which you will ſufficiently underſtand, if I clearly lay before you, from *Boyle* and *Mariotte*, the wonderful Law of this elaſticity.

Under a certain Law.

Theſe Gentlemen, then, have diſcovered, upon the evidence of elaborate Experiments, that the following is to be looked upon as the principal Law of this property; namely, that the Air by compreſſion is contracted into ſpaces, which are always exactly ſo much ſmaller, as the compreſſing weights are greater. Hence, therefore, the denſity of compreſs'd Air is always in proportion to the compreſſing weight. Let us, for inſtance, ſuppoſe a cylindrical Veſſel full of Air, and the inſide of this Veſſel to be ſo very firm and immoveable, that it will not in the leaſt give way to the preſſure of the contained Fluid. Let the *Baſis* of this Veſſel be exactly an *Area* of one *Rhineland* foot, its height 64 inches. The Air then contained in this Cylinder, will on its upper Surface ſuſtain the preſſure of the Atmoſphere, which we will ſuppoſe to be 2112 pounds *Troy* weight;

and the Air which fills up the capacity of the Tube, will be the ſame as the common Air. If then the upper ſurface of this Air ſhould be compreſſed by a perpendicular column of Mercury of 29 inches height, the preſſure in ſuch caſe, would be twice as great as it was before from the Air ſphere alone. And according to the increment of the preſſure, the Air compreſſed would be reduced into ſmaller ſpaces, in the proportion hereunder mentioned.

℔. 2112	preſs the Air ſo as to make it fill this Cylinder	1
4224		$\frac{1}{2}$
8448		$\frac{1}{4}$
16896		$\frac{1}{8}$
33792		$\frac{1}{16}$
67584		$\frac{1}{32}$
135168		$\frac{1}{64}$
270336		$\frac{1}{128}$

and ſo on continually. Hence, then, it very clearly appears, to ſuch as conſider the thing, firſt, that it is not a very eaſy matter by this method to reduce the common Air into a ſpace 64 times leſs than that which it naturally poſſeſſes; ſince ſo enormous a Weight, and ſo firm a Tube 203 inches high, are required for this purpoſe; and the Air in point of weight, would be then to Water, about as 1 to 13. But if the weight here aſſigned to the Atmoſphere, *viz.* 2112 pounds, was eleven times doubled, then the Air, which by this means would be reduced into a ſpace 1024 times leſs, would be a great deal denſer and heavier than Water. In the ſecond place, it appears certain, that this Air can never be abſolutely reduced into no ſpace at all, tho' the weight, and conſequently the compreſſure cauſed by them, ſhould be ever ſo immenſly increaſed, as a view of the Table annexed ſufficiently demonſtrates.

How far this Law extends.

Beſides, I ſhall, perhaps, hereafter make it appear, that one thouſandth part of the common Air, at leaſt, conſiſts of aqueous, ſpirituous, oily, ſaline, and other Particles ſcattered through it, which being united together by this compreſſure, form at length a Body no farther compreſſible. So that on this account, it ſeems to me quite incredible, that common Air can ever be reduced into a ſpace, a thouſand times leſs than it uſually takes up, without being compreſs'd by this means into nearly ſolid Maſſes; which indeed, with reſpect to the elaſtic aerial part, may be always contracted ſomewhat cloſer, but never in a *Ratio* with the compreſſing weights, becauſe then the Bodies too, mingled with the common Air, muſt likewiſe follow the ſame Law of elaſticity, of which we ſufficiently know from Experiments they are abſolutely incapable. But as theſe Particles in the Body of the common Air, which are not compreſſible, rarely make one eight hundred and fiftieth part of the whole, it is nothing ſtrange, that this proportion has always been obſerved, in the Experiments which have been made, concerning this Law: The reaſon of which will immediately appear, when I come preſently to lay before you the Experiments of Mr. *Townley*.

This Law, in the firſt ſtep of the Experiment, is very viſible.

Let us then in the ſecond place conſider, that it is an eaſy matter, by the means of compreſſing weights, to contract the common Air into a ſpace, leſs by half than that which it took up before: And in this ſtep of the Experiment it has been very accurately obſerved, that this double condenſation was effected by doubling the weight. For in this caſe, thoſe compreſſible Corpuſcles which take

take up only a thousandth part of the first Space make so little alteration, that they utterly escape the notice of the Senses. The rule, therefore, in this first step answers exactly to the Senses, and is capable of ocular demonstration.

But in the third place, those who are acquainted with these things will easily apprehend, that the less the Spaces are, into which the Air is compressed, the greater gradually does the difficulty become of demonstrating this Law. For since we are informed from Hydrostaticks, that the pressure of heavy liquids on the bottom and sides of their containing Pipes is always in proportion to their perpendicular Altitudes; hence you readily conceive how mighty strong the Tubes must be, for the carrying on of these Experiments, till the Air is reduced into the one hundredth part of its natural Space. But you know likewise, it was long ago discovered by the Academy *del Cimento*, that even metalline vessels have been inlarged in their capacities, by being filled with ponderous Liquids: How much more certainly then must this be the case in Glass? And yet you very well know, that it is requisite, that the instrument here made use of, should be made of Glass, that the height of the compressing Mercury in the inexpansible Tube may be compared with the height of the Air, compressed by the Mercury; because it is only by an accurate knowledge, and an exact comparison of these heights, that we can come at the thing we are in search of. But what a vast deal of caution and accuracy is here again required! The Tube must be very long, not dilatable, every where exactly of the same figure, and perfectly transparent. The Air to be compressed, throughout the whole course of the Experiment must continue exactly of the very same degree of Heat, for every little increment of it in this case will act by so much greater an expansive power as the Air is more condensed by the compressing weights. And, indeed, not only in this, but in the other parts of Natural Philosophy likewise, our Experiments are performed amidst a thousand concurring causes; any one of which being neglected, our conclusions upon the events will vary from the truth. Afterwards always harder to be discovered.

But that you may have still a juster notion of the matters we are handling, give me leave to lay before you the method by which the Philosophers discovered this Law of the Air's Elasticity. This will enable you to judge more accurately, what is justly to be thought of this Law, and of the extent of it, in which point, perhaps, they have carried it rather too far. The great *Boyle*, then, took the double-legg'd Tube, A B b C, inflected as you see in the Figure, open at A, and hermetically made at c. He took care it should be every where exactly of the same capacity in b c, and should be made very thick and strong. The Leg b c, was 12 inches long, and was accurately divided into Lines: The other, AB, contained a good many feet. By pouring Mercury then into the Tube at A, and by this means condensing the Air in b c, from 48 to 3, or from 16 to 1, he found, that the Space into which the Air was compressed was always diminished in proportion to the Increment of the Weight. See *Boyle* against *Linus*, p. 60, &c. *Mariotte*, *of the Nature of Air*, p. 151, 154. The discovery of this Law. Pl. VII. Fig. 1.

As this therefore was the manner, and this the extent of the Observations, by which the condensibility of the Air, in respect of the compressing Weights, was discovered, every one sees, that this condensation was not carried beyond one sixteenth of the whole. Nor, for my part, have I ever met with any authors that have made any farther advances in this matter, who have published their Experiments. The famous Dr. *Halley*, indeed, and the celebrated Academy *del Cimento* With caution.

(*Mem. de l'Academ. Roy. des Sc.* 1703. p. 102.) inform us, that the Air cannot be condenſed beyond $\frac{1}{800}$ part of its natural Space; but the Experiments, by which theſe great men were able to condenſe the Air ſo far, as that after ſuch condenſation, it could not be reduced into a leſs Space, have not yet been made publick. Whatever thoſe Experiments were, however, this is certain, that the Air ſo compreſſed, and reduced into ſmaller Spaces, will again expand itſelf gradually into greater Spaces, exactly in proportion to the decrement of the compreſſing Weight, which *ratio* is conſtantly obſerved to hold true. And, indeed, the ingenious Mr. *Richard Townley*, as the great *Boyle* relates in the place juſt cited, diſcovered by Experiments that might be depended upon, that this ſpontaneous expanſion of the Air, upon the diminution of the compreſſing Weights, did moſt exactly follow this Law from 1 to 32. Upon the evidence, however, of theſe truths, thus far indeed certainly demonſtrated, let us take care we don't launch out too far, and abſolutely aſſert, that this Law, namely, that the Spaces taken up by the compreſſed Air, are in a reciprocal proportion to the compreſſing Weights, always holds true. For indeed, I confeſs, it is my opinion, we are at as little certainty on this point, as the moſt illiterate perſon whatſoever. Let us proceed, therefore, and ſet forth what we certainly know of it from experimental proof. In the firſt place, then, we are aſſured, that the common Air may be reduced into a Space ſixteen times leſs than it took up before; and that therefore it may be condenſed in this proportion. In the ſecond place, we are equally certain, that ſuch is the diſpoſition of this Air, that it may, by expanding itſelf, be diffuſed into a Space, two and thirty times greater, and fill that Space with as equal a diſtribution of its parts as before. In the third place, that this contraction of the compreſſed Air into a Space ſo much leſs, than what it poſſeſſes naturally, is owing only to the force of the externally applied Weight, by which it is reduced into ſo ſmall a Space. And again, in the fourth place, that the ſame Air being by any means freed from the force of the compreſſing Weight, does, by the power of its own peculiar nature, without the intervention of any other cauſe, excepting only the Fire that is preſent with it, expand itſelf in ſuch a manner, as always exactly to recover ſo much Space as it had before loſt by the compreſſure. And in the fifth place, which is pretty extraordinary, that this virtue of expanding itſelf, peculiar to the Air, does always remain after the greateſt compreſſure, ſince it always continues ſo accurately proportional to the quantity removed of the preſſing weight. In the ſixth place, that its capacity too of compreſſibility is equally indeſtructible; for after the Air has been rarified, by removing the compreſſing Weights, to two and thirty degrees, there has ſtill remained in it, ſo rarified, a property, by which it was again capable of being compreſſed, as before, by the like force of the former Weights. In the ſeventh place, we know from the moſt certain Experiments, that this dilatability, and compreſſibility of the Air, by the ſole action of Weight, anſwers accurately, as far as our ſenſes are able to judge, to the increment or decrement of the compreſſing Weight. In the mean time, however, the Philoſophers of *Great Britain* and *Italy*, men formed by Nature for unravelling theſe myſteries, have declared in their Writings, that the common Air cannot be rendered above eight hundred times denſer. This, therefore, we learn likewiſe from their Experiments, which they have hitherto concealed. Of the great probability, however, of their aſſertion, I ſhall diſcourſe my ſelf by and by, when I have communicated to you ſome things that are known for a certainty, concerning the Corpuſcles which float about in the common Air. In the eighth place, therefore, Spaces filled with the ſame quantity of Air, are ſo far in a reciprocal proportion to the compreſſing Weights. In the ninth place, this is always true, as well in that Air, which is reduced into a Space ſixteen times leſs, as in that which is only compreſſed by the common Atmoſphere. In the tenth place, it appears, according to the Experiments of Mr. *Townley*, already mentioned, that this proportion never varied in all the compaſs from 32 to 1. In the eleventh place, therefore, it is exceeding probable, that the ſame rule obtains likewiſe in a farther condenſation; but ſo as that by little and little, as the Air is more condenſed, greater Weights are requiſite, for the ſame condenſation, till at length all farther compreſſibility is utterly at an end. In the twelfth place, we ſee that the Air ſo contracted and compreſſed, does not tranſpire, or penetrate thro' Glaſs, nay, indeed, cannot paſs through the pores of the Mercury; for it ſtill remains in the ſame part of the Tube, though by means of ſuch an incumbent Weight of Mercury, it is reduced to ſo much greater denſity. Nay farther, tho' the Air, by means of Fire, is rendered warmer, and made to elevate the incumbent Mercury, it does not then penetrate either through that, or through the Glaſs.

Another law, which we find to obtain in the Elaſticity of the Air, is that it cannot be deſtroyed; inaſmuch as upon examination by every kind of Experiment, it has always remained elaſtic; nor are its elaſtic parts either by long reſt, or the greateſt preſſure, ever ſo diſpoſed as to loſe the Elaſticy we have been juſt explaining. For Mr. *Boyle* and *Mariotte* having, with a particular view to this matter, kept common Air ſtrongly compreſſed, and ſhut up in a Wind-Gun, found, upon their ſetting it again at liberty, that it was perfectly as elaſtic as it was before. And lately, that great Geometrician *Robervallius*, examining Air which had been ſhut up for the ſpace of fifteen years after the like manner, found, that it had not loſt any thing of its Elaſticity. See *Du Hamel. Hiſt. de l'Ac. Roy. des Sc.* p. 368. But it will hereafter farther appear, that even thoſe elaſtic Particles of Air, which are detained in the interſtices of the moſt internal parts of fluid or ſolid Bodies, do, when they are ſet free from thoſe confinements, and are afterwards united to other Particles, exert again that Elaſticity, which they then ſeemed ſo utterly to have loſt, as not to give the leaſt indication of retaining it. For as ſoon as ever they recover their liberty, they produce incredible effects, which can be attributed to their Elaſticity alone, and thus evidently make it appear, that neither time, nor reſt, nor even their ſuppoſed concretion with Animal, Vegetable, or Foſſil Subſtances, is ever able to deſtroy this wonderful property of the Air. In the mean time, however, we learn from the ſame Experiments, that ſuch is the nature of Air, that its elaſtic Particles, when ſeparate and by themſelves, may be ſo united to other Bodies, by which they are intercepted, or at leaſt may reſt in them in ſuch manner, as not, for Ages together, to produce any elaſtic effect; and that yet, upon their being freed from thoſe Bodies, and mingled with others of the like nature, they demonſtrate, that they have intirely retained their Elaſticity. Hartſhorn, for inſtance, may be preſerved for ſeveral ages; and yet upon a chemical examination of ſome which had been kept above fifty years, and by this means was grown exceeding hard and dry, it's ſurprizing what a quantity of elaſtic Air it yielded in its reſolution! Hence, therefore, it is very probable, that one ſingle, elaſtic, aerial

The elaſticity of the Air not to be deſtroyed.

Particle

Particle is not elaſtic, with reſpect to the increment or decrement of incumbent Weights; but that this Elaſticity then only has being, when two ſuch Particles of Air come to touch and repel one another; and that, conſequently, if theſe elaſtic, aerial Particles were ſo far diſtant from each other, as that this repelling force ſhould utterly ceaſe, then this whole Liquid would, for that time, neither ſpontaneouſly expand itſelf, nor in the leaſt reſiſt any compreſſion; but would then only exert this power, when, by being preſſed cloſer to one another, they ſhould begin to come within the ſphere of each other's activity. One aerial Particle, therefore, would have nothing of this elaſtic power; but it would be only the joint effort of ſeveral. Hence then, in all appearance, the elaſtic power of Air ought to be regarded as conſtant and immutable.

Air condenſed continues fluid.

But in what manner, or to what degree ſoever, this Air has been condenſed by the utmoſt power of Weights, it has always remained, even in that condition, very fluid; for after it has been contracted into the greateſt denſity, it has conſtantly reſtored itſelf again in all its Particles, with the ſame facility, ſo as to fill up exactly the former Space; all the Particles retreating with the ſame eaſe with which they before came together. Since, therefore, by every Experiment that has been hitherto made, this property has been always found to take place from 1 to 520,000, we may fairly aſſert, that the Fluidity of the Air, in all the large compaſs, from the moſt rarified, to the moſt condenſed, remains without alteration; and that therefore it is neither capable of being conſolidated by the intenſeſt Cold, or the greateſt degree of compreſſion.

The Elaſticity of any portion of Air of equal force with the whole Body.

But nothing now in this elaſticity of the Air ſeems a greater paradox to perſons not Maſters of this affair, than what Mr. *Boyle* has evinced with ſo much certainty; *viz.* that the elaſtic Power which prevails in any particular portion of the Air, can, without any greater condenſation than what is owing to the compreſſing Air itſelf, ſuſtain all the force of a whole column of the incumbent Atmoſphere: And ſecondly, that this elaſtic Power, in ſuch a very ſmall portion of Air, can, by expanding itſelf, repel the Bodies which compreſs it, with as much force, as that which is exerted by the whole external Body of Air. The truth of theſe aſſertions, I prove to you by the two following clear and eaſy Experiments that are borrowed from Mr. *Boyle* himſelf. You ſee this Barometer, which contains in its hollow Tube, Mercury elevated to 28 inches, the lower part of which is immerſed into the Mercury contained in this cylindrical Veſſel. And you ſee likewiſe, that this Veſſel is ſo contrived, that by means of a little Cock, all intercourſe between the external Air, and that little Portion which is in the Veſſel above the Mercury, may be cut off at pleaſure. If now I ſo turn the Cock, as that neither any of the external Air can get into the Veſſel, nor any of the Air in the Veſſel can get out to the external Air, then we are ſure, that the external Air can no longer act upon the Air in the Veſſel; and that only the Air which is incloſed in the Veſſel above the Mercury, can preſs upon the Surface of the Mercury in the Barometer. And you ſee evidently, that the height of the elevated Mercury is exactly the ſame as it was juſt now, when the weight of the whole Atmoſphere preſs'd upon it. That elaſtic Power, therefore, which is in the little portion of Air contained within this Veſſel, can ſuſtain as great a weight of Mercury, as the whole incumbent Atmoſphere. But if you pleaſe to obſerve again, you ſee, that while I am heating the Veſſel remaining juſt as before, the Mercury in the Barometer riſes higher and higher

every

every moment. How comes this to paſs? Why thus: The Air incloſed in the Veſſel cannot make its way out; by the action therefore of the Heat upon it, it acquires a greater degree of Elaſticity, expands itſelf, preſſes with more force upon the Surface of the Mercury, and by this means makes it aſcend. Nor does it at all ſignify, how little a quantity of Air is contained in this Veſſel above the Mercury; for the effect of the elaſtic, or heated Air, will in this caſe be always exactly the ſame. But in the ſecond place, if this Veſſel, with the ſame *Apparatus* remain ſhut, and is ſo nearly filled with Mercury, as to have but a little portion of Air above it, and then a barometrical Tube, open above and below, is fixed in the Veſſel in ſuch a manner, that no Air can either get in or out by the ſides of the Tube; then, if the Air in the Tube is exhauſted with an Air-pump, the Mercury in the Tube will riſe to near * 28 inches, in the ſame manner as if the whole Atmoſphere had preſs'd it up into the empty Tube. See upon this head *Boyle* of *Mechanical Experiments*, Vol. I. Part II. from Page 1. to 24. And this very efficacious power of the Air, the Chemiſts ought by all means to have a particular regard to; ſince 'tis certain, that in all chemical Operations performed with Fire in cloſe Veſſels, this elaſtic force produces wonderful, and often very terrible effects; acting with a violent compreſſive force upon the contents, often burſting the Veſſels aſunder, and producing many other ſurprizing events.

Hence the ſmalleſt portion of Air is equal, in its elaſtic force, to a large one.

A very little portion of Air, therefore, wherever it is cloſely confin'd, is capable of producing the very ſame effects, as are owing to a very large quantity in another place. For if any portion of common Air is perfectly intercepted within a cavity that is eaſily compreſſible, it will there ſuſtain, and from that place wholly keep out the large preſſure of the Atmoſphere. And whenever the Air in that place is heated by Fire, or freed from its external preſſure, it immediately, by expanding itſelf, becomes ſo rare, as to produce ſuch effects as are equal to thoſe of the greateſt Body of Air.

Air rarified by Heat, acquires a greate elaſtic for

Another Law, therefore, of the elaſticity of the Air, is this, that when it is condenſed in a certain and determinate degree, it acquires by the application of Heat, a greater power to expand itſelf on all ſides, than it had before. And this power of rarefaction ariſing from the Heat, is the very ſame, as if that Air had been made ſo much denſer in the degree of Heat in which it was before. The thing will be evident by an Experiment. For if in the caſe, and with the *Apparatus* laſt exhibited, the Air in the Veſſel ſuſtains the Mercury in the Barometer to 28 inches; then if the Air in this Veſſel was made twice as denſe, it would raiſe it up to 56, as the Experiments of Mr. *Boyle* demonſtrate. But now if the former Air being ſtill cloſely confined within the ſame Veſſel, is by the application of Air made twice as rare as it was before, then would that Air, tho' the very ſame in quantity, but thus rarified, elevate the Mercury likewiſe to 56 inches. This is a truth, which the Thermometer and Barometer, being tried together, have, in every variation of the Experiment, moſt certainly evinced. And thus by the application of Fire to Air, there ariſe a great number of very ſurprizing chemical effects which could not be foreſeen, which cannot be aſcribed to any other cauſe, and which ought to be very accurately taken notice of.

* This is only true, when the Veſſel which contains the Mercury is very large, with reſpect to the capacity of the Tube, the height to which the Mercury riſes being always different, as the proportion betwixt thoſe two is varied.

Fire rarifies Air sooner than it does any other Body.

This augmentation of ſpace now, into which the Air, by means of Heat, expands itſelf on all ſides, is effected by Fire ſooner in the Air, than in any other Body, either Fluid or Solid, hitherto known in the Univerſe. In *Drebbelius's* Thermometer, an increaſe of Heat, not perceptible without ſuch a contrivance, ſhews immediately a ſenſible rarefaction of the Air. But, indeed, the whole Hiſtory of Fire already delivered, proves all theſe things ſo clearly, that there will be no need of the leaſt repetition.

And to a greater degree.

It is evident from the ſame Experiments, that of all known Bodies, Air is the only one, which may be expanded by Fire to ſo great a degree. For Air, by the application of Fire, becomes ſo rare, that neither the meaſure, or limits of ſuch its dilatation, has been yet diſcovered. The Heat of boiling Water expands the Air to a third part of its bulk. *Hiſt. de l'Acad. Roy. des Scien.* 1699. p. 101. In the Heat then which is capable of fuſing Iron, certainly this expanſion of the Air muſt be immenſly great. But I refer you to what I have already delivered upon this head in the Hiſtory of Fire.

Air of the ſame denſity is by the ſame Heat expanded to the ſame degree.

We find, likewiſe, that Air of unequal Maſſes, but the ſame denſity, is always expanded in the ſame meaſure by the ſame degree of Fire: So that theſe expanſions in the ſame denſity of Air are, by a conſtant Law of Nature, always proportional to the augmentations of the applied Heat. Hence, therefore, if the expanſion of Air of a given denſity, by a certain degree of Heat, is once diſcovered, it will conſtantly hold good in all ſimilar caſes. Upon this head let me refer you to ſome very curious Obſervations in the *Memoirs of the Royal Academy of Sciences*, 1699. p. 113. and likewiſe in the *Memoirs* for 1702, from the 1ſt Page to the 5th.

The more the Air is condenſed, the greater elaſticity it acquires by the ſame degree of Fire.

But with regard to the elaſticity of the Air, this is likewiſe conſtantly obſerved, that the more it is condenſed by preſſure, the greater elaſtic force will it acquire by the ſame degree of Fire; and that nearly in a direct *Ratio* of the denſities: Which very curious property, to the great advantage of Chemiſtry, was diſcovered by the very ingenious *Monſieur Des Amontons. Hiſt. de l'Acad. Roy. des Scien.* 1702, from the 1ſt Page to the 5th. *Mem.* 155. Hence, then, it follows, of conſequence, that a portion of Air that is exceeding denſe, may, by means of a very little Fire, acquire the greateſt reſiſting force. If therefore it were poſſible, as I mentioned formerly, that common Air could in reality be condenſed into a ſpace eight hundred times leſs than what it naturally took up, then in ſuch caſe, it might, by being acted upon by the Heat of boiling Water, ſuſtain 29600 inches of Mercury; ſince common Air, by the ſame degree of Heat, will elevate it to 37: Which immenſe force certainly teaches us, that if the fierceſt ſubterraneous Fire ſhould, in the bowels of the Earth, be apply'd to Air reduced to $\frac{1}{800}$ part of its bulk, there would thence ariſe a moſt incredible power, vaſtly ſuperiour to all the effects that we are acquainted with. This, however, at leaſt, is certain, that if you increaſe the denſity of the Air, and at the ſame time augment the Heat that is applied to it, then the elaſtic Power of the Air will always be increaſed in a compound *Ratio* of both.

The more rare the Air is, the leſs elaſtic force it acquires by the ſame degree of Fire.

But on the other hand, now, the leſs the Air is compreſs'd, and ſo ſpontaneouſly rarer, the leſs is the elaſtic force that it acquires from the ſame degree of Heat. So that Air which by any means is render'd twice rarer, requires twice as much Heat to make it retain the ſame elaſticity that it had before; and thus in any other degree of rarefaction.

Theſe things the ſame celebrated Author, in the places laſt mentioned, has demonſtrated

monſtrated by the moſt correct Experiments. And hence we underſtand, that the Air in the higheſt regions of the Atmoſphere, will ſcarcely acquire any increaſe of its elaſtic force from the moſt intenſe Heat, but on the contrary, will become here almoſt unactive, on account of its exceeding rarity; which anſwers, too, perfectly to Obſervation.

The laſt Law which we diſcover in the elaſticity of Air, is, that it is contracted into a ſmaller ſpace by Cold, as it is by an increaſe of Weights. Hence its denſity is always increaſed in proportion to the augmentation of the Cold. Since therefore the intenſeſt degree of Cold in the northern parts of *Europe*, was diſcovered to be at O in the *Fahrenheitian* Thermometer, hence by deſcending from the degree of Heat in boiling Water in this Inſtrument down to O, the effect of Cold in condenſing Air was known likewiſe. And as ſince that, an artificial Cold has ſunk the Spirit in the Thermometer to 40 degrees below O; the power of Cold on Air, in increaſing its denſity, is now demonſtrated. We diſcover, therefore, that there is not a Body in the World, the dimenſions of which are more contracted by Cold, than the Air. Air is condenſed by Cold.

If we recapitulate now, what has been ſaid, we find the ſum of the matter to be this. If the Atmoſphere being according to *Fahrenheit*'s Thermometer 46 degrees hot, has its Heat ſtill farther increaſed by 166 degrees, it will then acquire a Heat of 212 degrees, which will make Water boil: But then the Air will become one third rarer, according to the Experiments of *Des Amontons*. A Heat therefore of 166 degrees, expands the Air one third. But now, if 40 degrees of Cold are added to 212, the ſum 252 will be the diſtance between the greateſt known Cold, and the Heat of boiling Water; within which diſtance, therefore, the Air is condenſed to $\frac{42}{83}$, or about one half of the whole. If after the ſame method of computing, we ſuppoſe the greateſt Heat of the Atmoſphere, in the open Air, and from natural Cauſes, ever to have reached to 90 degrees, which I ſhould think has been rarely obſerved; then it appears, that the rarity or denſity of the Air, from the ſharpeſt natural Cold, to the intenſeſt natural Heat, may be increaſed or diminiſhed to $\frac{15}{83}$, or about $\frac{1}{5}$. And hence it is manifeſt, what alterations in Nature are brought about by the Air, conſidered only, as it is changed by natural Heat and Cold, whilſt it ſurrounds and reſides in Bodies; the knowledge of which, certainly, will hereafter be of the greateſt uſe in accounting for fermentation, or putrefaction. The greateſt diſtance, now, which Mr. *Boyle* diſcovered between the rareſt and the moſt denſe Air, he computed to be as 1 to 520,000. How far.

In the laſt place, this elaſticity of the Air is ſo proper to it, and inſeparable from it, that it is not to be deſtroy'd by the intenſeſt Heat; as appears by the following Experiment. Take a ſpherical Glaſs with a ſlender neck, put it into a Glaſs-houſe Furnace, and hold it to a part ſo hot, that it is juſt ready to melt, and in that Heat let it be hermetically ſealed; then take it out, and ſuffer it to cool leiſurely, and whilſt it is yet whole and cloſ'd, immerge it in cold Water, and cautiouſly break off the top of the neck under the Water, and you will ſee the Water will be forced into the open neck with a very great *impetus*, and will fill the Glaſs, but with this limitation, that in the upper part of the belly of it, there will be ſome true elaſtic Air, thus evidently ſhewing, that the elaſticity, by ſo intenſe a Heat, could not be deſtroy'd. And in this ſame Experiment, by weighing the Glaſs quite filled with Water, The elaſticity of the Air not to be deſtroy'd by Fire.

and then weighing it again filled with Water and this Air together, we may discover the expansion of the Air in that Heat, in which Glass is ready to melt. Hence the Chemists might know what changes may be expected in their Operations, when Bodies full of Air are committed to so strong a Fire: Yet all these are things but rarely thought of, tho' it very much concerns Operators to have an Eye to them.

Nor any other way. In a word, since after the greatest rarefactions from 1 to 520,000, and upwards, and the like reciprocal condensations; after the application of the most piercing Cold, and the intensest Heat; after the greatest compressure and relaxation; and after the Experiments continued for so many years, as beforementioned, this elasticity remain'd perfect, and without diminution, we may very probably conclude, that the Air in this respect, is created such an Element, as by means of its immutable elasticity, and mobility, is constantly vigorous and active, undergoing as is were a perpetual ebullition and *subsultus*, penetrating into, and acting upon all Bodies, and keeping them in a continual agitation.

Of the contents of the Air. After having, for the service of the chemical Art, considered the properties of Air, the order of our subject requires, that in the next place we should treat likewise of those Corpuscles which are blended and contained in the common Air. And these, in reality, are incredibly numerous, of various natures, and perfectly different in different parts of the Atmosphere. Rightly, therefore, to conceive of the Air, is to consider it as an universal Chaos, in which Corpuscles of almost every kind being confounded together, make a composition, consisting of the most different parts. 'Twill be our business to give you a particular account of them, that we may be able to make just conclusions concerning it.

In the first place there is Fire in it, and under what Law. In the first place then, in the common Air, there is always and every where Fire. This has been shewn already in our History of Fire; where likewise it has been demonstrated, by every trial of the Thermometer, that Fire resides in the common Air, in the same manner, and in the same quantity, as it does in any other Body whatever. Nay farther, and it there exists, just in the same quantity as it does in the *Vacuum* of *Torricellius* or *Boyle*. This I learnt evidently from the Thermometer, by comparing one that was in an exhausted Receiver, with another that was in the common Air. And this Experiment I have repeated frequently, after different methods, but always with the same success. And hence I was fully convinced, that Fire of itself, and without any other cause intervening, exists in *Vacuo*, the Air, and every other kind of Body in the same quantity, and with the same activity; and that therefore this rule was again confirmed, that Fire is distributed as the spaces in the Universe. Hence, too, I discovered likewise, that after all the Air in the *Vacuum* of *Torricellius*, and almost all of it in that of Mr. *Boyle*, is extracted out of any space, Fire never then makes its way into that *Vacuum*, so as to fill up the space deprived of Air. For if this were the case, then there would of course arise a greater Heat from the accumulated Fire in this *Vacuum*; and consequently, a very sensible Thermometer, would give some indication of such increase: Or at least, you must be obliged to allow that there is Fire there, that is not capable of expanding Bodies, which to me is the same thing, as if you should say, that Fire is not Fire. Whatever, therefore, the Followers of *Descartes*, and others, have commented upon this subject, their reasonings have never been found

found to anſwer to any Experiment. And again, ſince Bodies that under the ſame ſurface contain the greateſt quantity of corporeal maſs, or the moſt denſe of all, as Gold, and Spaces the moſt empty, as the *Vacuum* of *Torricellius*, of themſelves poſſeſs perfectly the ſame degree of Heat, it follows very evidently, that neither Bodies, nor *Vacuums* have any power of attraction with regard to Fire. And as I have in a former Diſcourſe proved, by undeniable arguments, that no one Body is naturally more attractive of Fire than another, it follows, that no part of the Air is more or leſs hot on account of its being replete with different kinds of Bodies. Fire, therefore, of itſelf is always very equally diſtributed through the Air, conſidered alone, and without the intervention of any other cauſe; nor are there in the Air any Magnets to Fire. In the mean time, however, an infinite number of cauſes may ariſe, and be applied to the Air, by means of which there may happen in the Air a collection of Fire, ſcarcely to be determined in any particular place. Of which matter I have treated already in our Hiſtory of Fire, and ſhall have occaſion to ſpeak again hereafter.

In the ſecond place, there is Water contained always in the Air, and in every part of it, and that in ſuch a manner, that it does not appear that it can be wholly ſeparated from it, by any contrivance whatſoever. Does there not a watery Vapour perſpire continually from every healthy perſon? Does not *Sanctorius* compute, that in the ſpace of one night and day there exhales from a man in health nearly the weight of 5 pounds, much the greateſt part of which is Water? Conſider then, I beſeech you, what a vaſt quantity of aqueous Steams muſt be continually exhaling from the animals of all kinds, that are ſcattered all over the Earth; and that all plants, likewiſe, ſend forth a dewy, aqueous Vapour, is a thing that has been long confirmed by obſervation: But the very induſtrious and ingenious Dr. *Hales* has lately, in his curious treatiſe of *Vegetable Statics*, reduced the vaſt quantity of aqueous Vapours exhaling from Plants to computation. Why ſhould I mention the Water, that by means of ſubterraneous, culinary, private, and chemical Fires, is continually forced up into the Air? What the incomparable *Halley* has delivered upon this head is ſufficient. From the obſervations which he made with the greateſt care, and accuracy, it has long been certain, that from the ſurface of the *Mediterranean* alone, in the ſpace of a ſummer's day, there exhales by means only of the the æſtival Heat, without any aſſiſtance of Wind, 52,800,000,000 tuns of Water. See the *Phil. Tranſ.* Vol. II. p. 109. And the Wind and Sun raiſe up and diſperſe from the ſurface of that Sea, ſtill a larger quantity, *id. ib.* pag. 110. and 111. if you compare now the quantity of Fog, Dew, Rain, Hoar Froſt, Hail, Snow, and nocturnal Moiſture, that may be collected in the ſpace of a whole year, with the Water which in the ſame time, by means of the natural Heat, has exhaled into the Air, you will find, that in one year's time, there falls upon, and exhales from the Earth, about the height of thirty inches; as the very ingenious *Krukius*, with the greateſt labour has plainly proved in his Meteorological Tables. Hence it is very likely, that *cæteris paribus* there every year exhales into the Air, from the whole ſurface of the Earth, the value of thirty inches height of Water. And of conſequence, ſince the *area* of the Earth's ſurface is ſufficiently known, it is eaſy to compute the immenſe quantity of Water, that is always ſuſpended in the Air.

And Water.

Which appears to the eye.

And that Water is contained in every portion of the Air, is continually evident to the eye in Mr. *Boyle*'s Air-pump; for there, as the Air, by means of the action of the pump, becomes more and more rare, and leſs fit for the ſuſpenſion of Water, the inſide of the Glaſs becomes cloudy with a truly aqueous moiſture; the very ſame Experiment thus evidently evincing, that Water does really reſide in all parts of the Air, and that as the elaſticity of the Air is diminiſhed, it becomes leſs and leſs capable of retaining it.

And appears likewiſe in the augmented weight of a fixed Alcali.

But that there is a very large quantity of Water always, and every where diſperſed through the Air, appears evidently to the eye in your dry, alcaline, fiery, fixed Salts; for if theſe, when they are perfectly pure, are expoſed to the Air, they will ſpontaneouſly diſſolve, by means of the Water which they attract out of it. But that you might have ocular proofs of this yourſelves, I took, three days ago, at nine in the morning, two ounces and one drachm of Salt of Tartar, dried in ſuch a Heat, that it melted in the crucible; ſo that there was no Water at all remaining in it. I then laid it into this glaſs baſon, which was made very clean; and in this manner expoſed it to the Air, this cold, dry weather, from the 17th of *January* to the 20th, in this place, which is pretty high, and very dry. And what now is the conſequence? Why you ſee, upon examining it by the Scale, that it weighs three ounces four drachms and a half; and conſequently, that it has gained an additional weight of one ounce three drachms and a half. Nay, if we thus examine this Salt by a pair of Aſſay-Scales, we find it is every moment gaining ſomething in weight. And as there appears ſuch an increment of weight, within the compaſs of three days, ſo if it is kept a conſiderable time in the Air, the whole of it generally diſſolves into a liquor intirely fluid, pinguious, thick, ſomewhat tenacious, and unctuous, and that is almoſt three times heavier than the Salt firſt expoſed; and this Liquor the Artiſts call Oil of Tartar *per Deliquium*, beſides which, there will then remain at the bottom of the Baſon, a very ſmall quantity of a white Earth. If now, as has been done, you put this Liquor thus produced by the Salt and Air, into a glaſs Cucurbit, and with an alembic, which is a very tedious operation, you draw it to a dryneſs, there will then very pure elementary Water diſtill into the Receiver, and a dry Salt of Tartar, purer than it was before, and leſs ponderous, will remain at the bottom of the Cucurbit. This Salt, therefore, by being expoſed to the Air, receives from it this large quantity of Water. And here we may obſerve, that the Water thus communicated to the Salt by the Air, diſſolves it in a very different manner from what it would have been diſſolved if pure fluid Water had been poured upon it; for this dilution in the Air, being ſlow and ſucceſſive, by the application but of a very ſmall quantity of Water at a time, diſſolves only the pure alcalious Salts that are eaſieſt of all diſſolved, and therefore moſt nicely ſeparates this part from the reſt that is diſſolved with more difficulty, that is, that is ſomewhat more terreſtrial; which cannot be effected in any other manner. And hence it comes to paſs, that by ſuch a diſſolution, and coagulation, this whole Salt is at length converted into an Earth, and a volatile principle, which diſappears, and is ſcarcely perceptible afterwards. This *Van Helmont* knew very well, and other Alchemiſts had come to the knowledge of it long before him. In this Experiment, now, it appears to me particularly ſurprizing, that the very moment, as it were, that this Salt is taken out of the ſtrongeſt Fire, and expoſed to the Air, this humectation and diſſolution, commence, and the increment of weight, perceptible by the ſmaller balance, is begun, and from that inſtant, increaſes every moment. And this, which I have very often beheld with aſtoniſhment, has happened even while the Salt has continued exceeding hot, and been detained in a place too, which itſelf was very much heated by being near enough to the Fire ; ſo that I could not, with the utmoſt care, keep off the Water of the Air from the Salt. And again, now the weather is ſo cold, and dry, that the height of the Barometer is twenty nine inches and a half, I ſet the Salt with this Baſon in a place, walled on all ſides with a very cloſe timber covering over head, which is always cloſe and ſtill, and into which no Wind can enter, and you obſerve the effect is the ſame. But there is yet another thing more to be obſerved, in this wonderful attraction of Water from the Air into a dry alcaline Salt, which, ſome years ago, a good deal engaged my attention. I wanted a very acrid, dry, fixed, alcaline Salt, in order to demonſtrate to ſome perſons, who would not believe it, nay, who even denied the poſſibility of it, that there might be a Tincture produced in an inſtant from that Salt, and pure Alcohol; a truth, which ſome famous chemical Authors have in their writings proſcribed as a fiction. This Salt, then, rightly prepared, glowing hot, and as yet in fuſion, I poured into a very hot braſs Mortar, and with a very hot braſs Piſtil, rubb'd it as faſt as I poſſibly could, and as ſoon as ever it began to come to a conſiſtence, I ſhut it up into a very hot and dry glaſs Bottle, and immediately ſtopping the mouth of it with a Cork, and a piece of Bladder ſoftened with Oil, ſecured it as cloſe as poſſible. And what do you think was the iſſue? Why when I came to try the Experiment, though I had frequently before met with ſucceſs, yet the event at that time would not anſwer. Surprized at this, I carefully examined every circumſtance, that might produce this variation, and diſcovered at laſt, that the ſurface of the Salt was a little moiſtened by the Air in the Bottle, and that therefore, this being already impregnated with Water, the Alcohol could not come immediately to it.

It makes the greateſt part of the weight of the Air.

Now whilſt I carefully conſider theſe things, I am clearly convinced, that in ſo ſmall a portion of Air as can be contained in a Bottle, which will hold but three pints of Water, there is Water enough to moiſten an ounce of Salt of Tartar, and to increaſe its weight. And having repeated the Experiment with the ſame ſucceſs, I learnt at the ſame time, that the Water contained in that portion of Air, which perhaps is 850 times heavier than the common Air, muſt of conſequence make up the greateſt part of the weight, which is ſtatically diſcovered in the Air itſelf. For if one eight hundred and fiftieth part of the common Air was Water, then the whole weight of the Air would certainly be owing to the Water alone which floats about in it, and the other parts contained in the aereal Maſs, would make nothing towards the weight of it ; nay, would not, perhaps, gravitate at all. Upon which ſubject I had ſome converſation formerly with my good friend Mr. *Henry Van Deventer*, famous for his valuable writings on Midwifry, who told me, he had thought of the very ſame thing.

A wonderful property of the Air.

Whoever now conſiders all theſe *Phænomena* with attention, muſt certainly hence infer one, two, or all three of the following propoſitions. Either, firſt, the Air, in all ſtill, cloſe, and ſubterraneous places, muſt be in a perpetual motion, that by this means it may apply that little quantity of Water, which is

diffuſed

diffused through its whole Mass, to the surface of the Salt of Tartar, so as to leave it there; for if a cubic foot of Air contains at the most $\frac{12}{425}$ of a pound *Troy* weight of Water, and communicates, within a Vessel close stopt, this Water to the Salt, then it follows, that all that Air must so revolve about the surface of the Salt, as that all its parts may successively come in contact with it, and thus deposite the Water they contain: Or else, secondly, we must conceive, that those Particles of Water, which at one time are dispersed throughout the whole mass of Air, are at another time so moved through that Mass, as that they are perpetually and successively now in one part of the aerial Space, and now in another, till at length they all happen to meet with that Salt which is placed within it: Or, in the third place, we must acknowledge, that there is a true attractive power between a fiery, fixed Alcali, and Water, so that like two Magnets, they reciprocally attract one another, in the same manner, as we read in *Sendivogius* of an Alcali of the Earth, that attracts the cælestial Dew, in order to a fertile impregnation. Whoever, now, prefers this last way of thinking, must perceive, at the same time, that this attractive power between the Water of the Air and an alcaline Salt, must extend to a considerable distance, since a very little of the Salt will grow four times as heavy as it was at first, by means of the attracted Water; for an ounce of Salt of Tartar, whilst it is converted into 4 ounces of Oil of Tartar *per Deliquium*, must have drawn into it 3 ounces of Water. But 3 ounces of Water require at least two cubic feet and a half of Air to be diffused through in order to be attracted into that one ounce of Salt; which Space, with respect to that one ounce of Salt, is certainly exceeding great. But from all kinds of Experiments, it appears very probable, that all these three causes concur, at the same time, to the production of the same effect.

The elastic quality of the Air don't unite with an Alcali.

But nothing appears to me more extraordinary in this affair, than that whilst the Water is drawn into the Alcali from the Air, and thus makes Oil of Tartar *per Deliquium*, which in weight is to Water, as 7 to 5, but to Air, as 1190 to 1: I say, that whilst the Oil of Tartar *per Deliquium* is thus produced, there should be found in it nothing at all of the aerial Elasticity; so that this Alcali thus separates the Water from elastic Air, and unites it to itself, but rejects intirely the aerial elastic Quality. Hence, therefore, again it appears, that Air, free from Water, is very elastic; but on the contrary, when it is replete with watery Vapours, it proportionably loses somewhat of its proper Elasticity; and again, that by means of a great quantity of fixed alcaline Salt produced on the Earth, a vast deal of Water may be drawn out of the Air.

At what time there is the most Water in the Air.

In a continuance of serene, and very dry weather, the Air becomes always more ponderous, the Atmosphere heavier, and the Water mounts higher in the Air. So that in reality there is never more Water in the Atmosphere than at that time, when by reason of the dryness here below, people generally imagine there is the least of all: But the Water, then, is far more widely distributed, and dispersed; for you easily apprehend, Gentlemen, that the higher from the Earth the Water ascends in the Atmosphere, the greater are the Spaces into which it is diffused, and the farther, consequently, its Particles recede from each other; and that then they exist separately, and do not immediately unite, nor afford any moisture. But if the Barometer is very high, and at the same time, thick and stinking Fogs appear, then do the watery Particles

almost

almoſt always float below along with groſs, unctuous, and ſaline exhalations; all which, at that time, will not, in an exact mixture, be equally diſtributed or united. But again, when the Barometer is very low, and the weather at the ſame time is very hot, and very cloudy, then the Water comes down to the lower regions, but in an uniform Vapour, very moiſtning, but not yet producing Rain. From theſe obſervations it is manifeſt, that the Air, when loaded with abundance of Water, often appears very dry, bright, and perfectly clear; and that on the other hand, when there is leſs Water in it, it may, by the deſcent, collection, and unequal diſtribution of the Water, appear cloudy, dark, and very moiſt. And this is demonſtrated evidently in Cucurbits, Alembics, and Glaſs Receivers, whilſt Water is diſtilling in them: For if the Veſſels are kept ſtopt very cloſe, whilſt a diſtillation is going forward, all appears bright and clear, and no ſuch thing as a cloudy Vapour is ſeen; but as ſoon as ever the Water in the Cucurbit, upon the removal of the Alembic, begins to exhale freely into the Air, the whole appears covered with watery, and very thick Vapours, the equable compreſſure being now deſtroyed.

But if in the ſummer ſeaſon, when the weather is fair and very dry, and the ſurface of the Earth has been for a conſiderable time parched with a great Heat of the Sun, then not only the watery, but other Particles likewiſe leſs volatile, as the oily, and ſaline, are by the power of the ſolar rays carried up into the Air, and fill that part of it which lies neareſt to the ſurface of the Earth. And ſo long as theſe exhalations are kept in agitation by the Heat of the Sun, ſo long nothing of them appears to the eye: But as ſoon as the ſolar Heat, which at three in the afternoon is the greateſt, begins to remit, the Air not long after begins to grow cool, tho' the Earth, which retains the Heat communicated to it by the Sun a thouſand times longer than the Air, being yet hot, continues to exhale the agitated Corpuſcles; by which means there is collected a white, denſe Vapour, which is cool above, but ſtill continues warm below. This Vapour, therefore, appears firſt in ditches, and watery or marſhy places, whence diſperſing itſelf by degrees, it covers the face of the Earth in the evening, and night time, with a cloud conſiſting of this kind of Particles, which in the morning is again diſſipated by the Heat of the riſing Sun. And this is what we uſually call Dew; which appears, from what is here ſaid of its production, to be a very compounded liquid; ſo that nothing uſeful can be aſſerted concerning its proper nature, which would in every circumſtance hold true. For ſince it is a compoſition of all the Corpuſcles of the Earth, which are rendered volatile by the æſtival ſolar Heat, exhaling and deſcending again, and blended and confounded together, it muſt doubtleſs appear, upon the leaſt conſideration, to be a perfect Chaos. Nay, and in every particular part of the Earth, it muſt be likewiſe of a quite different kind, according to the various nature of the Bodies in the place where it is produced. In gravel-pits, for inſtance, and in high, dry, heathy grounds of a large extent, there is collected but a very ſmall quantity of this Vapour, and that almoſt intirely watery; whilſt that which is collected about ſtanding Waters, Fens, Marſhes, and fat bituminous grounds abounding with putrified fiſh, and other animals, is perfectly of a different nature, and very often pernicious to mankind. It is no wonder, therefore, that the Chemiſts, in the artificial reſolution of Dew, have met with ſuch contrary principles, and written ſo differently upon the ſub-

Aerial Dew.

 ject,

ject, that you can ſcarcely find two of them that give the ſame account of it. And as for thoſe who expect to find the Spirit of Life, the univerſal *Menſtruum*, the Mercury of the Philoſophers, and the Nitre and Steel of *Sendivogius* in Dew, they certainly ſcarcely ſeem to have read the works of theſe Philoſophers to any valuable purpoſe. That this however is a very ſharp, ſaponacious, pinguious Liquid, abounding with a good deal of nouriſhment for Vegetables, I do not go about to deny. A Dew too collected in a certain part of the Earth, has yielded by diſtillation a Liquor that impreſſed upon Glaſs the lively colours of the Rainbow, which could neither be removed by friction, an alcaline *Lixivium*, or *Aqua Fortis*: And this Liquor was inflammable, like Spirit of Wine; as appears from the chemical Experiments related in the *Republick of Letters*, Tom. I. p. 590. And again, diſtilled Dew, digeſted for the ſpace of eight days in a gentle Heat, and by repeated diſtillation rendered ſix times more ſubtil, is ſaid to have broke three glaſs Veſſels, and to have remained perfectly inſipid; tho' it was ſo very thin, that it reſembled pure Spirit. *ibid.* 1708. p. 152. And farther, in the *Britiſh* Obſervations, Dew is deſcribed as being like Butter, of a yellowiſh white colour, ſoft, melting by being rubb'd upon the hand, and growing dry and hardning by a moderate Heat, of a very fetid ſmell, in the Winter, and in the Spring, particularly, produced in the night time, in pretty large Lumps. *Philoſoph. Tranſact. Abridg.* Tom. II. p. 143. But the nature of Dew is likewiſe ſurprizingly various, according to the different diſpoſition of the weather, and according to the various and ſucceſſive changes of the meteors in the Air; for hence it comes to paſs, that the very minute Seeds of ſmall Plants, and the inviſible Eggs of the ſmalleſt *Animalcula* are mixed with it, together with an infinite number of other things; which being all digeſted, fermented, putrified, and diſtilled together, yield at different times principles of very different natures, and hence lead the Chemiſts into very extraordinary opinions. See *Abridg. Philoſoph. Tranſact.* Tom. I. p. 141. The principal part therefore of Dew is Water; the reſt, on account of their manifold variety, cannot poſſibly be deſcribed.

The Clouds. That the Clouds are produced in the Air, from almoſt Water alone, there is ſcarce any one that doubts. But Water every where equally diſpoſed, is tranſparent. Clouds, therefore, are collected from what is beginning to be Water, but the parts of which, in the mean time, are circumvolved among one another with an unequal motion, neither reſting nor moving equably; as I juſt now hinted. If the Water that is floating about in the Air, now, mounts higher and higher, its particles at length arrive in places ſo far above the Earth, that they are not any longer much united together, but receding from each other, they do not then conſtitute Water, but only the elements of it. But when theſe Elements of Water come to deſcend again from thoſe upper regions, and are contracted into ſmaller Spaces, where they aſſociate together, and become a kind of Water, they then form Clouds. The higher, therefore, the Water aſcends in the Air, the ſerener and dryer the weather will be, and the freer from Clouds; and the contrary. But Water is carried up to a very conſiderable height in the Air; for in *Carniola* in the neighbourhood of *Venice*, there are mountains 10274 geometrical feet high, on the tops of which there are indications of moiſture. *Act. Lipſ.* 1689. p. 552. And on the higheſt tops of thoſe Mountains, Nature preſents to our view perpetual Snows; a certain Proof of the elevation of Water to ſuch heights. Nay, and over the Mountain *Teneriff*, the

the higheſt in *Europe*, there conſtantly about noon hang Fogs, or little white Clouds, which are daily reſolved into Water, which flows in ſuch plenty down the mountains, that it ſupplies the place of Showers, and waters the whole Iſland, without Rain, *Act. Lipſ.* 1691. p. 98. We are certain, therefore, that Water aſcends to ſuch a height. But had we ſufficient obſervations to confirm the account *Maignan* of *Thoulouſe* gives, in his treatiſe of *Perſpective*, p. 93. of the wonderful *Phænomenon*, which he ſays he had obſerved, the aſcent of the Water in the Atmoſphere would be found to be abundantly higher: For he tells us, that in a very clear night, and that at midnight too, there appeared in the month of *Auguſt*, an exceeding bright little Cloud, which ſpread itſelf almoſt as far as the Zenith, or vertical part of the Heavens; and ſays, that *Riccius* obſerved the ſame thing, in the neighbourhood of *Rome*; and from theſe Obſervations he infers, that Clouds may be elevated beyond the projection of the Earth's Shadow. But this projection, now, if aſtronomically computed from the given time and place of the appearing Cloud, would give a prodigious diſtance from the Earth; and hence, perhaps, that appearance was rather to be aſcribed to ſome other unknown cauſe, reſiding in the upper regions of the Air, and exceedingly lucid, ſince on the tops of the higheſt mountains, there are rarely obſerved any Clouds, but on the contrary, to a ſpectator placed there, they appear below him, towards the Plain.

The lower Air being full of Water, begins to unite the Elements of Water cloſer together, and by this aſſociation to form very little drops, which falling down, produce a ſmall Rain, for the moſt part thick, but deſcending with no great force. For the leſs theſe drops are, the greater ſurface they contain, in reſpect of their quantity of Water, and conſequently are the leſs able to deſcend ſwiftly through the reſiſting Air. Small Rain.

But when the Water in the upper regions of the Atmoſphere is collected together, and thereupon becomes heavier, and begins to deſcend; then, by gradually coming down into ſmaller ſpaces, it continually unites to it the other Particles of Water which it meets with in its fall. By this means, therefore, are produced thoſe very large drops which in *Europe* have been obſerved to have been three lines in diameter, but among the *Negroes*, a whole inch, *Act. Lipſ. Suppl.* 1. 425.; which Drops containing a great weight of Water under a leſs Surface, ruſh more violently through the Air, and fall to the Earth with a mighty *impetus*. The higher, now, the place is from which they fall, the larger the Drops are, and ſo *vice verſa*; for it has been always obſerved, that the Rain, in the upper part of a high mountain, is the ſmalleſt, but that, as you gradually deſcend, it forms larger and larger Drops, till at the foot of the Mountain it produces the largeſt of all. Hence it comes to paſs, that the hardeſt Showers happen in Summer, when the Water, being driven rapidly downwards on a ſudden, cauſe thunders, lightnings, and tempeſts. And hence, likewiſe, the Drops of the Showers, in Summer time, are uſually larger than they are in Winter. Laſtly, obſervation has made it very certain, that Rain, in every part of the Atmoſphere, is there the ſmalleſt, where it is firſt produced. Great Showers.

But now when the Air, abounding with Water, and waxing cold in the night time, is carried againſt the upper parts of high mountains, eſpecially if they are diſpoſed in a long range, then this cold and denſe maſs of Bodies, particu- Springs.

 larly

larly towards the North and East, during the first part of the night, and towards the South and West after midnight, stops, cools, and unites this Water of the Air, and converts it into a watery humour, which gives rise to a great many little *striæ* of Water, which in the highest part of the mountain are small, but as they descend, and are joined with one another, become larger, and by this means produce a perpetual trickling down the mountain, and afford an incredible quantity of Water, which runs down, and produces various rivulets, according to the various channels of the mountain, or the land about it; and when these by subterraneous passages descend from a high part of the mountain to any part of the declivities, and there burst through outlets, and so discharge their stream, they then yield a pure Water, either falling right down, or bubbling up from a spring. And here it is very easy to conceive, that, according to the different height of the springs, in respect to the outlets, the playing of the fountains must be various. And hence, likewise, it is easy to account for the variety of springs, both in the quantity of Water, and every other circumstance. And hence again it appears farther, how it comes to pass, that there are no springs, but where there are pretty high mountains, and that wheresoever these are, there likewise are observed springs: The truth of which appears no where with more evidence and beauty, than in the fortunate valley of *Cassimire*, mentioned by *Bernier*, in his *Description of the Empire of the Great Mogul*.

Brooks, Rivulets, and Rivers.

Again, wheresoever there are such Mountains, and Springs, there the Water, after running down from the Mountains, or perpetually bubbling up from the Springs, is discharged into Rills or little Currents, continually flowing, but for the most part with a gentle course at their heads. When afterwards different currents join their courses together, the stream becomes stronger, and being continually augmented by Rivulets which discharge themselves into it, in a short time produces a River. This again, not long after, being still as it passes augmented in strength and quantity by the accession of other streams, forms a River still flowing with a more rapid course, always tending from the higher to the lower ground, and at length discharging itself into the Sea, from which it never returns again; whose contents, however, in the whole, are by this means never increased, inasmuch as what it receives by the discharge of the Rivers into it, it gives up again continually by exhalation. Sometimes it happens likewise, that the rapid torrents of Rivers sink down into passages under the Earth, disappear, and rise up again in some other place. Hence it comes to pass, that in flat countries, where there are no Mountains, or Springs, there are never formed any Rivers. And for this reason, the supreme Wisdom has thus distributed Mountains throughout the whole Earth, that they might be beneficial to mankind, by producing these collections of Water. And hence, lastly, all the World over, the courses of Rivers answer the order or rangings of the Mountains. Upon this subject, let me refer you to the discoveries of the incomparable *Halley*, in the *British Philosophical Transactions*, which he truly has a right to the merit of. All these things now, it concerns us to be particularly acquainted with, who are prosecuting the study of the chemical Art, in which there is almost a perpetual necessity of considering the variety of the qualities of Air and Water. And these Observations will likewise be of singular use in our following Treatise of Water.

By

By all that has been hitherto ſaid, however, it does not appear certainly, how great the utmoſt height is, to which Water can aſcend in the Atmoſphere: But this, at leaſt, in the mean time, we are abſolutely ſure of, that on the top of the higheſt Mountain on Earth, there never is any Air without ſome Water in it, ſince the top is always found moiſtened with humid Vapours. And hence it is evident, likewiſe, that it is not poſſible, by any manner of Art, to make uſe of Air in our chemical Operations, in which there is not contained Water. Perhaps, indeed, from a given quantity of Air pent up very cloſe in a dry glaſs Veſſel, all the Water may be drawn out: For if ſome Salt of Tartar, coming as hot as poſſible from the Fire, is reduced to a fine Powder, and thrown very dry into this glaſs Veſſel, and the mouth of it is immediately ſtopt cloſe; then this exceeding dry Alcali will attract into it all the Water that is contained in the included Air: But then, no-body can apply this Air to any chemical Operations; becauſe as ſoon as ever the Veſſel is opened, this dry portion of Air mingles again with the common Air, and is immediately moiſtened by the Water which that was filled with.

There is every where Water in the Air.

Water ſeparable from the Air chemically.

But farther, we are aſſured from undeniable Obſervations, that the higher the Water is carried into the Air, the farther it diſunites its parts, diſperſes them through wider and emptier ſpaces, and at the ſame time grows colder. For upon examination it has been conſtantly found, that in every part of the habitable World, the Heat *cæteris paribus* is greateſt at the Surface of the Earth; and that at the very ſummits of the higheſt Mountains, a freezing cold preſerves a perpetual Snow. This is true, even at the Equator and in the Torrid Zones: So that there is not in the hotteſt part of the Earth a Mountain very high, whoſe top is not exceeding cold. Nay, and the cold increaſes gradually, as you aſcend from the foot to the ſummit of the Mountain, in ſuch a manner, that the increment of Cold is always proportional to the increaſe of height. This is an Obſervation that will always hold true, if all other circumſtances are alike. When Water, therefore, aſcends to ſuch a height in the Air, that it meets with a freezing Cold, it muſt neceſſarily be congealed into Ice, unleſs its Elements are ſo ſeparated, that none of them touch one another; for ſo long as the Particles of Water are there diſperſed from one another, ſo long there will be no appearance of Ice: But as ſoon as ever in this high and cold region of the Air, theſe Elements begin to come into mutual contact, then they begin likewiſe immediately to be congealed into little icy Globules, which float up and down through the clear Air, and falling upon the Surfaces of the Bodies they meet with in that region, produce a very fine hoar Froſt, but otherwiſe are ſcarcely perceptible. In the Atmoſphere, therefore, there is an Orbit concentrick to the Earth, in which the Water of the Air, when it is carried up to that height, is always frozen if it is united together. And the higher it is elevated above this Orbit, ſo much the ſooner and harder it will be frozen. But at the ſame time, however, it is not improbable, that when the Water arrives to ſuch a height, its Particles will be ſo much the leſs united, and therefore, will rarely be congealed, but on the contrary will float about ſeparately, 'till ſome other cauſe ſhall happen to unite them together, and by this means form them into Ice.

Water in the higheſt places becomes Ice, or ceaſes to be Water.

When the Water, therefore, in the Orbit juſt mentioned, is congealed, then by an adunation of a greater weight of Water under a leſs Surface, it muſt like-

Hence Snow.

likewise immediately become heavier, by which means, it will of consequence begin to fall downwards, and thus descending into spaces that are smaller, and are more replete with Water, will associate to itself other watery Particles, and so gradually form larger icy concretions, which will now put on the appearance of Snow, or small Hail. But as there may be a great number of causes, and those perfectly different ones too, by means of which, the Elements of Water, that were before scattered in the upper Air, may on a sudden, and in a very large quantity, be brought into contact with one another in the icy region of the Atmosphere; hence you easily apprehend, that considerable pieces of Ice may in a pretty short time be there produced.

And Hail. But these icy Bodies may in like manner be collected together; and when this happens, there will appear little Clouds, high in the Air, and white by means of the reflection of the Sun, which suddenly falling downwards with a mighty velocity, seem to increase very fast in their magnitude, and rushing from on high upon other like Clouds, by that collision produce Thunder, Lightnings, Tempests, showers of Rain and Hail, which are always the more violent, the higher the place is from which they fall. And hence it comes to pass, that in Summer time, when the Weather has been long clear, the lower Air very dry, the Atmosphere heavy, and the Water therefore in it carried up to a very great height; then the Atmosphere being on a sudden rendered lighter, there usually very soon follow the *Phænomena* we have just mentioned, especially between the Tropicks, where, if a little white Cloud appears very high in the Air, it is a sign that a terrible Storm is just at hand. And it is exceeding probable, that the Hail, which is always formed in the upper and colder regions of the Air, as it descends by its weight into the inferiour and warmer ones, is there dissolved by the Heat, and produces those great showers of Rain, which accompany, follow, and put an end to Thunder and Lightnings. But if the Hail happens to be so swiftly brought down through the Air, as that by reason of its quick descent it cannot be melted, it then falls to the Earth in form of icy Stones, which often, by their size, weight, and motion, do a great deal of mischief. In the Abridgment of the *Philosophical Transactions*, N. II. p. 144. we have an account of some of these that weighed a full pound.

Thunder and Lightning. This certainly we are assured of by Observation, that Clouds of a very white colour, to which there presently succeeds a pitchy blackness, terrible Thunder, Lightning, and Tempests, are always accompanied with Hail. And hence I imagine, you will be more ready to believe, that the causes here assigned for these *Phænomena*, are the true ones, than to come into the opinion of Dr. *Hook*, concerning the concretion of Hail in the course of its descent; which you may see in his Posthumous Works, in the Life of the Author, p. 24. And hence it may likewise be questioned, whether, for producing even the greatest Thunders, and Lightnings, Nitre and Sulphur are always necessary; since the very violent collision of hard Ice suffices, perhaps, for the striking out a vast quantity of Fire; doubtless, it is sufficient for producing the loud peals and rumblings of Thunder. Especially, if we likewise consider, that the Fire of the Sun, by its heat, reflexion, and refraction, can act in infinitely different ways, upon the aqueous congealed Matter, we are here speaking of. If this then be taken into the consideration, what variety of Colours, what diversity of Figures, and what difference of Dimensions may we not suppose to happen in this aerial Ice?

But amongst the principal causes that are concerned in the production of such extraordinary and various *Phænomena* so suddenly produced in the Air, which before was calm and serene, we have a particular regard to the diminution of the weight of the Atmosphere. For the Water always begins spontaneously to separate itself from the Air, when it becomes lighter, and thus discovers itself, tho' before it did not appear. In the next place we imagine, that the Bodies of Air which are driven from opposite quarters, often strike against one another, and by this collision, very quickly unite together the Elements of Water, which before were floating about separately. Something likewise may perhaps be owing here to the various Aspects of the Planets; not to mention the efficacy of the Winds, and the vicissitudes of Heat and Cold towards these productions. Every one of which separately, or all of them together, may easily enough bring about the effects we have mentioned, with many others. The Cause of these productions.

On the other hand, now, if we have a mind to turn our Eyes to the causes which mingle Water with the Air, and carry it up into it, we shall find there are a great many. The principal, however, of these, is the Sun, the direction of whose Rays upon the Water, the nearer they approach to a perpendicular one, the more Water they always carry up into the Air. Upon which head consult the Observations of Dr. *Halley*, which I have already cited in their proper place. Another cause wonderfully assisting the foregoing, is the subterraneous Fire, which is always in action, never at rest. For it has been evinced by Observations, that in Mines sunk lowest, or in the deepest Wells, you first come to a depth in which Water never freezes, but which continues almost always of the same Heat, without any alteration; as the celebrated Academy at *Paris* observed long ago in the Well of their Observatory; but that as you descend lower, the Heat begins to grow greater, increasing gradually more and more, in proportion to the depth, till at length it becomes so suffocating, that unless it be attempered by the coolness of running Water, and the Air that is thence produced, it overcomes the Miners. And we see likewise, that in Winter time, when the Water is covered with Ice, and the Earth with its hard frozen Crust, if the Ice is broke, or the Earth is opened, both the Water and the Earth smoke with heat. Nor had the Philosophers, whom I have formerly heard discoursing on this subject, any grounds for asserting that this was all a fiction, and that it was impossible that Fire should thus exist in the bosom of the Earth, because it can neither be supplied with a proper *Pabulum*, or be agitated by Air: For certainly we ought to consider, that by the sole attrition of the condensed Air, in the bowels of the Earth, this Fire may be produced and preserved without any other Air or any *Pabulum*. For should the Air at any vast depths under Ground be condensed six hundred times more than the common Air, what effects wou'd it not be capable of producing? Incredible ones without dispute, since Authors worthy of credit have declared, that Air, forcibly compressed in an iron Tube, has grown warm there. It is not to be question'd, therefore, but that, in the deepest parts of the Earth, where the Bodies are compress'd by the prodigious weight of those which lie above them, the smallest attrition must produce the greatest Heat. And hence as the action of this Fire is perpetual, so likewise must be the effect of it too, *viz.* a continual exhalation of Water. In the third place, we have regard to the very great Causes that carry Water up in the Air.

great and constantly repeated effects of the common Fires, made use of by Mankind in every part of the inhabited World, in the dissipation of Water, whether alone, or contained in Animals, Vegetables, or Fossils. For doubtless, if any one computes the measure of this exhaling Water, which such Fire carries up and distributes through the Air, he will find it to be incredibly great. Again, in the fourth place, the force of a very sharp Frost carries off from Ice every moment a surprizing quantity, so that in a little time the Mass is consumed, being dispersed into the Air by the cold alone; as the excellent Mr. *Boyle* plainly discovered by an Experiment examined by the Ballance. But daily Observation likewise certainly evinces, that by the piercing Cold of a very severe Winter, all kind of Bodies are strangely worn away, diminished, consumed, and dispersed through the Air. In the fifth place, it seems probable also, that every physical cause, which is capable of so disuniting the Particles of Water from one another, as to make every one of them exist separately, will also by this means effect, that those Particles will immediately acquire so large a Surface in respect of their very small weight, that they will be able to float about in the Air. And indeed, this solution of Bodies into their smallest parts, appears at length so to increase their Surfaces in respect of their quantity of Matter, that in every division of them, this aptitude to swim in a lighter Liquid is very much augmented, as the Geometricians have long ago observed. But it is farther discovered by physical Observations, that besides the gravity of Bodies, there is likewise a certain repelling force, which tends to prevent the contact of the Surfaces of different Bodies, and which consequently, is always increased in proportion to the augmentation of their Surfaces. Hence therefore it follows, that Bodies very minutely divided, descend on this account with more difficulty by the force of their gravity, than they would do, if they were acted upon by the Law of Gravitation alone. And the action of this second property of Bodies seems particularly to prevent the continual and immediate descent of all the Particles of Water out of the Air that is about the Earth. Sixthly, it seems to be the effect of the very same property, that the Particles of Water may be expanded round the Air contained in them, and thus form that spherical Body which we call a Bubble. And besides, any other Heat, or expanding Spirit whatever, while perhaps it performs the same thing, may, as well as Air, be always at length capable of rendering Water lighter: But when afterwards the Water, being so divided into very light spherical Bubbles, is carried upwards, then does every Bubble expand itself more and more continually, and so is able to ascend for a long time, and to keep aloft in the Atmosphere. And hence it is manifest, that the Particles of Water may ascend to a great height. See *Halley* in the *Philosophical Transactions*, 1692. N. 192. p. 468, *&c.* But in the seventh and last place, there is no cause whatever which carries up such a quantity of Water from the Earth into the Air, as the Wind; as the same admirable *Halley* has elegantly demonstrated, and as I myself have learned from various Experiments, not without astonishment; for having exposed a copper Cylinder full of Water to the Wind in stormy Weather, I was surprized at the incredible quantity of Water carried off in a little time; whereas when the Wind was down, which happened presently after, but a very little Water exhaled, tho' the heat of the Weather was still the same. For this reason it seems ordered, that pretty high Winds should follow large quantities of of Rain; that by thus agitating the fallen Water, and carrying it up again into the Air, they may prevent its ſtagnating and putrifying, and by this means proving deſtructive to the vegetable kingdom. All theſe cauſes, therefore, when they conſpire together, are ſufficiently capable of diſſipating Water into the Air, and there keeping it in continual motion.

The power of elaſtic and moiſt Air, on human, vegetable, and foſſil Bodies.

If we conſider, now, the action of this elaſtic Air, replete with Water, upon the body of a Man, Foſſil, or Vegetable, we ſhall find it brings about very many, and very wonderful changes. For if we reflect upon its particular fineneſs, by means of which it is exceeding penetrating, and is perpetually inſinuating itſelf into every little ſpace; and if at the ſame time we take into conſideration its conſtant mobility, by which 'tis always kept vigorous and active, it is manifeſt, that theſe qualities being determined upon Bodies by the force of Gravity, are capable of producing an infinite number of effects. But the Water that is diſtributed through the Air, will likewiſe be ſtill more efficacious, being itſelf agitated by the motion of the Air; and by this means it will more readily diſſolve the Salts, and the ſaline and ſaponaceous Subſtances of the Bodies it is applied to. And as there are very many ſuch parts in moſt Bodies, and thoſe parts too are the principal inſtruments of their action; hence you very eaſily apprehend, that by means of the application of the Air, the proper vertues of Bodies may be excited, as far as they depend upon their peculiar Salts, and *Sapo's:* But theſe vertues, as we obſerved juſt now, are often their principal ones. In the mean time, however, the chief alteration induced upon Bodies by the Water of the Air, is its rendering fixed Salts, and other compound Bodies, volatile. This *Phænomenon* was obſerved by all the chemiſts of old, and is conſtantly found to hold true: That is to ſay, all native Salts, if they are rendered exceeding dry by an open Fire, and then pounded and expoſed to the Air in a Glaſs Baſon, will there, by means of the Water in the Air, be converted into a Liquid; and from the perfectly ſaline part there will be ſeparated an Earth, which did not appear before. If this ſaline Liquor, then, thus freed from this Earth, is again throughly dried by a large and clear Fire, and afterwards the Salt beaten, and again diſſolved in the Air, it will afreſh depoſite ſome earthy *Fæces.* And if by ſeveral repetitions of this ſolution, and inſpiſſation, you thus remove all the earth that is every time produced, you will at length procure an incredible quantity; but at the ſame time you will have nothing elſe remaining; for that other principle, which before, in conjunction with the Earth conſtituted the Salt, is by this repeated action of the Water of the Air ſo diſengaged from its earth with which it was incorporated, that now, exiſting ſeparately, it becomes perfectly volatile, is diſſipated into the Air, nor does ever again come within the cogniſance of our ſenſes. Nor has the induſtry of the Chemiſts diſcovered this wonderful *Metamorphoſis* in native Salts alone, but likewiſe in the fixed Salts prepared by Fire from Vegetables; for by this tedious operation, theſe Salts are likewiſe reſolved into an Earth, which ſerves to fix them, and a Principle perfectly volatile, which is intimately united with it. And theſe reſolutions which are really very ſingular and wonderful, can be performed by no other means than this very ſubtil application alone of the Water diſtributed in the Air, which Art, formerly held a ſecret, being now more put in practice, has let abundance of light into the Chemical Art; though at the ſame time it has often too proved of diſſervice to the Chemical

Artists, who being quite tired out with the tediousness of the work, have lost in the end both their labour and the thing they were in search of. But again, whenever the Air abounds with Water, and is at the same time agitated by Heat or Wind, then this Water will relax the parts of Bodies so suddenly and so efficaciously as must surprize every one who is not acquainted with these things. But by this means, likewise, very many bodies are macerated; and others are thrown into fermentation. And as for the putrefaction of Bodies certainly, it is scarcely more promoted by any other cause than the humidity of a hot Air, which in a very little time resolves the Bodies, which are that way disposed, into a putrid, sanious matter. And for this reason the Physicians long ago asserted, that the plague itself is generated among Animals, from an Air that has been both very moist and warm, for a considerable time. In short, therefore, since it so dissolves Salts, and saponaceuos and saline Substances, carries up all together, disperses them about, drives them against, and makes them penetrate into the Bodies they meet with, it is manifest, that by this means it must apply the particular forces of some Bodies to others, and thus brings about such actions between Bodies, as hardly ever happen from other causes. For what else appears by the fetid butter-like Dew, described in the *Abridgment of the British Transactions*, Tom. II. 141; or what else by the Salt Rain, observed at Sea? *Journal des Scav.* 1683. 435.

Other corpuscles in the Air.

Thus far then, Gentlemen, we have sufficiently considered the Air, with respect to its Elasticity, and the Fire and Water contained in it. We are now to regard it in another view. Let us then carefully inquire what other Corpuscles, besides those we have examined, float up and down perpetually in this Air. But this is a field of inquiry which has hardly any bounds: For as the Earth, considered in its whole extent, receives every thing that falls out of the Air; so on the other hand, the Air receives every thing again from the Earth; and thus between these two elements, there happens, as it were, a perpetual revolution and distillation of all things.

The native Spirits of Vegetables.

In the first place, then, all the parts that we can observe in Vegetables, are continually changing, and dispersed throughout the Atmosphere. That the Spirits of Vegetables do always, and every where exhale and fill the Air with a continual fragrance, there is none of you to be sure makes the least question. And that the Scents scattered though vast tracts of the Ocean from odoriferous Plants, inform the Mariners, before they discover Land, of their approach to the Shore, you are as well apprised of. And you know, likewise, that these Spirits spontaneously exhale out of the Bodies, in which they are generated, and are scarcely to be confined and preserved, except in Vessels stopt very close. Hence, then, it follows, that whatever odoriferous Spirits are at any time by Nature produced in Plants, all these are, certainly, at length, contained in the Air alone. And for this reason it is not at all to be wondered, that these Spirits should afterwards return with the Water of the Air, into the Bodies destin'd to receive them, and that the Air should thus yield up to the Earth what it had first received from it. In reality, we find nothing in Nature less imitable by Art, than the fragrant Spirits peculiar to each Plant, which we have in a foregoing passage called the *spiritus rectores*: But these, when they are once freed from the tenacity of the Sulphur that entangles and retains them, always, from their own proper nature become volatile, and are dispersed through the Atmosphere.

Atmosphere. How various, then, and how beautiful must be the Effects that are hence produced? And how wonderful must be the grand *Metempsychosis* or transmigration that is by this means brought about?

But again, when we consider, that Vegetables, duly prepared by a proper fermentation, yield a vast quantity of vinous spirits, that are almost immutable, and of themselves continually exhaling; must we not hence conceive, that all those Spirits which have ever been produced from any fermented Vegetable whatever, over the whole Face of the Earth, have at length exhaled into the Air? And in this view we now look upon this Air again as a Cloud, as it were, of Spirits of Wine. In reality, whether Wine be drank by Men, or any other Animals, be outwardly apply'd by way of fomentation, or made use of either in Cookery, or Physick, certainly all its Spirits must sooner or later exhale into the Air, there remain for some space of time, and thence, at a convenient season, return to the Earth again. What wonder, therefore, if fermentation, which is the productive cause of Wine, should never produce Wine, without the free admission of the external Air. Does it not, possibly, return back again to Places and Bodies the Spirits which it had before drawn up, and for this reason must be always called in to our assistance, when they are to be generated again?

The fermented Spirits of Vegetables.

And finally, all those parts of Vegetables, which the Fire divides into exceeding minute Corpuscles, and converts into a volatile Vapour, the Chemists have likewise called Spirits; but these are likewise intirely carried up into the Air, and are continually floating about in it. As the Water of Vegetables, therefore, so likewise all these kinds of Spirits are perpetually tending upwards.

And those that are produced by Fire.

But farther, it is certain, that the proper native Oils of Vegetables, do by time, and the natural heat of the Air, at length intirely evaporate; and that whether they reside in compound Bodies; or spontaneously sweat out; or are forced out by pressure. For in reality, there are but few sorts of Wood, in which their Oils are so united with their proper Earth, that they are able to remain for ages together in the open Air. And as for the Oils of Vegetables, which Chemistry draws from them by Fire, whether this be done with Water, or dry, these are far more volatile, and sooner fly off. Thus, then, they form pinguious exhalations in the Atmosphere, which are very well disposed both to take Fire, and to support it. For as these oleaginous Particles are now so minutely divided, that they nearly resemble Alcohol while they float in the Air, being first heated by the attrition of the Clouds, they may be excited into a Flame by the dioptrical or catoptrical Fire, which I have already demonstrated may be produced in the Air. All these Oils, therefore, which ever were in Vegetables, a very few perhaps excepted, are dispersed into the aerial Chaos; whence, as Water and Spirits do, they return in their time, impregnate the Earth with a pinguious moistening Dew, and by thus circulating backwards and forwards, bring perpetually fresh prolific Supplies, and being deposited for a short time, return into the Air again. All this, now, happens chiefly in very hot weather. For if a long Drought, with a very great Heat, has carried upwards both the Water, and the pinguious Corpuscles of the Earth, then the first Fires that happen aloft with Thunder and Lightning, send down a Rain which is very different from that pure Snow which falls in a sharp Frost; and is far more acrid, and more disposed to froth. And hence Summer

All Oils also.

Rain, or Rain produced in hot weather, is always fruitful, whereas that in cold is ſcarcely endued with any ſuch quality.

And Salts. If you conſider now the native Acid, auſtere, thoſe that come the neareſt to alcaline, and the ſaponaceous Salts of Plants, procured by cryſtalliſation, fermentation, putrefaction, and combuſtion, you will find that all theſe do, ſooner or later, diſappear, not one of them excepted; ſince all theſe Bodies when they are freed from their fixing Earth, aſcend up into the Air.

Nay even Earth. Nay, and that very Earth too, which furniſhes a fixed Element to Plants, does by its fineneſs acquire ſuch a diſpoſition, that it flies off, and is carried aloft. For pray, does not Soot, collected at the very top of a Chimney, from the volatile Smoke of a burnt Vegetable, yield, by a chemical diſtillation, a remarkable quantity of pure Earth? Hence, therefore, we are certainly aſſured, that Smoke which floats at liberty through the Air, carries along with it real Earth, mounts with it aloft, and widely diſperſes it through the Air. Not to mention the Winds, which ſweep away the *Ægyptian* and *Lybian* Sands in Waves, as it were, through the Air, and carry the Aſhes of Mount *Ætna* to prodigious diſtances. What think you of the Sparks of *Veſuvius*, ſcattered above a hundred miles through the Air? *Phil. Tranſ. Abr.* Tom. II. 142. What of the Ivy-berries diſperſed over a vaſt deal of Ground? *Ibid.* 144. The little Fiſhes? *Ibid.* Or the maſculine, ſeminal Duſt of Vegetables? *Phil. Tranſact.* 168. p. 911. Hence, then, from theſe obſervations it is clear, that all the Elements of Vegetables may be carried into, and intermixed with the Air.

And alſo intire parts of Vegetables. But it is likewiſe certain, that parts of Plants, and thoſe pretty conſiderable ones too, are carried into the Air, and are born up along with it to an incredible height. Conſider the Seeds of downy-ſeeded Plants, which are carried up to the tops of the higheſt Towers, and there, as one ſees daily, if they meet with ever ſo little Earth, propagate their *Species.* The celebrated *Tournefort* too has elegantly ſhewn from obſervations, that the Fungus's, which are almoſt all ſeminiferous, by means of the Air, diſperſe their inviſible Seeds all about, which meeting with a proper Soil, thrive and ſpring abundantly. Moſſes, likewiſe, and the mucilaginous and capillary Plants, as alſo the *Epiphylloſpermopheræ*, or thoſe which bear their Seeds upon their Leaves, ſcatter and diffuſe their Seeds to very diſtant places. Nay, and even the ſmall ſeminal duſt of the Male-Willow, being ſhaken from the *apices* of the Flowers, and carried by the Wind into places remote from thoſe Trees, and afterwards, when the Wind was down, falling out of the Air, has been falſely taken, by perſons unacquainted with theſe things, for Flower of Brimſtone, and afterwards believed by the credulous Vulgar to be a Shower of Brimſtone. *Vide Phil. Tranſact. Abr.* Tom. III. And if ſuch a ſmall Duſt ſhould happen to be of a remarkable red colour, why ſhould not the Vulgar for the ſame reaſon have aſſerted, that it had rained Blood? Were there not Aſhes thrown out of a vulcano, and carried by the Wind, in the year 1633, the ſpace of one hundred miles! *Phil. Tranſ.* No. 21. p. 377. But theſe are things not to be wondered at, ſince that excellent Philoſopher *Mariotte*, in his treatiſe *of the Motion of Waters*, p. 334. obſerved in a Cloud that poured forth a ſhower of Hail, that the Air had carried this Cloud for fifty *French* miles. If we reflect, therefore, upon theſe things, we muſt naturally believe, that there are a vaſt number of ſurprizing things in the Air, and produced by by it; all which are intirely owing to a mixture of vegetable Subſtances that are diſtributed through it.

And if you enquire, in the next place, whether the parts of Animals are contained likewiſe in this Air? We anſwer, there is certainly a great quantity of exhaling Spirits, and thoſe wholly peculiar to every Animal, and diſtinguiſhed among Phyſicians by the name of the perſpirable Matter of *Sanctorius*, that are continually diſſipated through the Air from living Animals, and adhere to other Bodies; and by theſe Spirits it is that your Dogs, that follow by ſcent, diſtinguiſh ſo accurately the Animals from which they exhale, and follow thoſe particular ones over large tracts of ground. And how full the Air is frequently of contagious Particles, exhaling from Animals, appears evident from the Infection too often obſerved in Diſeaſes. The Spirits of Animals are contained in the Air.

But again, the excrements continually diſcharged by every kind of Animal, are in ſo ſhort a time diſſipated and diſappear, that we are hence certainly convinced, that the whole quantity of excrementitious matter will be always diſperſed into the Air, hardly leaving ſo much as the lighteſt Duſt behind it. In the hotter countries, the Dung of Animals, being expoſed to the open Air, becomes perfectly volatile by the Heat of one ſingle Day. And even in our own country, which is not ſo hot, the very Dunghills are quickly conſumed. And as for Urine, how quickly does that ſpontaneouſly become perfectly volatile, and exhale? And their Excrements.

But there is ſomething in this affair ſtill more remarkable. For pray tell me, does not an intire Whale, the largeſt of Animals, when in hot ſummer weather it is by the Sea thrown dead upon the Shore, I ſay, does not this Animal quickly infect the places, to a great diſtance about it, with a peſtiferous ſtench? And is not the whole of it reſolved into volatile infectious particles, ſo that at length there remain only ſome whitiſh Bones, the whole maſs of the other parts being converted into volatile matter, intirely ſcattered up and down in the Air. What vaſt numbers of Carcaſſes of Elephants, Camels, Horſes, and of almoſt all other Animals, as well as human Bodies, that are the Carnage of War, remain from time to time unburied, and are reſolved into putrefaction, become volatile, and diſſipate almoſt all their Elements into the Air? Hence, therefore, it follows, that Bodies of Animals are, from their own natural diſpoſition, as much entombed in the Air, as in the Earth. And thoſe very Bodies, likewiſe, which are buried in the Earth, are not then preyed upon by the Worms, but are quickly converted into a very light, volatile matter, which afterwards eaſily exhales into the Air out of the Earth itſelf. All the corporeal matter, therefore, that has ever entered into the compoſition of the Bodies of living creatures, has been carried up into the Air, with this difference only, that if the Bodies were burnt, this was brought about immediately; if left to rot in the Fields, more ſlowly; and ſtill in a longer time, if they were interred; but yet even in that caſe, they have in time exhaled away. What wonder, therefore, if from the Air, there ſhould be returned a Matter, of the ſame nature or kind with the food of the former Animals, which is capable of affording a proper nouriſhment to the Bodies, that are by this means to ſpring up afterwards? Nay almoſt all animal Bodies.

But there is yet another thing upon this head, which it will be worth our while to take into conſideration, as the right underſtanding of it will keep us clear of many miſtakes. I aſſert then, that the very Eggs, impregnated with the And their pregnant Eggs.

the fruitful offspring of their respective Animals, are carried up and down the Air. For the excellent *Redi* has demonstrated, that all Insects, without exception, are generated, by the copulation of Male and Female: *Leeuwenhoeck* has proved, that the Seed of the Male lodges the first Embryo in the Egg of the Female: And *Boyle* has made it appear, that pregnant Eggs will not exclude their young, except they are in the open and the fresh Air. Being furnished, then, with these Observations, I purposely took a piece of Flesh, which had been kept a pretty while in boiling Alcohol, and was afterwards rubb'd over with some bright Oil of Turpentine, and fastening it to a long small thread, hung it up in moist warm Air, in a place where it was imagined there were no *animalcula*, and the consequence was, that in a little time after the suspended Flesh was full of living Maggots, which were devouring whatever of the succulent parts remained in the Flesh. In this case, then, the Eggs, from which these *animalcula* were produced, could not possibly come at the Flesh, but by being born along through the Air, in which it was suspended. How much do the Farmers experience the truth of this to their detriment, when in a warm spring, certain Winds very suddenly infect the Trees with numberless Vermin, which in an instant, as it were, are produced from their invisible Eggs! But give me leave to mention one thing farther, that is still more remarkable, and that is, the Rains that frequently happen among the *Negroes*, which strike a man with such a sudden chillness, that it makes him shudder. These Rains fall in drops, of an inch diameter, which, if they come upon the Skin, eat into it; but if they lodge on any Garments, produce living Worms, and Moths, *Act. Lips. Suppl.* Tom. I. p. 425. Many other things of this kind might be here taken notice of; but these may suffice, to let the Chemists understand, that the new and wonderful *Animalcula*, which are oftentimes produced in Bodies, and even, perhaps, while they are at work upon them, owe their Being intirely to little Eggs, which are thus carried about in the liquid Air, and not to the efficacy of any chemical Substances or Operations. Let them, therefore, be always mindful of the nature of the Air, and its very wonderful fœcundity, before they deduce the origin of such appearances from any other causes. But the knowledge of these things at the same time, likewise, is not less necessary and advantageous to the Physician, and Natural Philosopher.

Fossils in the Air.

But we must not detain you too long upon this head, and therefore let us now pass on to Fossils: For Fossils, I am certain, are likewise discovered in the Air. Fossils, say you, in the Air! 'Twere as reasonable to suppose Castles there. But please to hear only what I have to offer upon this head, and then you yourselves be judges.

First Salts.

Do not, then, all fossil Salts whatever, though ever so fixed, if they are dissolved in Water, (especially in that which they attract from the Air) and are afterwards digested for a long time in a putrifying Heat, and are then distilled with a great degree of Fire, and have their fixed *Residuum* calcined with a strong open one, and then dissolved in the Air: Do not, I say, all fossil Salts whatever, managed after this manner, at length fly off into the Air? This is a Truth which a great Chemist communicated to the World more than an hundred years ago. Not to mention the distillation of these Salts, with Sand, Bole, Brickdust, Potters and Tobacco-pipe Clay, performed with the intensest Heat! Do not the Chemists every year convert, by this method, many thousand

ſand pounds weight of ſuch Salts, into acid volatile Fumes, which they call Spirits? And does not every ſuch chemical Operation infect the very Air? And does not this Air deſtroy the Bodies that are expoſed to it? The ſingle and ſimple mixture of Oil of Vitriol, Oil of Alum, or of Oil of Sulphur by the Bell, with Nitre, Sea-Salt, or *Sal-Gem*, converts in an inſtant thoſe very fixed Salts into Fumes, ſo volatile that they can hardly be confined, with which the Air is in a ſhort time ſo ſtrongly impregnated as to carry thoſe Salts to great diſtances all around. But infinite are the Methods by which the ſame thing is effected. Before the induſtrious *Glauber*'s time, indeed, this admirable method of thus changing Salts, was not diſcovered. But who will pretend to determine how many Methods lie hid in Nature even at this day, by which the like converſion from a fix'd to a volatile matter may be brought about? The Vapours about Mines, which are often ſo fatal, that no living Creature can breathe in them with ſafety, ſufficiently prove, that Nature herſelf thus diſperſes Salts through the Air, and conſequently, has ſecret Methods which we are not acquainted with, for performing the very ſame Operations. In the mean time, however, it is true, that this happens only in certain parts of the Earth; namely, in thoſe places where there is plenty of ſuch a matter, and where likewiſe the means are not wanting, for working upon it after this manner. And it is likewiſe as certain a truth, that even thoſe ſaline Vapours are elevated only to a certain height in the Air, and that not a very conſiderable one. And upon this foundation it was, that the Adepts aſſerted long ago, that the Air was divided into certain diſtinct *Strata* or Beds, each of which contained a diſtinct kind of Exhalations and Vapours. Hence, then, it is evident, that by the means of Water, Heat, Digeſtion, Solution, Exſiccation, Diſtillation, Calcination, Combuſtion, Mixture, Adunation, and Separation, Foſſil fix'd Salts are rendered volatile, and are thus intermix'd with the Air.

Next Sulphurs.

And as for the principles of Foſſils, which go by the name of Sulphurs, theſe, whenever the Foſſils are burnt, are intirely carried up into the Air, and being intermixed with it, diſappear, the ſaline acid part changing into a ſuffocating Fume, and the oleaginous part being attenuated by the action of the Flame, and flying off in an inviſible, or a ſooty black Vapour. It is very certain, that hardly any thing at all of theſe parts remains in the Earth. Sulphur now itſelf, when alone, is carried into the Air in form of an impalpable Flower, and is there diſperſed about. But when it is mixed with other Bodies, it often acquires a ſurprizing volatility. The Chemiſts have taken notice of a great many methods, both natural and artificial, by which Sulphurs are ſo changed, that they fly off into the Atmoſphere, and carry up other things along with them. In Mines, from time to time, there appear pinguious, ſtinking, ſuffocating Fumes, pretty often very troubleſome to the Miners, to which, if the Flame of a lighted Candle is applied, they inſtantly take fire, not without extreme danger to the Workmen. But it is certain, that Arſenicks, Orpiments, Cobalts, Sulphur of Antimony, Biſmuth, Zincq, and other Bodies, furniſh the matter of theſe Vapours. We are likewiſe informed of the falling of a ſhower of Brimſtone, attended with Lightnings, which when it was once on fire, could neither be extinguiſhed by Water nor Motion. *Nov. Literar. An.* 1684. p. 63.

Laſtly, Metals themſelves.

In the laſt place, Metals themſelves have been found to be ſo far changed, that they likewiſe, under the form of a volatile Fume, have been ſcattered up and down in the Air. This is universally known to be true of Mercury, which when agitated only by a Fire of 600 degrees, flies off, and becomes invisible. And if the Air impregnated with it, surrounds, and is applied to a human Body, how wonderfully does it penetrate it, and how quickly does it throw it into a Salivation! But besides, while it thus flies off, it carries up and bears away with it some part of certain Metals; as appears from the distillation of Lead and Tin with Mercury. Nay Lead, Tin, Iron, and Copper, if they are disposed in a very strong Heat, at length disappear, by means of the volatility they acquire there, and thus far are dissipated likewise into the Air. A great part of imperfect Metals is carried off too by Lead in the test. But when Cobalts, Arsenics, and the like rapacious Sulphurs, are intimately united with Gold and Silver Ore, the Particles of the Ore being by this means rendered volatile, when they come to the Fire, they carry away these noble Metals to that degree, that to the great damage of the Owner, a good part of them both is lost; which by a gentle calcination, and the addition of some fixing Powders, might be intirely preserved. Hence, therefore, it appears, what an abundance of Gold and Silver may be raised up into the Air. Nothing, indeed, seems a greater Paradox than volatile Gold, and yet we are certain from undeniable chemical Experiments, that if you take common sublimate of Mercury, and rub it well with Gold reduced to Powder, and then distill it in a Retort with *Regulus* of Antimony, the very Body of the Gold will ascend in form of a red Oil, and become perfectly volatile. By Sulphur, likewise, calcined Vitriol, and *Sal-Ammoniac*, mix'd and apply'd according to Art, almost all Metals may be rendered volatile in the Fire. No wonder then that in clear Weather, there very often appear about Mines sudden Fumes, which extinguish the Light of a Torch. See *Boyle*'s Works, Vol. I. p. 52. since even the most dense Bodies may, in the form of a Fume, be so carried up into the Air, as that it can hardly be determined what Bodies they were. But there is another cause which is frequently concerned in this affair, and which likewise impregnates the Air with these metallic parts, and that is the Air itself abounding with Salts and Sulphurs. For as I have already shewn above, that the whole Air is full of Salts and Sulphurs; and as it appears from what I have now delivered, that those Salts and Sulphurs can carry aloft even Metals themselves when they are dissolved, it is easy to apprehend, that the Air itself can by this means effect that the parts of Metals may be suspended and float about in it. Are not Iron, Copper and Lead, by the contact, and motion of the Air always, and that in a short time too, turned into a *Calx*, Flowers, and a *Scobs?* And are they not hence converted into Rust, a bluish Mould, and a Ceruss? And have you never observed, that when after these changes, they are reduced to an impalpable Powder, they fly away, and are carried through the Air by the Wind. I confess, indeed, that Silver, Gold, and Tin, are less incident to these alterations, because the volatile Acids of Nitre, and Sea-Salt, which are the proper dissolvents of these Metals, are hardly ever dispersed through the Air, except about the Elaboratories of the Chemists. The Air in *America*, indeed, is of so corroding a nature, that it consumes the Tiles of the Houses, stony Bodies, and almost all Metals; as the *English* unanimously agree of the Air of *Bormudas*; for even Metals themselves perish there very soon. And that surprizing *Phænomenon*, which in all ages has been observed by Miners, seems likewise to be owing to the

the residence of these metallic parts in the Air, *viz.* that the fossil Glebes, when they are dug out of the Earth, and are exposed to the Air, are affected by it in a very extraordinary manner. How frequently is it seen, that Marchasites, the Pyrites, vitriolic Stones, and metallic Substances that are quite exhausted, are so acted upon by the Air, that they increase, come to maturation, are changed, renewed, and afresh impregnated, and become again inriched with a true metallic Offspring. In reality, the Air seems to be the grand universal distributer of the Seeds of Bodies, which being plentifully stock'd with every kind of Matter, commits to the Earth the Elements of Bodies it had before received from it, and thus generates most kinds of Bodies, rather by means of a revolution, than a new production. 'Tis certain, that Dew being changed by Distillation, has yielded a Liquor, which stained Glass with the Colours of the Rainbow, penetrating so deeply into it, that it could neither be removed by *Aquafortis*, Oil of Tartar, or a strong and long continued friction; and yet at the same time the Liquor itself was so subtil, that it burnt in the Fire like Alcohol; *Republick of Letters*, T. I. p. 590. Certainly this effect is very like that of a metallic Tincture upon Glass. *Philosophical Transactions Abridg.* T. II. p. 143.

From what has been said is gathered a true knowledge of the Air.

Thus, then, Gentlemen, the few things I have laid before you, are sufficient to instruct us in our chemical Inquiries, what notion we ought to form of the Air. In reality, it is to be considered as a true Chaos of all things intermixed and compounded together: For in it there float up and down the attenuated Particles of all Bodies whatsoever. And since these little Corpuscles are always in motion, they may, by running among one another in this aerial space, produce all those wonderful operations of Nature, which are owing to the efficacy of particular Bodies: But these are almost infinite. So that indeed, it is not at all to be wondered at, that there are produced and appear in this scene of the Air, such extraordinary, and frequently such terrible events in Nature, as never happen any where else: I mean the Meteors. In this Air there doubtless must be Bodies that are endued with a magnetic vertue, which by their mutual attraction, repulsion, cohesion, rarefaction, and by infinite other methods, must every where excite stupendous *Phænomena*. An instance of this you have here before you. In my right hand I hold a small open glass Bottle, in which there is an alcaline Spirit of *Sal-Ammoniac*; and in my left I have another, in which there is Spirit of Nitre. You see, that whilst I keep these Bottles at a distance from each other, nothing at all appears extraordinary; but that as soon as ever I bring them gradually so near towards each other, that the Vapours issuing from the two Bottles, begin to meet with one another, there immediately, in the place where they thus mix, appears a little Cloud, arising from the concurrence of the Alcali and Acid in the Air. If an Amalgama prepared with Tin and Mercury is distilled in a Retort with Spirit of Sea-Salt, it yields a Liquor, which, if it is kept in a close Vessel, produces no effect; and yet if it is exposed to the open Air, tho' many years after its preparation, it immediately goes off in a very thick Smoke. But Nature is every where full of the like instances. We know not what other hidden Salts there may be besides in the Air, that we are not acquainted with, or with what vertues they may be endued. Nor are we less ignorant what Spirits and Oils may float up and down in it; tho' in the mean time, from the particular Nature of those unknown

known Salts, Spirits, and Oils, ſuch ſtupendous effects may be produced, as are never obſerved to proceed from any other cauſes. If the diſtill'd Oil of Saſſafraſs happens to meet with *Glauber*'s Spirit of Nitre; what a terrible effect is produced in an inſtant? An effect hardly to be exhibited by any other Experiment. If at any time, now, there ſhould chance to get into the Air a number of Particles endued with the like properties, and theſe ſhould be there mixed together, very ſtrange and ſurprizing appearances muſt neceſſarily follow. Certain times, it is evident, do preſent us with *Phænomena*, that are never ſeen at any other. To the production now of theſe rare and very extraordinary effects, it is poſſible that the Comets, Meteors, various Aſpects of the Planets, and perhaps the Stars themſelves, may principally exert their influence; whoſe actions may be very conſiderable, on account of their attraction and repulſion, of their Heat, Light, and Cold, and of the *Effluvia* which they generate and emit.

In conſequence now of all the things I have here mentioned, this Air is of a quite different nature in particular places; firſt, on account of the Land or Soil, or the part of the Earth which the Air under conſideration hangs over: For according to the various Bodies with which the Earth abounds in any particular part, the Exhalations and Vapours that ariſe from it will poſſeſs as various qualities, and for this reaſon, the Air in that part will be full of Corpuſcles, that are not to be met with any where elſe. The truth of this has always been confirmed by numberleſs Examples. And hence it will come to paſs, that in ſuch particular parts of the Air, certain Experiments may be made, that will never ſucceed in any other. In the ſecond place, a very great diverſity is here obſerved likewiſe, in reſpect to the Soil, in different places, according as Men inhabit it, and keep Animals there, and according as they dung and turn up the Ground, and exerciſe various Occupations there, and by this means raiſe up almoſt all kinds of Bodies into the Air: On which account again, an infinite number of changes are obſerved to happen, which are not to be effected elſewhere. A certain Chemiſt, for inſtance, in his Elaboratory, where he was daily employ'd in the diſtillation of large quantities of Vinegar, expoſed to the Air ſome pure, dry, alcaline Salt of Tartar in a glaſs plate. The Air, of conſequence, being full of acid Vapours, diſſolved the Salt into an Oil of Tartar *per deliquium*, and at the ſame time ſo cloſely united the acid parts of the volatile Vinegar with the Alcali of the Tartar, as at length to convert the ſaturated Maſs into a *Tartarum Regeneratum*, or regenerated Tartar, which melted in the Fire like Wax, and yielded a very noble Remedy for the reſolving of viſcid tenacious humours, in almoſt all Diſeaſes. He was mightily pleaſed therefore with this production, for he reckoned he had now diſcovered the great ſecret of the Alchemiſts for Incerating, according to the language of thoſe Gentlemen, a fix'd alcaline Salt: But when afterward he attempted to repeat the Experiment in another place, where there was not ſo great and conſtant a quantity of Vinegar in the Air, he met with nothing like the former ſucceſs. The ſame thing might be farther made appear by a vaſt number of inſtances, but you yourſelves are ſufficiently appriſed of it. Conſider then a little, how prodigiouſly the Air may be changed in any particular place, when a great Earthquake has occaſioned exhalations to ariſe there very different from what there did before. And this is again confirmed by Hiſtory, which

which informs us, that certain parts of the Earth have become uninhabitable, by reaſon of the abominable ſtinking Vapours with which they have been infeſted after Earthquakes. But again, inundations by Rain, overflowings of Rivers, and the breaking in of the Sea, make ſuch alterations in the Atmoſphere, by means of the humid Vapours, and Exhalations from putrified Bodies hence occaſioned, that the whole nature of the Air, in thoſe places, is intirely changed. The very Winds, likewiſe, as they carry the Air with all its contents from one place to another, muſt always bear along with them ſomething from the places from whence they began to blow, and conſequently are thus always varying the contents of the Air, continually carrying off from particular places the matter peculiar to them, and ſupplying them again with what they juſt brought from ſome others. From which cauſe likewiſe, there muſt needs happen in chemical Operations, a remarkable diverſity. And as for the influences of the Heavens, particularly in reſpect of the various Aſpects of the Sun and Moon, their acceſſions, receſſions, perpendicular or oblique irradiations, conjunctions, and oppoſitions, what changes muſt theſe produce in the Air, by their attraction, repulſion, and the Heat and Cold that depend upon them? What variation muſt they cauſe in the Vapours and Exhalations that are carried up from the Earth into the Air? But there is one thing farther on this head, which, as Chemiſts, we ought to take particular notice of, and that is, the viciſſitude of the ſeaſons of the year, which is here of ſuch efficacy, as is wholly incredible; even ſetting aſide that which ariſes from the various actions of the Sun in this ſtated annual courſe. You'll underſtand what I mean, in the following manner. If the Sun on the tenth of *March*, in a certain altitude, and with a certain degree of Heat exerts its Power on the Earth, it then acts on a Body, which in the preceding Winter, being lock'd up by the Cold, has kept in and accumulated, under an icy or cold Cruſt, its own proper Exhalations, and at the ſame time, has received and retained whatever came down upon it out of the Air: Hence, as ſoon as it begins to thaw, and the Earth reſolves itſelf into a looſe Mould, the firſt ſucceeding Heat of the Sun acts upon this fertile pregnant Body, and immediately fills the whole Air with Vapours: On which account a vernal Heat hardly ever ſucceeds a Froſt of long continuance, but there preſently follow Showers, Thunders, and Lightnings, and an igneous Vigour appears in all Animals and Vegetables. But now, when on the tenth of *September*, the Sun at the ſame Altitude, and with the ſame degree of Heat, acts upon the Earth, it then finds it parched up, and exhauſted by the Heat of the preceding Summer, and not yet moiſtened with autumnal Showers; for which reaſon, neither the ſame Heat in the Earth, or Air, will produce the ſame effect, nor will excite this vigour in Animals and Vegetables, as it does in the Spring. Theſe few things then will be ſufficient to let us eaſily ſee the variety there is in the Atmoſphere, according to the diverſity of the ſeaſon of the year, as far as it ariſes principally from this cauſe; a Speculation very uſeful both in Chemiſtry and Natural-Philoſophy. And, indeed, it's plain the Chemiſts had ſome inſight into this matter long ago, when they attributed to the vernal Rain, a vertue ſo much ſuperiour to that of the autumnal, produced in the very ſame degree of Heat: For they found that this *Lixivium* of the Air brought along with it out of the Air, very different Vapours and Exhalations, according to the diverſity of the ſeaſon now explained.

A quality in Air intirely singular.

Before we leave the examination of the various Bodies that are contained in the Air, and of the different Powers which prevail in it, we must yet take under consideration one quality of it, which is very salutary and necessary to the life of Animals and Vegetables; a quality which has not been yet accounted for from any other property of the Air, but by a diligent inquiry, however, may possibly, hereafter, be come at the knowledge of. Whether, now, this latent vertue of the Air is actually drawn out of it by Animals and Vegetables, and hence is in a short time exhausted and consumed; and whether, when it does thus fail, the Animal dies, no-body is, I think, at present able to determine. This, however, is certain, that if a small Bird is put into a large Receiver, full of common cold Air, and the Receiver is then very closely stopt, the Bird will grow sick and vomit within a quarter of an hour, and die in the space of half an hour after. *Boyle*, *Of the Air*. 184. A Fish kept in Water in a Vessel well closed, without renewing the Air, dies in a short time. Fish likewise die in Ponds that are every where frozen over, and quickly perish in Water out of which the Air is exhausted. *Hist. de l' Acad. Roy. des Scien.* 1699. 240. 1701. 46. and *Mem.* 224. Flame, and a red hot Coal, quickly go out in Air that is close pent in. The little Eggs of any Insects whatever, being accurately stopt up in glass Vessels, do not produce their young, tho' assisted by a kindly Warmth. The Seeds of Plants likewise, duly moistened, and sowed in the best Earth in close Glasses, do not grow, or give any signs of active Life, tho' excited by a due degree of Heat. On the other hand, the upper Surface of Blood that is exposed to the Air, is of a bright scarlet colour, whilst in every other part, where the Air don't come at it, it grows as black as the juices of the Cuttle-fish: And yet, as soon as ever this black part is laid open to the Air, the black colour is immediately changed again into a scarlet. All these Experiments then make it appear, that there is in the Air a certain hidden vertue, which cannot be accounted for from all the properties of the Air, which have been hitherto discovered. *Sendivogius* maintained it openly, that there lies hid in the Air the occult Food of Life; and other Chemists have asserted the same: But what that is, or how it acts, or what is the proper effect of it, is a matter still in the dark. Happy the Person that shall happen to discover it. Let this Hint suffice for Persons that are hitherto ignorant of it, is it not the elastic part of the Air alone?

Hitherto explained by no-body.

For my own part, I confess, I cannot apprehend, that either the Natural-Philosophers, or Physicians, have yet discovered the physical cause of this wonderful quality of Air. I have seen, indeed, a great many conjectures upon it; but they have almost all fallen of themselves. After all that has been said then, we have now a proper opportunity in the last place, of treating a little briefly of the proper weight of the Air: And to this purpose, if you please, let us take the sum of what has been laid down.

The weight of the elastic part of the Air.

The Air then is full of Water, which is ponderous, solid, and not to be condensed by any weights. With this Water, the Air is so plentifully stocked, that Salt of Tartar, upon Experiment, has attracted so much Water out of a small quantity of Air, contained in a glass Vessel close stopt, as to grow sensibly moist. Besides Water, too, almost all kinds of Bodies are contained in the Air, and dispersed up and down in it: All which Bodies taken together, must at least be as heavy as the Water. But these Corpuscles, likewise, as they are there in a liquid form, can scarcely be driven closer together, by the force of any imposed weights. If therefore from a given portion of Air, all that truly ponderous Matter, which, as has been demonstrated, the Air naturally receives from all kinds of Bodies, was very accurately separated from it, how much weight do you think would there remain belonging to its real elastic part? Undoubtedly you perceive, unless I am exceedingly mistaken, that there would remain but a very little: Nay, if from the assistance of so many Experiments, we may be indulged a conjecture, perhaps there would be really none at all. For let but the eight hundred and fiftieth part of the whole space of a cubic foot of Air be filled with Vapours and Exhalations, not elastic, and with dusty Particles floating up and down in it, then the remaining elastic part of the Air will have no weight at all. And hence it might come to pass, that the Air in that compass could never be reduced into a less space than the $\frac{1}{850}$ of the whole, notwithstanding the *Newtonian* Law should constantly hold good in the elastic part; namely, that the Elements of Air always endeavour to recede from one another with so much more force, as the weight is greater by which they are compressed. And from this supposition it would likewise necessarily follow, that when the other parts are contracted into a space 850 times less than the former, then the elastic part cannot be reduced closer by any weight whatsoever, since all that space would be then filled up with Water, and other incompressible Bodies. And this exactly answers to the Experiments of the famous *Halley*, and the *Academy del Cimento*, who assert, that the Law of the reduction of Air into spaces, proportional to the compressing weights, does not hold good beyond that space which is 850 times less than that which is taken up by the common Air. *Hist. de l' Acad. Roy. des Scien.* 1703. 7. *Mem.* 102. We ought not, however, thence to conclude, that the purely elastic part of the Air, if it could be made trial upon alone without the mixture of other Corpuscles, could not, by the same Law, be condensed a great way farther. And who will pretend to determine how far? Perhaps this would always be the case.

Perhaps it has no weight at all.

For these reasons, I have frequently considered with myself, whether the supreme Being has not created both Fire, and purely elastic Air, intirely without gravity, nor tending naturally to any particular point, but equally distributed throughout the whole Universe, and that under this Law, that the Fire should always so act upon the Air, as never to suffer it to be at rest, no not even in the extremest Cold. For, if in the upper region of the Atmosphere, the Heat of the Fire is less, the Air likewise in the same proportion being there less condensed, as there are fewer heavy Bodies to compress it, must be always rarer, and consequently will be so much the easier kept in an ebullition by a less degree of Fire, and will at all times be agitated with a tremulous motion. What room is there here then for admiration! What a mighty moving power upon every thing, lest at any time they should be at rest! But it's very likely you will be apt to think with yourselves, if the Air, with respect to its elasticity, be without weight, what is the reason then, that it is not rarer about the Earth? Why, let us, Gentlemen, only consider, that its Elements are not so easily to be disengaged from the other Particles with which they are intermixed and intangled, and consequently, that by this means it will be compressed by the other Bodies that are incumbent upon it; and then the reason of this *Phænomenon* will be very evident.

A duumvirate of motion in Fire and the elastic part of the Air.

And

The properties of the elastic part of the Air. And thus I might here have put an end to our History of the Air; but there remains, however, a small, but very valuable Article, which may still be added, *viz.* the demonstrating this purely elastic Air by Experiments, and the prosecuting it in its wonderful effects. And upon this head, whilst I have consulted a great number of Authors, I have found the excellent *Mariotte* to be the principal one, who has broke the Ice, and led the way. Pursuing then the steps of this famous Gentleman, I have digested these Experiments in the following order.

EXPERIMENT I.

Elastic Air adheres to Solids. I have here in my Hand a Plate of pure Silver, curiously polished, and very carefully cleaned, and as warm as the present temper of the Atmosphere, *viz.* 52 degrees. This Plate, as you see, I immerge gently, without any concussion, into very clean Water, of the same degree of Heat, in this glass Vessel; and yet you see there are formed aerial Bubbles, sticking to the Surface of the Silver, thence rising up through the Water, and then bursting asunder. This, therefore, upon examination, being constantly the event, we may hence conclude, that common Air, by its invisible Particles, adheres in such a manner to the solid Surface of the Metal, that it descends with it through the Water, keeps its hold by a certain viscid tenacity, and will not give way, and leave its Surface, till it is forced upwards by the weight of the Water. When this Silver Plate, therefore, is moved through the Air, undoubtedly the Air next its Surface will adhere fast to it, till by Wind, Heat, or a rapid motion, it is dislodg'd from it, and then at last it yields up its place to some other Air that succeeds it. This property now of merely elastic Air, ought well to be taken notice of in chemical Operations. For since it sticks only to the Surface of Bodies, not being able to enter into their solid Mass, 'tis evident that Bodies, when they are minutely divided in the Air, and consequently have their Surfaces greatly multiplied, always carry far more Air with them into the Receiver, than they would have done in a single solid Mass. And for this reason, the Air that is generated in the solution of Silver Dust by Spirit of Nitre, is not to be supposed to proceed from the Spirit of Nitre, or the solid Mass of the Metal alone, but partly likewise from the very Air which is convey'd on the Surfaces of the Particles of Silver. If the Experiment is made with a Plate of Gold, the *Phænomena* are the same. If very solid polish'd Gold then attracts Air after this manner, all other Bodies certainly will do it much more. All Bodies, therefore, when they are immersed in Water, carry Air along with them; tho' those Bodies do it more so, which are rough, and whose Surfaces consequently are greatly increased. If at the same time too they are fungous, spungy, and full of Pores, they will carry with them still a much larger quantity of Air through the Water; especially, if such Bodies are dissolved into their smallest parts by the dilution of Water. This then is the first method of demonstrating the adhesion of elastic Air to solid Bodies.

EXPERIMENT II.

And Fluids. Again; you see this pretty large Cylinder, which is bright, clean, transparent, and dry. Please to observe, into this Cylinder I pour pure Water, till the Vessel is almost full. This Cylinder, now, thus full of Water, I so apply to the Air-pump, that by means of it, I exhaust the Air that rests upon the Surface

Surface of the Water; and at first you perceive no alteration in it. As the Atmosphere, however, now, is a great deal diminished, you perceive Bubbles of Air appear; and in what numbers! How swiftly are they carried upwards! How quickly do they increase in magnitude! But whence now do they arise? Why certainly, as far as we can any way discover, from the Surface of the bottom and sides of the Vessel, or of the Water. And hence an unwary person, who should see this Experiment only, might be induced to imagine, that all the Air, which by this method is fetch'd out of the Water, lay concealed only between the concave Surface of the Glass, and the convex Surface of the Water. But this opinion will by other curious Experiments be refuted hereafter. In the mean time, however, this we are assured of, that Air adheres to the Surface of Glass, and Water, with the same tenacity that appeared in the preceeding Experiment.

Experiment III.

But the very Air itself, by its Surface, adheres to the Surface of other Air, with a pretty remarkable tenacity, notwithstanding its Elements seem to fly from one another. The demonstration of this, which indeed has been given in a former part of this work, I repeat again in the following manner: This Glass Vial, which from a large spherical Belly, runs out into a long cylindrical neck, the diameter of which is nearly 4 geometrical lines, I have filled with Water; and now I invert it in such a manner, that the mouth of the neck, which is open, points directly downwards, and yet not one drop of Water falls out; nor does there enter one bubble of Air; a manifest indication, that the fine Elements of Air do not here easily recede from one another, but, by a certain adhesion, cohere together. (This Experiment I exhibited formerly, when I was treating of the divisibility of Air; but as I am now considering Air as elastic, or very light, I am obliged to repeat it again). For if the very light elastic Particles of Air were as easily separable from one another, as the united parts of Alcohol are, then the elastic Particles of Air passing through the Water, would make their way upwards; and the Water would proportionably run out of the Glass, as we saw on the foregoing occasion, when we set this same Glass in Alcohol that was coloured. See p. 258. and the following. And that the effect we are speaking of is chiefly to be attributed to such a tenacity of the aerial Particles, is confirmed by the following Experiment. The same Vial, filled with a very strong *Lixivium* of Salt of Tartar, I immerge again, thus, into distilled Oil of Turpentine. Do not, now, the viscid parts of the Oil ascend, through this more ponderous *lixivium*, far more slowly than Water or Spirits of Wine? Most certainly. You will say, perhaps, that the repulsion there is between the aqueous Particles, and the oily ones, is the cause of this *Phænomenon*; and that the Air is repell'd in the same manner by Water. I grant it. But in the mean time, you see, that this slowness in the Air in ascending appears equally evident, whether the Vial is filled with Water, Alcohol, Brine, any *Lixivium* whatever, or even with Mercury. Hence, therefore, It seems not altogether improbable, that the tenacity of the elastic parts of the Air, among one another, is greater, in these instances, than in the other Liquids. When the elastic parts of the Air, therefore, are once united together, they seem to be less easily separable, and less easily divisible into their minute parts; and, consequently, they appear to be mixed with other Liquids, with more difficulty than any other Fluid we are at

And to its own parts.

present acquainted with. I know very well, that all the Philosophers I have hitherto consulted, are of another opinion, and think nothing more true, than that the Air immediately enters any Liquid whatever that it can but come at. But careful observation obliges me to think in a quite different manner. For if I fill two thirds of the capacity of this Vial with any Liquor whatever, and the other third contains nothing but Air, and I perfectly close it with a glass Stopple, and then shake the Vial over so long, I shall never bring the Water to be wholly mingled with the Air, but only large bubbles will be produced from the Water, within which the aerial Particles are entangled and rolled up, whilst the agitated parts of the Water form little spherical Bodies that keep them in; and thus, from a number of such Bubbles there arises a white Froth, consisting purely of Air and Water, into which they are again resolved; the diameters of these Bubbles being nearly three lines. But that you may see the truth of this Paradox still more evidently, be pleased likewise to take notice of the following Experiment. This glass Vial, the Mouth of whose Neck is open, and not four lines wide, is full of our common Air. This Vial, now, I sink thus perpendicularly under Water, so that the mouth of it, which is open, and points upwards, is quite below the Surface. The Water, therefore, now rests upon the Surface of the Air, and nevertheless does not descend into the Vial, but the Surface of the Air bears it up. Water, therefore, which is eight hundred times heavier than this compounded Air, cannot so divide the Particles of the Air asunder, as to insinuate itself among them, and descend through the Air. But there is another thing remarkable upon this head, which is as follows. This glass Vial is full of Water, and the mouth of its neck is 5 lines wide. This, as you observe, I so invert, as that the mouth points downwards; and now you see, that there arise not small, but large capacious Bubbles of Air; that they enter into the neck, through the Water, and make their way upwards, thus whole and united; and that they are not, while they pass through the Water, divided into very small parts, but ascend in form of large intire Bubbles. You perceive at the same time too, that the Surface of these Bubbles is at both ends convex, and that the Water accommodates itself to them in a Surface that is concave. But this appears still more distinctly, when I place the neck of this Vial in a horizontal position, for then these aerial Bubbles remain equally large, and being on all sides confined within the Water, shew very clearly their bulk, which they retain a long time together with their Figure, which is convex at both ends, as you see in the Plate. The same thing holds true likewise with regard to this convexity of the Air, in narrow glass Tubes full of Air, and open at both ends. For if you set them perpendicularly in Water, the Water will rise in the Air in such a manner, as to form a concave Surface on its upper ascending part; whilst the surface of the Air that is contiguous with this of the Water will be convex. This too you see in the Plate. All these things, then, considered together, seem to evince, that the Elements of the elastic part of the Air possess a determined and pretty considerable tenacity, with respect to one another. Those things, I say, taken all together, for I am not ignorant, that very celebrated Authors explain some of them from the attraction which is observed between Glass and Water.

Tab. VII. Fig. 3.

Pl. VII. Fig. 4.

Fig. 5.

EXPE-

EXPERIMENT IV.

I have here, three conical Glaſs Veſſels A B C growing narrow towards the top, and open; and with plain or level bottoms. In one of them there is Water, as cold as the Air is at preſent, *viz.* 44 degrees. In another there is Water of the ſame warmth with this place which we are in, which is about 91 degrees. In the third there is Water heated to the 150th degree. And I have choſen the Veſſels pretty tall, that the Experiments I ſhall exhibit may be the more conſpicuous. Theſe Veſſels then, thus prepared, I forthwith ſet upon the Air-pump, under the Bell; and immediately exhauſt the Air. Do you not now very plainly perceive, that as ſoon as I have drawn out a little of the Air, a very large quantity of Bubbles are generated in the hotteſt Veſſel C, which are formed at the bottom and ſides of the Veſſel, and aſcend, grow larger, and break aſunder at the Surface of the Water, juſt in the ſame manner as if the Water was now really boiling, which notwithſtanding is, perhaps, 70 degrees below the Heat of boiling Water in the open Air. In the Veſſel B, however, where there was but juſt now a heat of 91 degrees, you ſee, there is yet no ſuch agitation. But having now drawn out more Air by the Pump, there appears in B too, the like production of Bubbles; ſo that there is now an ebullition both in A and B, but none yet in C. Having now, however, drawn out a great deal more Air, an ebullition at length is produced in C likewiſe; and all of it being now exhauſted, the boiling continues for a very conſiderable time. Hence then we infer, that pure elaſtic Air, in a certain quantity, lies inſenſibly concealed in Water, without any diſcovery of itſelf in the cold, and under the preſſure of the Atmoſphere; and yet in the Experiments of the *Academy del Cimento*, Water, though it contains in it this latent Air, which is ſo compreſſible, could not in any manner be itſelf condenſed by weights. For this reaſon therefore we conceive, that the Air which inſinuates itſelf into Water, is there lodged in the interſtices which are left between the Elements of the Water, which are in contact with one another, and cannot themſelves enter into thoſe vacuities; but that it does not interpoſe itſelf between the Elements of the Water, where thoſe Elements can naturally touch one another, and by this means hinder them from coming together; for in ſuch caſe, the Water, which contains this Air, would likewiſe be compreſſible. Thus, then, we are certain, that the Air poſſeſſes only thoſe vacuities, which are conſtantly left between the immutable Elements of the Water, and which are not to be altered or diſturbed by any varied ſituation of theſe Elements, being, perhaps, whilſt it is at reſt there, divided into its perfectly diſtinct elementary Particles. Hence farther, we are induced to believe, that this Air, ſo lodged in the Water, and not diſcovering itſelf for ſo long time in the Cold, requires, in order to its being retained there, that the Water be compreſſed by the force of a ponderous Atmoſphere; but that when the particles of the Water are compreſſed together by an effort leſs ſtrong, then theſe latent Elements of Air elevate the incumbent Water, diſengage themſelves from the interſtices where before they lay quietly hid, and then leave thoſe interſtices empty of Air. In the third place, we ſee likewiſe, that Heat diſpoſes the intercepted Air to extricate itſelf with greater eaſe from the ſurrounding Water; and that in ſuch manner, that the hotter the Water is, the more readily, in proportion, will the Air get out of it. Hence therefore,

There is elaſtic Air in Water, as appears by this Experiment.

Pl. VIII. Fig. 1.

when Water has boiled on the Fire for a confiderable time, having by that means acquired its greateft Heat, it will have expelled almoft all the Air that was contained in it. And in the fourth place, we learn likewife from Experiments, that every fort of Wine, Malt Liquor, and Spirits of Wine, do in Mr. *Boyle's* Air-pump difcharge themfelves of thefe aerial Bubbles fo much the fooner as thefe Liquors abound with a greater quantity of inflammable Spirits.

And another.

Fig. 2.

But this other Experiment, which now follows, will make all thefe things more evident. You fee I take a cylindrical Veffel AB, with a flat bottom, and fill it half full of common clean Water. I have likewife a fpherical glafs Bottle CD compofed of a Belly C and a Neck D which I fill quite full with the fame Water. Then with my Finger laid upon the Mouth D, and touching the very Water at the top of the Neck, I fo immerge this Neck D into the Water in the Veffel AB that no Air can poffibly enter into it, and hence the Bottle remains ftill quite full of Water, without the leaft Air at top. Both thefe Veffels then thus difpofed, I put, as you fee, under the Bell upon the Air-pump. And you obferve, now, whilft I exhauft almoft all the Air, that the Water in the Belly of the Bottle C defcends by its gravity through the Neck D, into the Veffel AB, becaufe the Surface of the Water in the Veffel AB is no longer preffed by the weight of the Atmofphere. In the upper part therefore of the Belly C above the defcending Water, there is now formed a *Torricellium Vacuum.* Hence the Water is there preffed by nothing, but exifts in *vacuo.* And by this means the Air which is in the Water in this Bottle, produces a vaft number of Bubbles; all which make their way through the Water in the Neck and the Belly, towards that upper *vacuum,* and there burfting afunder, give you all the Air which is collected out of the Water in the Bottle CD. I leave every thing now in this ftate till no more Bubbles are formed, nor afcend into the upper part of the Bottle; and then, as you fee, I let the Air into the Bell, which immediately preffing upon the Surface of the Water, in the Veffel AB, forces up the Water thro' the Mouth D into the Belly C; and now you perceive, that tho' there is a free communication with the external Atmofphere, yet the Water does not quite fill the whole Belly C, as it did before, but there remains in the upper part an aerial Bubble, confifting of true elaftic Air, which was forced out of the Water in the former operation, in thofe little Bubbles, which were then produced, and there burft afunder. Nor were thofe Bubbles generated there, till the greateft part of the Air had been exhaufted out of the Bell. Nor indeed do thefe little Bubbles ever arife from this Water, 'till it appears by the Mercury in the Barometer, that the weight of the Atmofphere under the Bell is diminifhed more than one tenth of the whole. Since, therefore, the greateft variation of the weight of the Atmofphere with us never exceeds one tenth part, hence there will never be any danger of Water's difcharging the Air that is contained in it. But Water, likewife, made ninety degrees hot, and then freed in the Air-pump from a tenth part of the weight of the Atmofphere, does not even then fend out its Air by Bubbles; and hence the Air likewife in the Fluids of our Bodies will never be feparated from our Blood, or Humours, by the greateft lightnefs of the Atmofphere that ever is obferved amongft us, as by a particular Experiment too I fhall demonftrate hereafter. It happens, indeed, fooner in this hot Water, than it does in colder; but yet even here it is not obfervable, upon a diminution only of a tenth part of the aerial preffure. But you will

will be apt to ask me now, Gentlemen, and that very juſtly, how I know that the great Bubble in the upper part of the Belly is true elaſtic Air? This, I confeſs indeed, it is abſolutely neceſſary that I ſhould demonſtrate. The reaſon then that I look upon this to be true elaſtic Air is, firſt, becauſe, as you ſaw yourſelves, it expands and contracts itſelf in proportion to the compreſſing weight; and in the ſecond place, becauſe if Heat is applied to it, it expands itſelf into a much larger Space, and if Cold acts upon it, it contracts itſelf into a far leſs: But that theſe are the peculiar and moſt certain marks of Air, who will go about to diſpute? But there is another Thing ſtill that muſt be cleared up, and that is, whether the Air produced in this manner be really exhauſted out of the Water; or whether it only comes from the interſtices between the Surfaces of the Water and the Glaſs; for this indeed ſeems to be evident to the Eye, as I obſerved to you but very lately.

But if I am not very much miſtaken, there are not wanting arguments to prove, that it ariſes out of the very Water itſelf. This is very evident, if we conſider, firſt, that a very different quantity of this Air is produced from the ſame quantity of different Liquors; for Mercury, Water, Wine, Spirit of Wine, Beer, Alcohol, Wine that is foul, and that is fermenting, Beer not duly work'd, and Muſt, differ incredibly in the quantity of Air which they thus generate *in vacuo*; whence it plainly appears, that this Air is ſeparated, not from the Surface only, but from the inmoſt receſſes of Water, and other Liquors. And if we add to this, that there are ſome Fluids, which in this way generate no Air at all, our opinion will be ſtill farther confirmed. Thus, for inſtance, Oil of Tartar *per Deliquium*, tho' it is produced itſelf in the Air, will ſcarcely yield any Air, if it is treated in the ſame manner. And, which one would hardly believe, even the Spirit, which we call the alcaline, volatile Spirit of *Sal-ammoniac*, if it is very ſtrong, will afford but an exceeding ſmall quantity of Air, in the ſame Experiment. But there is another Argument, which will ſerve as a farther confirmation of this truth, of which I ſhall quickly give you ocular demonſtration; and that is, that the whole quantity of that Air, which was produced after this manner, may intirely be abſorbed again by the ſame Water out of which it was drawn, and that no more than that quantity, exactly, can by any art or power be forced into it. All which conſiderations, if you weigh them with due attention, will furniſh you with arguments ſufficient to convince you, that far the greateſt part of that Air was really exhauſted from the very Body, or inmoſt parts of the Water.

Within the Water itſelf.

And finally, we may add, that this Air, by the ſame Experiments, has been drawn likewiſe out of Vinegar, Spirits of Wine, Urine, Spirits of Urine, Oil, Water and Oil, expreſs'd Oil, diſtill'd Oil, Milk, Blood, the Serum of Blood, Eggs, the White of Eggs, nay, and laſtly, even from Mercury itſelf. But here let me obſerve, that if this Experiment is made with boiling Water, which has boiled continually for the ſpace of an hour, hardly any Air at all will be got out of it; ſo that this doctrine ſtands upon a firm foundation.

And in all other Liquors.

Experiment V.

If Water is by boiling accurately deprived of all the perfectly elaſtic Air that is diſperſed through it, and afterwards, being cooled to the temper of the Atmoſphere, is expoſed to the common external Air, then will the elaſtic Air ſpontaneouſly,

Air will enter into Water that is void of Air.

neously, and pretty quickly, enter into this Water, which is now void of Air, and again lodge itself in the spaces left between the interstices of its Elements, and that always to a determined quantity. This wonderful relative property between Water and elastic Air, is demonstrated to the eye in the following manner. Take the whole *Apparatus* of Vessels, made use of in the second part of the 4th Experiment, just now exhibited, where the elastic Air was collected at the top of the Belly of the inverted Bottle. If, then, that aerial Bubble is compressed with the machine used for condensing of Air, the Bubble will not by that means intermix with the Water: But if I expose this whole *Apparatus* to the external Air, then this Bubble will in a little time begin to diminish, and at last will so perfectly vanish, that there will not be the least Air left at the top, but the Belly of the Vessel will be again quite filled with Water only. And this Experiment is constantly observed to proceed in this manner, namely, that in the beginning, a great portion of this collected Air enters pretty quickly into that Water, deprived of Air, but that the little quantity that then remains makes its way in but very slowly. Hence, therefore, it follows, that Water will always imbibe again exactly the same quantity of Air as has been drawn out of it before.

But not into Water saturated with Air.

* The event, now, of this Experiment is pretty extraordinary, when it is attempted with Water, which is already naturally saturated with Air. If therefore, instead of drawing the Air out of the Receiver, and thus forming a Bubble at the top of the Bottle, I take the same Bottle, and not filling it quite full, with my finger upon the Mouth, invert it into the other Vessel, then a Bubble will retire to the top of the Water in the Bottle, and if I then set by the Vessel in this manner, for the space of a year, the aerial Bubble I let in will never enter into the Water, but will always remain at the top, without being mixed with it. Nay farther, in what manner soever I shake these Vessels, I shall never be able to make that Air insinuate itself into this Water. This Bubble indeed would be divided into other small ones, but do what I could, it would never be mixed and distributed through the Water, in such a manner as to become invisible. I have tried what could be done by pressing, heating, cooling, shaking, and laying it up for some time; and yet still that Air constantly remained at top in the same quantity; nor was it possible to intermix any more with the Water, than what it had spontaneously taken in from the common Air.

* This Doctrine of our Author, that Air will not be absorb'd by Water that is already saturated, does not appear constantly to be agreeable to Experiment, as upon trial, at the hint of the learned Dr. *Jurin*, I observed in the following manner. I took a common *Florence* Flask, and filled it almost full of Water, and after letting it stand some time, with my Finger upon the Mouth of it I inverted it, and by this means procured a Bubble of Air at the top. I then, with my Finger still applied to it, immerg'd the Neck of the Flask into a wide-mouth'd Square, full of Water, upon which, drawing out my Finger, I left the Flask standing in the Mouth of the Square. In this manner I put it out of the way, and examining it from time to time, found the Bubble gradually lessen, till it at last intirely disappeared. This I repeated several times, with the same Success. When the Bubble was small, it was taken in in a few days, and as near as I could judge, faster in proportion than the large ones. The Diminution too of the large ones, at the beginning, was more sensible than afterwards, as I saw evidently in one of an inch and three quarters in diameter, set the 4th day of *June*, which, though it was considerably diminished the first month, yet is not this 10th of *December* reduced to an inch. Whether this, therefore, will be totally imbibed by the Water, or not, I cannot yet determine, not having made trial of so large a one before, but one of about $\frac{7}{8}$ths of an inch, by standing in the same manner, in time was perfectly absorb'd.

In the proſecutions, now, of theſe Experiments, I could not help being ſurprized, when I obſerved how ſmall a part of the Surface of the Water was come at by the Air, collected into a Bubble on the upper part of it; and yet ſaw, at the ſame time, that all that Air inſinuated itſelf by ſo ſmall a part of the Surface throughout the whole body of Water, out of which it had before been drawn. And doubtleſs, it had then diſtributed itſelf equally, throughout all the interſtices of the whole Water. There muſt neceſſarily, therefore, be in Water, a certain attracting, imbibing power, in reſpect of that Air, thus drawn from ſo little Space, through all its parts; for this Air ſtands in no need of concuſſion to force it into the Water; let it but alone, and it will make its way in of its own accord. It extends itſelf from a ſmall ſpace through the whole Body of the Water.

The illuſtrious *Stairs*, in his very elaborate Philoſophical Works, was induced by many reaſons to be of opinion, that there never was any true Air in Water, and that thoſe Bubbles produced from Water, in the Air-pump, did not ariſe from true elaſtic Air; but that in Water there always reſide little active Fires, which making their way through the Water, when this is freed from the preſſure of the Atmoſphere, and by their levity tending upwards, form thoſe little Bubbles which preſently burſt aſunder. I am apt to believe, however, if that worthy Gentleman, whoſe candour and virtue are every where ſpoke well of, had ſufficiently conſidered theſe laſt Experiments, he would have been of another opinion: For then, in theſe collected Bubbles, thus produced, he would have found all the true characters of pure Air. See *Stair*'s *Philoſoph. Experim.* p. 572. Let theſe things ſuffice then, touching the firſt method of ſeparating elaſtic Air from Water, by removing the compreſſing weight. Theſe Bubbles do not proceed from Fire.

Experiment VI.

It is very entertaining to ſee the manner in which Fire ſeparates this Air from Water, and to obſerve this Air, when it is thus ſeparated, and collected together, which is very eaſily performed by the following curious Experiment. Take a large wide Veſſel AB, able to bear the Fire, let the bottom of it be flat and plain, and let it be filled with common Water. Then let there be put in this Veſſel, a Funnel, ſo large, that the broadeſt part of it may nearly cover the bottom; and let the Neck of the Funnel CD be wholly immerſed under the ſurface of Water contained in the Veſſel AB. Let there then be provided a little glaſs Bolthead or Vial EF, the mouth of which is wide enough to admit the Neck of the Funnel. I now fill this Vial up to the top with Water, and having ſtopt the Mouth of it cloſe, with my Finger, I invert it, and thus let it down into the Water in the Veſſel AB, ſo that no Air at all can get up into it; and then, as you ſee, I put the Mouth of the Vial E over the neck of the Funnel CD. This done, I put the Veſſel AB with all its *Apparatus* upon the Fire, ſo that the whole may grow hot gradually, and at length the Water in the Veſſel AB may boil briskly. And when this is the caſe, then the Water of the Veſſel boiling under the Funnel, will determine the Air of the Water, which is now formed into Bubbles and tends upwards, through the Funnel into the Neck of the Vial, and thence into its Belly, and ſo collect it together in the upper part F. This then being continued for ſome time, there will at the top F be contained true Air thus ſeparated from the Water which boiled under the Funnel in the Veſſel AB. And this Air, again, will have a perfectly elaſtic quality, Air is ſeparated from Water by boiling. Fig. 3.

quality, and can be drawn out of the Water only in a certain and determined quantity, beyond which no more Air can be procured, how long ſoever the boiling is continued. In this Experiment, now, there occurs a *Phænomenon* that is pretty remarkable; for when the boiling Water has thus ſent up in Bubbles all its contained Air to F, there nevertheleſs, in the courſe of the boiling, are produced other Bubbles, with a ſudden and conſiderable *impetus*, which burſting with a great force, ſhake the Water and Veſſels, but do not by this means produce any Air. Theſe Bubbles, therefore, ariſe not from Air, but from the Fire which acts in the Water. Theſe therefore continue to the end, tho' you boil the Water ever ſo long; whereas the aerial Bubbles are quickly over: Theſe likewiſe are large; whereas the Air-ones are but ſmall: Theſe burſt aſunder with an *impetus* like that of Wind; whilſt the others diſcharge themſelves very quietly: Nor do theſe, as I obſerved before, generate any Air, though ſo exceeding large. And for this reaſon the excellent *Mariotte* gives to theſe Bubbles the name of Fulminations. And if the famous *Stairs*, in the Place above cited, means theſe Bubbles, he is ſo far in the right. Theſe things, then, being done, and the Air being collected at F, if the whole *Apparatus* is ſet again in the cold, the generated Air will return into its proper Water, out of which it was exhauſted. Having gone through this Experiment, with the ſucceſs I have now told you, I had a mind to proſecute this inquiry farther. Accordingly I took Rain-water, and kept it boiling very briskly, for the ſpace of two hours. This Water I then placed, boiling hot, with the *Apparatus* of the 4th Experiment, under the Bell, and drew out the Air, as carefully as I could; and at that time, no Air was produced in the upper part of the Belly of the Bottle. Afterwards, however, having thus kept the Water in this *Vacuum* for ſome days, there aroſe from it at laſt a pretty large quantity of Air. Surprized at this event, I was in doubt, whether, perhaps, the very Water was not tranſmuted into Air, by remaining ſo long in *Vacuo?* Or whether the Air was not ſo intimately mixed with the Water, that it could not be intirely expelled by boiling; though by the Water's being thus left *in vacuo*, it might, by length of time, have thus ſlowly diſengaged itſelf from it?

EXPERIMENT VII.

Air is ſeparated from Water by Froſt.

I took ſome Rain-water, and put it in a very diverging, conical, glaſs Veſſel, and then expoſed it in a hard Froſt. Some time after the Particles of the Water began to be conſtringed by the Cold, though it is not poſſible to condenſe it by the preſſures of the greateſt weights. But when the Particles of the frozen Water, thus more cloſely contracted, begin to leſſen the little Spaces intercepted between them, the Elements of the Air, which before were lodged in them, being now preſſed out of 'em, become united with one another; and by this means, while theſe elaſtic Elements, which before exiſted ſeparately, come into mutual contacts, they ſeem, by their reciprocal repulſive force, to acquire an Elaſticity, which they had not while they were apart from one another. Hence then, little Bubbles begin to be generated, which grow larger and larger, increaſe in number, become at length of a conſiderable ſize, and tending upwards, and being lock'd up within the hard Ice, remove it by means of their Elaſticity, and, notwithſtanding its hardneſs, make it ſwell out on every ſide, and by this means break aſunder the Veſſel that contains it. And here we obſerve, that

that the harder and longer it freezes, the greater, always, more numerous, and ſo much the ſtronger, likewiſe, are theſe aerial, elaſtic Bubbles. Hence it comes to paſs, that Water ſeems to increaſe in magnitude by Cold; whereas, in reality, the Ice itſelf is leſs than the Water was; but theſe Bubbles of Air, thus generated, whilſt they form within the Ice pretty large Spaces, where there is no Ice at all, muſt neceſſarily increaſe its dimenſions; and by this means, likewiſe, they acquire that prodigious power by which they become capable of ſplitting the Veſſels in which they are confined. If, therefore, the Froſt is very ſharp, and of a very long continuance, then all the Air, before diſtributed through the whole body of Water, extricates itſelf from the pores of the Ice, is united into thoſe icy Bubbles, and diſengaged from the Water. This then is another, and new method, by which Air is ſeparated from Water.

Experiment VIII.

Whilſt Oil of Tartar *per Deliquium* is prepared from the Water diffuſed through the Air, one would readily believe, that this frothy ponderous Liquor muſt be full of elaſtic Air; and yet upon examination in the manner juſt deſcribed in the preceding Experiments, it evidently appears, that whether the preſſure of the Atmoſphere is taken off of it, is boiled at the Fire, or conſtringed by Cold, this Liquor will afford no Air at all. Hence therefore we learn, that a fixed alcaline Salt, whilſt it inſinuates itſelf into Water, expels the Elements of Air which are lodged there, and takes poſſeſſion itſelf of thoſe little vacuities, and thus conſtitutes a Fluid which is the heavieſt of all we are acquainted with, except Mercury, being in weight to Water, as 7 is to 5. See *Boyle*'s *Mech. Exper.* p. 26, 27. Or rather, don't it fix the Air?

Air is ſeparated from Water by an Alcali.

Experiment IX.

The following Experiment concerns both the Chemiſt, Mechanic, and Phyſician, and therefore deſerves their attention. I took the Urine of a very hearty Man, made in the morning, after he had his full Sleep, and whilſt he was faſting, and put it into a Glaſs Veſſel that was warmed to the ſame degree of Heat as is obſerved in a Man in health. This Veſſel and Urine, the very moment it was diſcharged from the Body of the Man, I put upon the Air-pump, under a glaſs Bell, and drew out the Air as faſt as I could; and yet, for a long time, I perceived no ſign of any Bubbles of Air in this Urine, though it was ſo warm. I imagined, therefore, that there was no Air in Urine that could be ſhewn by this Experiment. And ſince this Urine was 90 degrees hot, and the Air was exhauſted to 26 inches, and yet there did not appear the leaſt ſign of any ebullition, would not any other perſon have been of the ſame opinion? When I had drawn the Air out however to 27 inches, then ſome Bubbles began to ariſe; and as I proceeded to draw out more, all on a ſudden, the Urine in this *vacuum* began to boil with ſo much violence, as it never boils in a Veſſel upon the open Fire. At the ſight of this I confeſs I was very much ſurprized: For whence could proceed ſo ſudden, and ſo violent an agitation in a Liquor which was before ſo quiet? How comes it to paſs, that the very little portion of elaſtic Air, which was exhauſted at laſt, ſhould (after it had born the Atmoſphere's being removed to 27 inches, without any ebullition) at once produce ſuch a prodigious alteration? Did this ſudden alteration ariſe from the Air of the

Air out of a hot animal Liquor.

the Urine, or from the Fire then residing in it, or from both together? Many other Experiments of this kind I made with various animal Fluids, with very strong *Lixiviums* of Sea Salt, *Sal-Gem*, Salt of Nitre, *Sal-Ammoniac*, volatile, alcaline *Sal-Ammoniac*, and with Mercury. If you would do the same, you would not at all think your time ill spent. To enter into a particular account of these things, would be tedious both to you and myself.

COROL. 1.

Elastic Air, therefore, notwithstanding its Particles adhere to one another, with some kind of tenacity, dissolves itself into its minutest Elements, that it may spontaneously insinuate itself into the vacuities of Liquids that are void of Air, and so disperse itself throughout their whole mass. That Air, therefore, is drawn into those Liquids, and those little Spaces.

COROL. 2.

And the Air so attracted into the Interstices, between the Elements of Liquids void of Air, is in that very action dissolved into its least parts; inasmuch as it is distributed through the large body of the whole Liquid.

COROL. 3.

But the quantity of Air, which after this manner is imbibed by Liquids, and distributed through their whole large Masses, is very little in quantity, and takes up but a very little room in those Liquids.

COROL. 4.

And when those Liquids, of whatsoever kind they be, are once saturated with that small portion of Air that they have imbibed, they will then receive no more of that Air afterwards, whatever art, motion, or compressing force is used to effect it; but they reject the Air, which is then super-added, repelling it from them in Bubbles or Froth.

COROL. 5.

But Liquids also, particularly aqueous ones, when they are perfectly saturated with certain Salts, will not dissolve any Air after this manner.

COROL. 6.

One Particle of Air thus dissolved, when it exists separately in the Interstices, which remain between the contiguous Elements of Liquids, does not seem to be Air, as Air is described by its physical marks. For one such intercepted particle, so long as it remains alone, within the Elements of Water which surround it, and by this means cannot touch such another like Particle, does not appear to be elastic; for this is not evinced by any Experiment. Nor, besides, is such a single Particle so easily dilatable by Heat, inasmuch as it requires a pretty considerable one before it begins to make its way out of its Liquid. Nay farther, though the Mercury in the Barometer descends 25 inches, such a Particle does not extricate itself out of the Water. As therefore one Magnet, by itself, in respect of another Magnet at a distance, would not effect any magnetical Operations, and could hardly in this circumstance be said to be a

Magnet;

Magnet; ſo in the ſame manner may we conceive of the Particles of Air: But as this Magnet, when it is brought ſo near the other, as to be within the ſphere of its activity, immediately diſcovers its vertues; juſt ſo again it happens with the ultimate Particles of elaſtic Air.

COROL. 7.

But when two ſuch ultimate Elements of Air are by any cauſe whatſoever forced out of their little watery Receptacles, and ſo united as perfectly to touch one another, they then ſeem immediately to exert a reciprocal repulſive force, and thus at laſt to form a Bubble of the very ſmalleſt ſize.

COROL. 8.

This little Bubble then, which is the leaſt poſſible one, as it conſiſts only of two Particles, acquires again all the qualities of elaſtic Air abovementioned. And this which is generated at the very bottom of the Liquid, as it tends upwards, paſſes through the Interſtices left between its Elements, where meeting with other ſingle Particles of Air, it unites with them, and by this means forms a larger Bubble; and this likewiſe ſtill tending upwards, and joining itſelf in like manner to other Particles all the way from the bottom to the top, is always the leſs preſſed, the nearer it approaches to the Surface of the Liquid.

COROL. 9.

From what has been advanced, it ſeems likewiſe to follow, that Salts are leſs attractive of this elaſtic Air, than Liquids are, eſpecially aqueous ones.

COROL. 10.

In every Liquid hitherto known, there ſeems to be contained one certain determined portion of Air; always, indeed, a very ſmall one, but very different in different Liquids.

COROL. 11.

Hence it may be queſtioned, whether that Air, which in the juices of Vegetables produces the mighty effect of fermentation, is, in reality, that Air which exiſts in ſingle Particles in their ſmalleſt Pores? Or rather, whether that united and truly elaſtic Air, is not contained in the Air-pipes diſcovered by *Malpighi*, and called their Wind-pipes? Or laſtly, whether it is not the external Air, which commonly intermixes itſelf with theſe fermentable vegetables, during the ſtirring and working them about?

COROL. 12.

The elaſtic Air, which is divided into its minuteſt parts, and is thus contained in the Fluids of Animals, does not ſeem to be the cauſe of the putrefaction which they are ſpontaneouſly diſpoſed to; becauſe, without the admiſſion of the external Air, they are hardly brought to putrefaction; but when this is let in upon them, they putrefy immediately.

EXPERIMENT X.

The quantity of Air in Water, is greater than the Water itself. Pl. VIII. Fig. 4.

This elementary elaſtic Air, which is thus divided into its ſmalleſt parts, and diſſolved and diſperſed through Water, ſeems there to take up but a very little room, which does not fall under the obſervation of our Senſes: And yet, when it is drawn out of the Water, and collected into one ſpace, it then takes up a larger compaſs, than all the Water does out of which it was exhauſted. The truth of this paradox is exhibited to the Eye by the following very elegant Experiment. Take a parallellopipedal Veſſel AB made of Copper. At the bottom let there be made a very little impreſſion or cavity C, big enough only to hold a drop or two of Water; let there be provided likewiſe a very ſmall conoidal glaſs Veſſel D, open at the baſe, like a common Thimble; by which name I ſhall here call it. Let then the Veſſel AB be filled ſo high with very pure expreſſed Oil, that the Thimble D ſtanding at the bottom of the Veſſel AB, may be quite covered. This done, let the Thimble be laid upon its ſide as in F, ſo that there may be no Air at all in it, but that by this poſition, it may be quite full of Oil. Theſe things being thus diſpoſed, let the Veſſel with the Oil and Thimble be ſet on the Fire, that the Oil in the Veſſel, and conſequently in the Thimble, may boil; and let the boiling be continued, till the crackling noiſe of the Oil is quite over. By this means, then, the Air, and Water, which happened to be in the Oil, or about the ſides of the Veſſel, or the Thimble, will be intirely expelled, and the Oil will be totally freed both from Water and Air. This done, take the Veſſel off of the Fire, and let every thing in this ſituation ſtand to cool; and then, let a drop of Water, by means of a little glaſs Pipe, be convey'd through the Oil into the little cavity C, which by means of its own weight, will be kept there under the Oil. Then let the little glaſs Veſſel D, keeping it always under the Oil, leſt any Air ſhould get into it, be placed with due caution erect over the little cavity C, ſo that the middle of its open Baſe may be very exactly over the drop. By this means then, as very evidently appears, the Thimble will be quite full of Oil, all Air and Water being excluded. This duly performed, let the Veſſel AB, with its *apparatus*, be ſo placed upon a ſtand, that the Flame of a Candle may be commodiouſly applied to the little convexity, at the bottom of the Veſſel, in the hollow of which is lodg'd the drop of Water. Let then the Flame be applied to that part, but in ſuch a manner, that the drop of Water may not be made hot at once, but very gradually. The drop then heated in this manner, and at length boiling, will produce a wonderful crackling noiſe, and being under the Thimble, or little glaſs Veſſel, and kept down by the Oil, will diſcharge itſelf of its Air into the upper part of the Thimble, where it will take up a very large ſpace while the Heat is continued, and will proportionably drive out the Oil; and the motion of this little crackling drop, will often be ſo great, as to lift up the whole Thimble. When at length, by this method, all the Air is expelled out of this little drop of Water, let the whole ſtand and cool. The Air then in the little glaſs Veſſel growing cool, will be preſſed into a Bubble, collected at the top of it, and appear of a greater bulk than the drop of Water out of which it was thus drawn. When you are perfectly ſatisfy'd of this, let the whole *apparatus* be put under a glaſs Bell on the Air-pump, and let the Air be exhauſted; and you

will

will then ſee how that Bubble of Air in the upper part of the Glaſs will expand itſelf, and drive out the Oil, and thus evidently demonſtrate a true aerial elaſticity upon the removal of the compreſſing Atmoſphere, as it did before upon the augmentation of the Heat: But as ſoon as ever you let in the Air again, the Bubble will be reduced to its former ſize; ſo that you cannot doubt, but that the Air, which is generated by this Experiment, is true elaſtic Air.

From this Experiment, therefore, we learn with the greateſt certainty, that Air, whilſt it is diſſolved in Water, is by no means ſuch a Liquid, now its Elements are thus divided, as the ſame Air conſtitutes, when it is drawn out of the Water, collected, and has its elaſtic Particles united into one Bubble. Air, whilſt in Water, is not Air.

And it is farther certain, that the Air which lies concealed in Liquids, has not, there, thoſe phyſical vertues, which it poſſeſſes, when it is united out of them: So that it will never perform the ſame Operations in both theſe circumſtances. Thoſe Gentlemen, therefore, appear not to reaſon ſo juſtly, who, after they knew that Air might be procured from Liquids, have concluded, that the Air, whilſt it remained in thoſe Liquids, had there all the active force, which it diſcovered when it was drawn out of them. But in this affair indeed, almoſt all Authors, even Men of great penetration, have been deceived. Of this let the great *Borelli* be an inſtance, in his very excellent Treatiſe of Animal Motion, where he talks of a vital oſcillation of elaſtic Air in the Blood. Warn'd therefore by theſe Examples, let us learn to reaſon cautiouſly, and prudently, leſt at any time we ſhould be refuted by our own Experiments. But here again, we diſcover another wonderful Paradox, and that is, that the elaſtic Particles of the Air, while they exiſt ſeparately, and apart from one another, take up a leſs ſpace, than the whole of them poſſeſs, when they are collected into one Body. Nor does it act like Air.

The power therefore which the Air has of expanding itſelf into larger ſpaces, ariſes from the approach of its Particles nearer to one another. Do they then, when they are very nearly united, repel and fly back from one another? This was the opinion of the incomparable *Newton*, and the continual advances that are made in experimental Philoſophy, make it every day more and more probable. The elaſticity of the Air, owing to the union of its Elements.

Now, from our Doctrine of the nature of the elaſticity of the Air, we learn, that Air, when it exiſts in ſingle diſtinct Elements, can make its way through very ſmall paſſages: For Water, which always of itſelf contains a certain portion of divided Air, will paſs, together with its own Air, through every thing, through which it can itſelf naturally make its way. This appears evident from the Experiments upon Animals, Vegetables, and even upon Foſſils; ſince in the Water drawn out of all theſe, there is always elemental elaſtic Air. For this reaſon, therefore, ſuch Air cannot be excluded thoſe places, into which the Liquids which conceal it can enter: And hence elaſtic Air, in this ſenſe, diſperſes itſelf through Bodies very extenſively. The elaſtic parts are very penetrating.

But now, when theſe aerial Elements are united, and conſtitute a part of the common Air, they will not then make their way through thoſe *Meatus's* into which they could eaſily inſinuate themſelves, when they were intermixed with Liquids. Nor will the ſmalleſt bubble of Air be able to paſs through thoſe places through which a Liquid with its Air would be admitted. And farther, Air itſelf is not very penetrating.

these Elements of Air can hardly by any means be made to paſs through Liquids, which are already ſaturated with Air, tho' at the ſame time they will ſpontaneouſly, and very quickly inſinuate themſelves into thoſe that are void of it.

For theſe reaſons, then, at length, we may perhaps fairly conclude, that it is nearly true in general, that Air, whilſt it is diſtributed through, and intermix'd with Liquids, does not act in thoſe Liquids, with any power which is ordinarily aſcribed to the common Air. For it appears from Hydroſtaticks, that when a very deep Veſſel is filled with any Liquid, the preſſures of the Liquid at different depths, are as thoſe depths, or the diſtances from the upper Surface. At the bottom, therefore, in this caſe, the preſſure will be greateſt of all; at the top very inconſiderable: And yet the Air in that Liquid, ſo long as it remains divided into its Elements, gives no manner of indication of this diverſity of preſſure; ſince it neither appears below in a greater quantity, nor above in a leſs; nor does it ſpontaneouſly paſs out at top; nor in *vacuo* do the Bubbles appear to be generated in the upper part. But as ſoon as the Air, by the means abovementioned, begins to be ſeparated from the Liquid in which it is contained, it immediately puts on the nature of true Air, and acquires all its properties. In the Chyle, therefore, the Milk, Blood, *Serum*, *Saliva*, Bile, Pancreatic Juice, and Urine of Animals, there is naturally Air; but Air that is diſſolved after this manner into its diſtinct Elements, and therefore in that ſtate, does not act as Air. And as it has already appeared from ſome former Experiments, that this Air, whilſt it is divided into its Elements in the Pores of Liquids, is not able to diſengage itſelf thence by the aſſiſtance of any alteration of the Atmoſphere, which naturally happens, even tho' the Liquids are heated to 92 degrees, which is the greateſt Heat of a healthy Perſon: Hence it follows, that the Air which is diſtributed through the Humours of a living human Body, cannot naturally extricate itſelf from them in ſuch a manner, as to collect itſelf within our Veſſels in form of aerial Bubbles, and thus produce there the effects of true Air. And if at any time this ſhould be the caſe, as the famous *Ruyſch* makes mention, who found the Heart in a dead Body diſtended with an aerial *Flatus*, and as *Hippocrates* intimates, in his Treatiſe *De Flatibus*, where he ſuppoſes ſuch flatulencies to happen in the Blood-Veſſels, it preſently becomes fatal; as has long ago appeared to be true by ſome anatomical accounts of Injections. See *Harderi Apiarium*, p. 114. and many other Authors, who have made the ſame Experiments, and always with the ſame ſucceſs. From theſe Obſervations, therefore, which are undeniably true, we may ſee what we ought to think of that Doctrine which has been laid down by very famous Men, concerning the mixture of the Air with the Blood and other Fluids, and the continual return of it from them again.

Air produced from Crabs-eyes and Vinegar.

It now remains in the laſt place, that by a few other Experiments which I ſhall make before you, we examine into ſome other Methods, by which elaſtic Air may be produced from Bodies, in which it before lay concealed. For this purpoſe, I have ſo prepared my Air-pump, as to be able at pleaſure, to mix Bodies together in *vacuo*, which by proper contrivances, you will ſee, I ſhall be able to do very conveniently. You ſee here then, the whole Machine duly fitted up. Under this glaſs Bell, there is as perfect a *Boylean Vacuum*, as by pumping I was able to procure. In the barometrical Tube affix'd to the Pump,

Pump, to ſerve as an *Index* to the *Vacuum* produced, the Mercury ſtands at the height of twenty-eight inches and a half. In the little glaſs Veſſel under the Bell, there is a drachm and a half of whole Crabs-eyes. On theſe now I pour *in vacuo* an ounce and a half of diſtill'd Vinegar, which being warm, the greateſt part of its Air is thereby drawn out, as the Air is out of the whole Bell: And you ſee now, as ſoon as I have poured in the Vinegar, there ariſes an incredible ebullition in the glaſs Veſſel; and immediately the Mercury in the barometrical Index deſcends, and that at ſuch a rate, that in the ſpace of half an hour, it ſinks twelve inches. This Receiver, out of which the Air is drawn, and under which this Experiment is performed, will hold ſeven pounds and two ounces of Water; and the Thermometer at this time ſtands at the degree 52. Hence, therefore, it follows, that there is here produced a quantity of Air which fills a ſpace capable of holding 114 ounces of Water, which Air is in denſity to the common Air, as 12 to 28 $\frac{1}{2}$, or as 24 to 57; and conſequently, if the Air here generated was reduced into a ſpace capable of containing but 48 ounces of Water, which is 81 cubic inches, ſuppoſing a cubic foot of Water to weigh 64 pounds, then this Air thus contracted, would be *in equilibrio* with the whole Atmoſphere. And by the way, in this Experiment you have obſerved in the firſt place, that this ebullition is much briſker *in vacuo*, than under the weight of the whole open Air; and that therefore, the preſſure of the Vinegar upon the Crabs-eyes is not requiſite to this agitation: In the ſecond place, that ſo much elaſtic Air is produced from theſe Bodies thus mix'd together, as fills up the ſpace of 81 cubic inches; and ſuch Air too, as by its elaſtic power is able to reſiſt the preſſure of the whole Atmoſphere: In the third place, that this ſurprizing quantity of Air can lie concealed in theſe Bodies, ſo as not to diſcover itſelf in any manner, till this efferveſcence has diſengaged it from its confinement: In the fourth place, that hence it is exceeding probable, that the elaſtic Air thus produced here, has no weight, as the common Air has which is filled with Vapours. In the fifth place, we hence diſcover, what would be the conſequence, ſhould an Abſorbent like Crabs-eyes, an Acid like Spirit of Vinegar, and a *Vacuum* ever happen to meet together in the Veſſels of a human Body: For which reaſon alone, we begin to ſuſpect, that Efferveſcencies of this kind cannot be brought about in our Veſſels, ſince they would hereby produce ſuch a quantity of Air; whereas a little Air in the Veins becomes fatal. And in the laſt place, it hence appears, that a *Vacuum* within us would be of vaſtly dangerous conſequence.

After I had made this Experiment, I took a drachm of Chalk, and poured upon it in this *vacuo* two ounces of diſtilled Vinegar; upon which there aroſe a more violent Effervesſcence, nay an exceeding violent one, much ſtronger than in the open Air. The whole *Apparatus* being the ſame, the Mercury in the Index fell from 28 $\frac{1}{2}$, to 6 inches: So that the generated Air reduced to the denſity of the external, would fill up a ſpace capable of containing 90 ounces of Water; and conſequently, the ſpace of 151 cubic inches. From Vinegar and Chalk.

But again obſerve, if you pleaſe, this Experiment, while I pour, *in vacuo*, Oil of Tartar *per deliquium* upon diſtilled Vinegar; what a ſudden and violent ebullition is hence produced! and yet when we mix theſe two Liquids in the common Air, there is at firſt hardly any agitation diſcernible by our ſenſes; as you yourſelves have ſo often ſeen, whilſt I have prepared before you the purging From Oil of Tartar *per deliquium*, and Vinegar.

purging Salt of *Sennertus*. This, therefore, you will again take notice of, with regard to the difference of an Effervescence produced *in vacuo*, or in the common Air. But what a large quantity of Air is here suddenly generated? and yet you remember, that upon examination of Oil of Tartar *per deliquium*, it did not discover any: And you know likewise, from the Observations of Mr. *Homberg*, that Vinegar is saturated with a very small quantity of the Alcali of Tartar; namely, with one 14th part. *Hist. de l' Acad. Roy. des Scien.* T. I. p. 52. Notwithstanding which, however, they are capable of producing so much Air. What mischief therefore would follow in a human Body, if such a *Vacuum* should ever happen there, with the like Effervescencies in it! But *in pleno*, as is evident, these Effervescencies would be far less dangerous. How plainly, likewise, do we discover, that the pressure of the Atmosphere, in order to apply and force these Bodies to one another, is not at all requisite to the producing these Effervescencies; since we see by Experiment, that on the contrary, they are more impeded and restrained by it. They rather arise, therefore, from some peculiar innate power in these effervescent Bodies, which is the cause of all this their motion even in *vacuo*. And here, farther, we observe, that by means of such Effervescencies, the Air which was in the Bodies before the Effervescence, is disengaged, and separated from them.

From Oil of Tartar and Oil of Vitriol.

The Experiment which I am now going to make, is a very dangerous one, and therefore requires the most cautious management. We will try what will be the consequence of mixing the best Oil of Vitriol, with the strongest Oil of Tartar *per deliquium* in *vacuo*: And since we learn from the Observations of Mr. *Homberg*, in the place last cited, that eight parts of the best dry Salt of Tartar will be saturated with 5 parts of Oil of Vitriol, I shall here make use of that proportion. We know very well now, that in the open Air, an incredible ebullition arises from the mixture of these Bodies; and therefore, in the first place, I shall endeavour, as much as possible, to draw out all the Air that is contained in these Liquids, that the aerial expansion may afterwards be so much the more moderate. And for the same reason, likewise, I have chosen for this Experiment, a Vessel twenty times bigger than would be necessary to contain these Liquors not expanded; for there is danger, lest by the ebullition that arises *in vacuo*, it should be burst asunder. And this Vessel likewise, in which this Effervescence is to be excited, should be set on a large flat glazed Plate, lest the acrid Liquor, which would corrode the Brass, should run over and damage the Pump. With these cautions, then, I thus perform the Experiment. You see here under the Bell, upon the Air-pump, these two glass Vessels, in one of which is the Oil of Vitriol, in the other the Oil of Tartar *per deliquium*. In the first place, then, I draw out all the Air that can be exhausted by the Pump. Whilst this is doing, you plainly see, that no Air at all is come out of the Oil of Tartar, nor so much as one little Bubble is produced in it. But on the other hand, having now exhausted a great deal of Air, you perceive that abundance of Air arises from the Oil of Vitriol, and continues to pass out of it for a considerable time; for great numbers of large Bubbles are here generated, which as you hear, make a considerable noise. I leave now this Oil of Tartar, and Vitriol *in vacuo*, for the whole space of fifteen hours, that I may, as much as possible, extract all their Air from them. After then they have stood thus long, I mix this Oil of Tartar and Vitriol together,

gether, both, as any one would imagine, void of Air; and what is the consequence? Why there arises, in an instant, the most violent Effervescence; such a one as every way disperses the conflicting Particles through the whole Bell, and throws them upwards with an incredible force. But to what a prodigious degree at the same time does the rarefaction of these Liquors thus mix'd together extend itself. Certainly, they are expanded to far more then twelve times their former bulk, so that if we had not been cautious in chusing a large Vessel, they would have run over the Brim of it. Here now we made use only of * four drachms of Oil of Tartar, and a drachm and a half of Oil of Vitriol; out of these too, all the Air was exhausted; no Air appeared at all, except only in the Oil of Vitriol; and yet the Air produced by this Effervescence, has depressed the Mercury from 29 inches to 12 $\frac{1}{2}$. Hence, therefore, it appears very clearly, that all the elastic Air, which is contained in Fluids, cannot be drawn out of them by means of the Air-pump, but only so much of it as can extricate itself when it is quite freed from the pressure of the Atmosphere; whilst in the mean time another part of it, and that much the greatest, is so closely united with them, that it cannot be separated in this manner, but may be procured from them by means of this Effervescence. The action of the pneumatic Machine in this affair, therefore, is very much limited; and hence any body would be deceived, who should imagine, that Fluids would be exhausted of all their Air, by letting them stand 24 hours *in vacuo*. If again, we carefully consider all these things together, that have been here proposed, we may almost venture to conclude, that the Effervescencies, which happen in this manner, between Acids and Alcali's, arise principally from the prodigious reciprocal attraction which there is between these Salts, by which, when they are placed at a certain distance from one another, they rush together with a mighty force, and by this means expel those Corpuscles which lie in the middle between them, and hinder their coming into an intimate union with one another. Supposing this then to be the case, then by the violent excussion of these aerial Particles effected in the very act of adunation, the elastic Particles of Air, here disposed, would be expell'd, which uniting with other like Particles, might produce the ebullition, agitation, and hissing noise, arising here from the continual displosions of these little crackling Bubbles. And then all the violent motion that is produced during the Effervescence, would not be owing to the mutual repulsion of these Salts, but rather to their reciprocal efforts towards a union. And for this reason it seems to happen, that all this agitation is intirely at an end, as soon as ever this adunation is perfectly compleated; whereas, so long as there remain any Salts not united, so long there likewise remains an Effervescence. In this Experiment we see likewise, that the Water is forced out of the interstices, which were between the Acid, and the alcaline Salts; for the Oil of Tartar, and the Oil of Vitriol, were both of them liquid before their mixture; but after they had been mixed together, and had undergone a violent ebullition, there was produced, by this union of their Particles, a white solid Salt in the middle of the Water that was forced out, and an aqueous Fluid impregnated with a little dissolved Salt, swam at the top. It must, however, be confessed, that the Salts so generated by the union of the Acid and Alcali, in

* This is only in the proportion of 8 to 3, not 8 to 5, as is mentioned in the beginning of the Experiment: These, however, our Author thinks, are the quantities he made use of.

this Effervescence, still contain Air, which is wonderfully elastic, and discovers itself plainly enough in other Experiments. For Sea-Salt, Nitre, and vitriolated Tartar, thus regenerated from their proper acids in the Alcali of Tartar, if they are mixed with Bole again, and distilled in an open Fire into their proper acid Liquids, produce a large quantity of a very elastic *Flatus*, which sometimes bursts asunder very large and strong Vessels. And hence, to persons who have frequently reflected upon these things, the nature of that violent and irrestrainable *Halitus*, or Vapour, which *Helmont* the Elder called, the *Gas Sylvestre*, has always appeared very wonderful; and it has sometimes been doubted, whether all that might be thus generated, would be so far of the same nature, as that it ought to be called by the same name of elastic Air? Or on the other hand, whether Bodies being resolved after a certain manner into their minutest parts, might not have their nature altered, and, by a real transmutation, be changed into this elastic Air, which afterwards, being again concreted with other things, might produce new solid Bodies? And consequently, whether, besides the common elastic Air, there was not in nature something else very much resembling it, and yet not perfectly the same.

From Spirit of Nitre and Iron.

But to return to our Experiments. Please to observe, then, I put under the Bell, with the same caution as before, a Glass, with very strong Spirit of Nitre, and then exhaust the Air as carefully as possible, and you see now, which is surprizing, that this Spirit of Nitre, though all the Air is exhausted, scarcely causes any ebullition *in vacuo*, neither did it whilst the Air was drawing out; whereas, in the former Experiment, Oil of Vitriol, which is more acid than Spirit of Nitre, yielded, from the same cause, a large quantity of Air. There seems, therefore, something extraordinary to obtain in this case, which appears to be still so much more wonderful, as Spirit of Nitre, as soon as ever the Vessel is open, and the Air comes at it, emits very volatile Fumes, and those pretty active ones too; whereas pure Oil of Vitriol, in the open Air remains without any such alteration. Let the cause, however, of this *Phænomenon* be what it will, let us see now what will be the consequence of throwing into this Spirit of Nitre, thus *in vacuo*, a grain or two of the Filings of Iron. You see, then, what an enormous ebullition is hence produced, and what a quantity of very red, dense Fumes diffuse themselves through the whole Receiver. And at the same time observe, what an incredible swelling and puffing up there is of so small a matter, now it is thus rarefied, together with an explosive Fulmination, so strong, as to make one afraid, that the Vessels would burst asunder. But what is most of all remarkable in this Experiment is this, that there is indeed an elastic Air immediately generated, but yet not with that power of depressing the Mercury, nor consequently in such plenty, as seems to answer to so great an ebullition, so violent a fulmination, and to such dense, red, and agitated Fumes. But you observe, now, every thing grows quiet the very instant I let in the Air, and the mass is no longer inflated, but reduced almost to nothing. Thus then, Gentlemen, you have seen two Experiments, by which it has appeared, that the greatest and most violent explosions of Bodies may happen, without a proportional concourse or production of elastic Air; namely, the Experiment where the Water boiled in the inverted Vial, and this, where Spirit of Nitre fulminates with Iron: A circumstance certainly worth the maturest consideration.

But

But give me leave to mention yet one more Experiment, which was formerly made, nor is to be attempted again without a great deal of caution. You have an account of it in the *Philosoph. Transact.* No. 213. p. 212. and it was thus performed: Upon the Air-pump was placed a glaſs Bell, 6 inches wide and 8 inches high. Under this was ſet half a drachm of Spirit of Nitre, in a little Veſſel, and a drachm of diſtill'd Oil of Caraway-ſeeds in another, and then as much Air as poſſible was exhauſted. Theſe Liquors were then mixed together in *vacuo*; and in an inſtant the whole Bell was thrown up into the Air, and the mixture was ſet on fire. From a drachm and a half, therefore, of Liquids, an Air was here produced, which forced up 468 pound weight, with a very great force. Nor did it by this means appear accurately, how much more weight it might have raiſed; ſince it toſs'd up the whole Bell with ſo violent a motion. And yet all the Air which was both in the Spirit of Nitre, and the Oil of Carraway-ſeeds, was drawn out by means of the Air-pump. But this power, or if you will, elaſtic Air, was produced in an inſtant, without any ſucceſſion of time: And ſince the whole Receiver that very moment was filled with Flame; hence the Air, by virtue of this Fire, being ſo much the more expanded, acquired ſo much the greater force, and thus acted both by its ſpring, and the rarefaction from the Heat, together. This force therefore could hardly by any method be brought to a calculation, unleſs, perhaps, by gradually increaſing the ſize of the Receiver, till the column of the Atmoſphere preſſing upon its ſurface, ſhould at laſt be greater than the force of the exploſion ſhould be able to elevate; for then in the laſt elevation, you would have the weight, which the effervescent matter would but juſt be able to raiſe, or be pretty nearly equal to. And to prevent the Bell's being broke by its riſing and falling down again, there may be faſten'd a cord to the top of it, which running over a Pulley, may be kept nearly upon the ſtretch, by means of a ſmall weight hanging at the other end.

From Spirit of Nitre and Oil of Carraways.

I ſhould now inquire into the laſt method by which Art and Nature produce an incredible quantity of very elaſtic Air, called by *Van Helmont* the *Gas Sylveſtre*; namely, by combuſtion, or an agitation cauſed ſolely by Fire. This uſually obtains in fermentation, putrefaction, diſtillation, and combuſtion. But this is a very fruitful ſubject, and of a vaſt extent. The wonderful expanſive force of a fermenting Vegetable appears to every one's obſervation, in Malt Liquor put up into Bottles before it has done working. That putrefying Subſtances generate a great deal of ſuch Air, the illuſtrious *Boyle* has expreſly demonſtrated. *Van Helmont* too, before this, had informed the World, that in the diſtillation of crude Tartar in Veſſels accurately luted, the Veſſels, tho' very ſtrong and capacious, were burſt to pieces. And in the diſtillation of Fleſh, Bones, or the Humours of Animals, managed with the utmoſt caution, unleſs there be ſome crack open, or the Receiver is very large, do not the Veſſels burſt aſunder? Not to mention the diſtillation of Nitre, Salt, Vitriol and Alum, in which are produced an incredible quantity of elaſtic Vapours, which by their violence often cauſe the loſs of the Veſſels, contents, and labour, and frequently prove very dangerous to the Operator. In theſe different ways then, which, however, all agree in this, that they act by the aſſiſtance of Fire, it evidently appears, that this elaſtic Air concurs, as a pretty conſiderable and remarkable conſtituent part in the compoſition of almoſt all kinds of Bodies. Or if

Elaſtic Air produced from Bodies by Fire.

any one yet doubts of it, this certainly he muſt readily acknowledge, that by the action of Fire there is ſomewhat ſeparated from every known Body, which after ſuch ſeparation, is fluid, elaſtic, compreſſible by Weight, and contractible by Cold, and again expanding itſelf by Heat, and when it is freed from the cauſe that compreſſes it. But as for that part of the Air, now, which when ſeparated from all the reſt that are mixed with it, we call the elaſtic part of the Air, we know nothing of it beſides the properties juſt enumerated. By Fire, therefore, at leaſt, elaſtic Air is always ſeparated from thoſe Bodies; and conſequently, ſuch a matter was in them before, though whilſt it was lock'd up there, it did not produce the effects of Air; but as ſoon as ever any of its Particles are ſeparated from them, and united with others, then it immediately returns to its former genius of elaſtic Air, and remains ſuch, till it is ſome how or other again divided into its diſtinct Elements, and united with other non-aerial Particles, with which it may for a time be concealed, grow together, and form one maſs: Tho' even in this ſtate, it ſtill ſo far retains its priſtin nature, that it will again become perfect Air as ſoon as ever it is diſengaged from this entanglement, and the aerial Elements come into union with one another. In all theſe caſes, therefore, Air is immutable; becoming, after its ſeparation from Bodies, what it was before it was united to them; and being able, when 'tis freed by reſolution, to return again, by concretion, into the ſame Body, from which it was ſeparated. This reſolution and compoſition appears by no Art more clearly, than the chemical one. I ſhould now therefore give you ſome inſtances of both kinds, as I have formerly in this Elaboratory made a great many Experiments to this purpoſe: But having ſeen, and to my advantage peruſed, a very elaborate treatiſe, publiſhed about two years ago by the famous Dr. *Steph. Hales*, called *Vegetable Statics*, in the ſixth chapter of which he has, with very great labour and accuracy, given an elegant account of his Experiments, which illuſtrate this Affair, and in ſhort quite compleat it, I chuſe rather to refer you to that work, which will give you a plain View of Nature, as diſcovered by Art.

Permit me now, then, Gentlemen, to put an end to this Diſcourſe upon Air; in which I have principally endeavoured to ſhew, how neceſſary the knowledge of Natural-Philoſophy is to a perſon who would make himſelf maſter of the chemical Art; and conſequently, how neceſſary it is likewiſe to be acquainted with all the Arts by which Natural-Philoſophy is promoted. Without theſe helps the Chemiſt is continually falling into errors himſelf, as well as deceiving others, whilſt he miſtakes the true cauſes of things, and aſſigns falſe ones in their room; whereas if he is ſufficiently furniſhed with theſe, he has paved a way by which he may readily arrive at the true knowledge of Nature.

Corollaries concerning the Air, for the uſe of Chemiſts.

I ſhall only add, therefore, the few following Corollaries, and ſo conclude. In every chemical operation we are engaged in, the Bodies to be examined under their various changes, are expoſed to this Air, of which we have been treating. All thoſe Bodies therefore, and all thoſe Operations, whilſt they are directed by the Chemiſt, according to the rules of his Art, muſt at the ſame time undergo whatever the Air, by being applied to them, is capable of effecting upon them. When the Chemiſt therefore goes about to compute the effects of his Art, he muſt always likewiſe have a very particular regard to the action of the Air, and what ſhare that has had in the Operation; which however

ever is but very ſeldom, and very ſlightly attended to. I have ſubjoined therefore to every property of the Air, which we have been conſidering, the peculiar effects which properly depend upon it. I ſhall now, with your leave, repeat, in a very few words, thoſe things which the Air performs by the concurrence of all its powers together. In the firſt place, then, it encompaſſes, is in contact with, confines, and compreſſes all Bodies, inſinuates itſelf into their penetrable paſſages, and being received into them, it there exerts all its power, as well upon ſolid Bodies, as fluid ones. In the ſecond place, being by its gravity determined upon thoſe Bodies, and being at the ſame time diviſible by its fluidity, whilſt it thus inſinuates itſelf by its minuteſt Elements, it meets with Bodies there, to a union with which it has a natural tendency, and hence unites its Elements with them, loſes its Fluidity and its fluid Elaſticity, and remains there cloſely confined, till by Effervefcence, Fermentation, Putrefaction, or Fire, it is again ſet at liberty. In the mean time, however. by virtue of the other Particles which it contains in it, it brings about an infinite number of effects. In the third place, it performs particularly the office of intermixing Bodies very intimately with one another, whilſt by ſuch weight, and ſuch perpetual velocity of motion, like the mechanical Peſtil, it puts them in motion, and rubs, and mingles them together, producing after this manner very ſingular effects, not eaſily accompliſhed by any other means: This the ancient Alchemiſts, *Van Helmont*, in particular, was well apprized of, and made uſe of it to very valuable purpoſes; as you will ſee, if you conſult him p. 151. § 45. 334. §. 84. and in a great many other places. And indeed if we expect to meet with the ſame ſucceſs in a place void of Air, or where the Air, by reaſon of the height of the place from the Earth, is pretty light, or rare, our labour will be all in vain. How evidently does this appear in the combination of diſtilled Oil of Turpentine with Salt of Tartar? How eaſily is this performed in an open, heavy Air, whilſt in very high places it is not to be effected? And in the defæcation of Salt of Tartar by the Air, the ſame thing appears as clearly. Of conſequence, therefore, in the fourth place, it determines and applies the action of one Body to another. For all things which are heavier than the Air, are compreſſed by the Air, which reſts upon them, and, as we obſerved in the laſt article, are moved by its motion, and intimately mixed together. Hence, therefore, if among theſe Bodies there are any which acquire ſome particular vertues by coming into contact with one another, then theſe vertues will by this means be excited by the Air, and diſcover themſelves by their effects. And hence it comes to paſs, that there are many diſſolvents, which in the *vacuum* of Mr. *Boyle* hardly diſcover any corroding quality; though if the Air is let in upon them, it becomes manifeſt immediately. This Mr. *Boyle* himſelf remarks in the Filings of Copper mixed with the alcaline Spirit of *Sal-Ammoniac*, and in Vinegar applied to Copper and Iron, *in vacuo*. But it appears likewiſe, in almoſt every inſtance, that, by the preſſure of Bodies upon one another, mechanical powers are brought into action; and that they ceaſe again, as ſoon as ever this preſſure is removed. A Diamond will not cut Glaſs, unleſs it be preſſed againſt, and moved upon it. Attrition begets no Heat, if Bodies are not forcibly compreſſed together. This appears no where more evident, than in *Papin*'s Digeſter. Here the Bones of an old Ox, for inſtance, with ſome Water and Air, are ſo cloſely included in a Copper Cylinder, that no Air or Water can

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by any means poſſible make its way out. Fire is then applied till the Water boils. The Air therefore acquires a power of expanding itſelf proportional to the applied Heat; and ſo likewiſe does the Water. Hence the preſſure of the Air and Water upon the Bones, muſt be exceeding great. In the mean time too, the Air and Water, within this Veſſel, are moved againſt one another, and upon the Bones with an incredible velocity; and by this means, within a few minutes, the Bones are ſoftned, and converted into a viſcid Liquid, or into a ſoft, tender Maſs, very readily yielding to the knife. In the *Fahrenheitian* Experiments, formerly mentioned, it appeared, that when the Atmoſphere was made but one tenth part heavier, the Water immediately took in more Fire before it would boil. What, now, could be the cauſe of this, but the Atmoſphere's preſſing the parts of the Water more cloſely together? In the fifth place, the Air, conſidered all together, is the occaſion that hardly any Body continues at reſt; becauſe this, by the ſmalleſt alteration of Heat, is immediately expanded or contracted, and, conſequently, ſuffers a reciprocal oſcillation: But theſe changes of Heat and Cold are perpetually happening; and hence there muſt of conſequence be a perpetual agitation in the Air. This appears likewiſe evident, from the continual variation of its weight; for Barometers ſet in a very oblique poſition, and thus, upon the leaſt difference in the weight of the Air running through a large Space, have been obſerved to be almoſt always in motion. But ſince two inches of Mercury are equal to 23,800 inches of common Air; hence, upon the ſmalleſt variation in the Barometer, the Air immediately runs through * 23,800 times the ſame ſpace. As therefore the Mercury in this reſpect never reſts at the ſame Altitude, we diſcover how much leſs the Atmoſphere remains of the ſame weight. And ſince this Air inſinuates itſelf between Bodies, and into their Pores, it ſeems certainly, with regard to theſe, to have the nature and power of a perpetual mover. Hence, perhaps, it comes to paſs, that all the principal Operations of Nature are brought about in the common Air, but will not proceed, in an exhauſted Receiver. Fermentable paſts, duly prepared, and diſpoſed in the *vacuum* of Mr. *Boyle*, will not ferment there though they are acted upon by a proper Heat, but diſcharging their Air, remain unchanged. The parts of Animals, which very readily putrefy, being ſhut up in the like *vacuum*, and freed from their exhaling Air, do not afterwards putrefy, tho' they are kept warm. The ſame thing is likewiſe true in your Summer Fruits, which being ſet *in vacuo*, puff, emit a *Flatus*, and then remain at reſt. So that the parts of Animals, Vegetables and Foſſils, being here included without Air, ſeem to undergo very little alteration. In the ſixth place, this Air ſeems always to contain in it ſuch Particles as are fit, by their application and motion, to perform the office of a *Menſtruum* upon all Bodies whatever: For as it contains and carries along with it almoſt all kinds of Bodies, in a ſtate of ſolution, it can ſcarce poſſibly happen, but that by the ſucceſſive application of ſuch a variety, certain particles will be ſometimes applied, which are proper, as a *Menſtruum*, to diſſolve every kind of Body. And in this reſpect it may be ſaid to perform the office of an univerſal *Menſtruum*.

* This in the original is 13,800. which our author ſays ſhould be 23,800; but it ſtill does not appear to me to be right; for ſince the ſpecific gravity of Mercury to Air is as 11,900 to 1. ſuppoſing Water to Air as 850 to 1, and Mercury to Water as 14 to 1, hence the Air, I think, will run only 11,900 times the ſame ſpace as the Mercury does. This I could not mention to the learned author, when I wrote to him firſt, becauſe I did not know how he would alter the original; nor did I take notice of it afterwards, till it was too late to write to him again.

It

It is very certain, there is neither Metal, nor Semi-Metal, which may not, ſooner or later, be diſſolved in the Air, and by the Air, and converted into its proper *Calx*. Gold, indeed, Silver and Antimony, are leſs diſſoluble there, and with more difficulty, becauſe they are hardly diſſolved, except by Mercury, Spirit of Salt, or Spirit of Nitre; but theſe rarely float about in the open Air; and hence it comes to paſs, that theſe Foſſils are not often diſſolved there. If Gold and Silver Veſſels, however, are for a conſiderable time expoſed to the Air in a chemical Elaboratory, where Spirit of Salt, or Nitre, or *Aquæ Regiæ* are preparing, theſe volatile Acids, very eaſily, ſo affect the poliſh'd Surfaces of the Metals, as to corrode them, and turn them into a *Flos*, or Mould, peculiar to each, and then into a *Calx*. In all other Bodies this diſſolution happens much more frequently, as being much eaſier. But not only theſe, but an infinite number of other things may be effected, by thoſe Corpuſcles, which the Air always, or ſometimes, at leaſt, carries along with it. For by this means it diſcovers Bodies that before lay concealed, and conceals others that before were manifeſt; it makes acrid the ſoft, and ſoftens the acrid; it fixes the volatile, and renders volatile the fixed; and it produces colours, and deſtroys them: But of theſe things there is no end. In ſhort, therefore, you may learn from hence, that it often happens that the very ſame object, treated exactly in the ſame manner, ſhall have very different effects, if it is managed in a different Air. In every account, therefore, of chemical operations, a particular regard muſt be had to the Atmoſphere, in which they are performed; ſince otherwiſe the event may very much deceive the operator, without his being in the leaſt aware of it. In any chemical proceſs it is impoſſible the iſſue ſhould be the ſame in a different Air, where it happens, that the Air has any conſiderable influence upon it. And finally, how great the effect of the Air is, whilſt it has free power of concurring with Fire towards the changing of Bodies, we have already obſerved in the hiſtory of Fire. Camphire melted in a Veſſel upon the Fire, and ſo incloſed, that the Air cannot come at it, aſcends, is purged of its impurities, and remains perfect Camphire, purer than it was before: But if while the Fire thus acts upon it, there is a free admiſſion of the Air to it, it is conſumed, producing a Flame, which burns even in Water, and ſends forth thick, black Vapours, convertible into a very black Soot. Sulphur ſublim'd by the Fire, remains always Sulphur, if the free Air cannot enter the Veſſels in which the Sublimation is made: But if the Air once comes to it, it is immediately converted into Flame, and an acid Liquor. Thus then we may finiſh what we had to offer concerning the Air, for the ſervice and advancement of the Chemical Art.

Of WATER.

The Nature of Water difficult to be underſtood.

As of all Bodies that lie continually before us, Water is the commoneſt, falling perpetually under the obſervation of our ſenſes, and being made uſe of for moſt of the purpoſes of Life, hence it comes to paſs, that every one is ready to imagine, that he perfectly underſtands its nature. Thoſe perſons, however, who have enquired into it, with the greateſt care, have ſcarcely found any thing among natural Bodies which it is more difficult to form a right notion of. And the cauſe of this difficulty lies chiefly in this, that it is ſo exceeding hard a matter to ſeparate Water from other Bodies, or other Bodies from Water. For this Element mixes itſelf with all the Subſtances that come under the examination of the Chemiſts, and reſides in ſuch a manner in the Air, in which all chemical Operations are performed, that it is ſcarce poſſible to ſecure any thing from it. Hartſhorn, after it has been kept for half a Century, and is grown ſo dry, that a Stone itſelf is not dryer, and ſo hard, that it reſiſts a File more than Iron, if it is diſtilled with a ſtrong Fire in a dry Glaſs, will yield a Spirit; and if, according to Art, you accurately ſeparate from this, both the Oil, and the Salt, you will procure a good deal of Water. Stones too, and Bricks, if they are reduced to powder, and expoſed to the Fire, in the drieſt Veſſels, always afford ſome Water; nay, to the Water, as a *Gluten* by which they are held together, they even owe their being what they are. What can be more evident than this? If fat Potters Earth is expoſed a good while to the ſcorching Heat of the Sun, it is converted into troubleſome volatile Duſt, which is eaſily blown about with the leaſt Wind, and never grows together again, ſo long as it is kept dry; and yet if you work it with Water, it becomes a ductile Paſte, and when it is burnt, becomes a hard, ſtoney Subſtance. Of the Air's always containing Water, and applying it to the Bodies that are placed in it, I have treated already. The Air without all diſpute is always full of Water in motion, as one may ſee evidently, indeed, in the following pretty Experiment. If in the ſummer time, when the Air is exceeding hot and dry, you expoſe to it a piece of Ice, juſt taken out of an Ice-houſe, there will preſently appear a Vapour about it; and if you hold your hand very near it, you will then perceive a Steam betwixt that and your hand; thus both inſtances evidently demonſtrating that the Water, which before being equally diſperſed through the Air, did not appear, does now, being condenſed by the Cold, diſcover itſelf in a viſible form. If in the ſummer time you pour Water into a large Glaſs Veſſel, that is perfectly dry on the outſide, it will ſtill continue ſo; but if you take $\frac{1}{3}$ of its weight of *Sal-Ammoniac*, reduced to Powder, and very dry, and mix it with the Water the whole external Surface of the Glaſs will be immediately covered with a Dew, which will ſoon run down in drops. This you underſtand, to be ſure, ariſes from the Water, which before was by the ſummer Heat diffuſed through the Air, but is now by the ſudden Cold forced to unite, and form a Vapour, Dew, and Water; juſt in the ſame manner as ones Breath, which does not appear in the Summer, diſcovers itſelf in the Winter in form of a Vapour. By theſe then, and infinite number of other inſtances, it is certainly demonſtrated, that the Air has always Water in it, and therefore that it is impoſſible to keep Bodies that are placed in it free from Water. But now, if Water, is ſeparated with ſo much difficulty from Air; ſo on the other hand, many other Bodies are not ſeparated with leſs, from Water, ſo as to leave one ſure that one has pure, ſimple, elementary Water. Who then will venture to affirm, that he is poſſeſſed of pure Water? Or who can pretend to ſhow it perfectly unmixed with any thing elſe? Every body knows, that there are infinite numbers of Bodies, and that as well compound as ſimple, which may be diſſolved ſo intimately in Water, that they ſhall not diſcover the leaſt ſign of their being there. Cuſtom, indeed, which fixes the meaning of Words, calls the Liquor thus adulterated, Water; but certainly, in a philoſophical ſenſe, it is very far from being ſo. But farther, if we examine its peculiar nature yet more nicely, we ſhall find, that moſt of its properties, and that its principal ones too, it poſſeſſes in common with other Fluids, and hence again it will be so much the more difficult to find out such a character of Water as shall perfectly distinguish it from every other Fluid whatever.

If a Person, however, would in a philosophical manner inquire into the nature of Water, he must have some certain character by which he may define that Water, concerning whose genius he is making his inquiry: For this, for the present, will serve to distinguish it from all other Bodies; and when afterwards all its properties are discovered, they must then be referred to the thing thus distinguished. Its Character, however, must be found out.

Following this method, therefore, by Water we mean a Liquor, very fluid, inodorous, insipid, pellucid, and colourless, which in a certain degree of Cold, freezes into a brittle, hard, glassy Ice; for these marks every body knows point out Water. If, therefore, such a fluid as this could be readily procured perfectly free of every other Body, then the examination of Water Chemically, Hydrostatically, Hydraulically, Mechanically, and Philosophically, would be very easy; for in this case we should be absolutely sure, that whatever we discovered by these helps, would belong truly to the nature of Water, as upon supposition there would be no Body in it to which it could be referred; whereas, if there are other Bodies mixed with it, we shall be always in doubt, to which of those any property we observe belongs, and ought to be attributed. A definition of Water.

But it is absolutely impossible ever to have Water quite by itself, because, so long as it subsists in the form of Water, it has always Fire in it, which can never leave it, nay, and is always in it in a large quantity; for as soon as ever the Fire in it is so diminished, that it comes to the degree 32 in *Fahrenheit*'s Thermometer, the Water continues Water no longer, but becomes a very different Body from what it was before, that is to say, Ice. But in that degree of Cold, there remain a great many Bodies still fluid, which will congeal in a greater. Nay, if the Heat is decreased 73 degrees below this freezing point, even in that intense Cold, neither Alcohol, nor Mercury, lose their fluidity. From these Observations, therefore, it evidently appears, that a great deal of Fire is necessary to prevent its being converted into Ice. Certainly, between the state of Water just beginning to freeze, and the same made as warm as the Blood of a Man in health, there is a less number of degrees, than between the same state, and the greatest observed Cold; as in the former case there is only 58, in the latter 73. Which is never alone, but always contains a good deal of Fire.

But all Water is constantly exposed to the Air, which enters into it in a certain quantity, as has already appeared. And there, likewise, it was observed, that the Air abounds with the Particles of, perhaps, all volatile Bodies. It is impossible, therefore, but that the Air should continually mix both itself, and its contents, with the Water, which by this means will be rendered impure, and be constantly receiving from it different Particles. This, perhaps, appears by no Experiment more evident, than by the examination of Rain Water, which comes from the upper regions, when after a long drought there happens Thunder, with very large Showers; for if the Rain-water is catch'd at such a time, it is found to abound with great variety of Bodies, as the Chemists have often taken notice. And is rendered impure by the Air and its contents.

But this Air, when it is once got into Water, cannot easily be disengaged from it again; for if it is placed under a Receiver upon an Air-pump, you must remove almost the whole weight of the Atmosphere, before the Air will And almost inseparably.

make

make its way out in 32 degrees of Heat. And if in a middle Atmosphere, you would separate from Water the Air that is mixed with it, you must increase your Heat to 150 degrees. Hence, therefore, the greatest Heat that is naturally produced, and the lightest Atmosphere that was ever observed, tho' they conspire together, are not able to fetch Air out of common Water. Fix'd alcaline Salts, indeed, when they saturate Water, seem, perhaps, to dislodge the Air that was in it; but then, at the same time, they fill it with Salt; and if afterwards you attempt to draw the Water from them, by its passing through the Air, it is filled with it again. In the mean time, however, there is a great deal of room to believe, that the reason why Oil of Tartar *per deliquium* don't discover any Air in *vacuo*, is only, because by a very strong attraction peculiar to its nature, it retains it very tenaciously. For in boiling the strongest fix'd alcalious *Lixiviums*, in any open Vessel, I have often observed, that when they became so inspissated as to be just ready to grow dry, then at last, there diluting Water being carried off by the excessive Heat, they began to rise into a very large frothy collection of Bubbles, which unless properly provided against, would run over the sides of the Vessel in such a manner, as perhaps one shan't see in any other Liquors. This remarkable *Phænomenon*, now, seemed to me plainly to evince, that a large quantity of true Air is very strongly attracted by a fix'd, pure, dry Alcali, as soon as ever it comes out of the intense Fire, in which alone it is made, and that it unites it with itself so very powerful, that it will not afterwards suffer it to be separated from it, except, by the action of a very strong Fire, or by its attraction of something else to which it has a greater tendency, as an Acid, upon its Effervescence with which it lets go its Air. Hence again, then, it appears, how seldom there exists any Water, without being impregnated with Air, and its contents. The consideration, therefore, of these things, puts us in mind, before we pretend to reason from Experiments concerning the nature of Water, to treat distinctly of the Methods by which it may be obtained in its greatest purity, that when we have got some of this sort, and have examined it by every kind of Experiment, we may be able to come the nearer to the nature of the purest. To this purpose, therefore, let us carefully take a view of all those properties, which can by any means be observed in Water so long as it continues to be so. And as we proceed to examine all these in order, we must particularly take notice how any discovered property appears in that Water which is most simple and freest from every heterogeneous Body; for this, I conceive, is the only method by which we can come at a true knowledge of it.

The proper weight of Water difficult to find out.

In the first place, then, the particular and proper weight of Water offers itself to our consideration. But to persons acquainted with these things, how difficult does it appear to find this exactly? For there are naturally in Water many things that are lighter than pure Water itself. This appears particularly in Rain-water, and that which in a chemical distillation in close Vessels rises into the Receiver. Whatever there is of fermented Alcohol mixed with either of these, it will most certainly render them lighter than if they were pure. And the Spirits likewise produced from putrify'd Vegetables or Animals, dispersed in the Air, and mixed with these Waters, will have the very same effect. In the mean time, however, there are many more Bodies found dispersed through Water, that are really heavier than simple Water, and which, consequently,

quently, by their admixture, render it much heavier than it is naturally. Hence Fountain, River, and Well-water, have by this means their ſpecific gravity increaſed; as ſaline, ſaponaceous, and vitriolic ſubſtances are frequently mixed with them in very large quantities.

Well-water, is properly that which comes from that ſubterraneous *ſtratum*, which is called a (*Sabuletum ſcaturiens*) ſpringing Gravel. For if you dig through the upper cruſt of the Earth where it is not rocky, at a certain depth you will come to a *ſtratum* of very pure Gravel; and if you then proceed to dig any deeper, you loſe your labour, for after you have removed a quantity of Gravel, there will in a little time as much be brought again from the neighbouring parts; and hence they have called this place a ſpringing Gravel. In this Gravel, now, the Water always riſes from the bottom, and runs down from the places about it. Hence this collection of Water is called ſpringing Water, or a Living-ſpring, and the Water itſelf (*Aqua Viva*) Living-water. If you take care now that no Water ſhall come into this Well, but what paſſes through this Gravel, then in that place the Water will be exceeding pure. For the Sand is nothing but a collection of very ſmall clean Flints, whoſe figure, and ſize, are ſo various, that they can never be ſo diſpoſed among one another, as not to leave little empty ſpaces among them: Hence the Water is always able to inſinuate itſelf between them, tho' they intercept almoſt every thing elſe; and by this means, when it has been ſo filtered for a conſiderable time, it loſes its impurities, and becomes very limpid. If there are no Salts therefore about this Gravel, this Well-water will be pure and pellucid. But if on the other hand there are any Salts, ſaline, or ſaponaceous Subſtances near the Spring, then theſe being intimately united with the Water, cannot be ſeparated from it, by this its paſſage through the Gravel, but will communicate their weight to it as well as their other properties. And this, in reality, is found to be the caſe almoſt all the World over: For the Earth is the grand Chaos from which all things ariſe, and to which they all return again. Since, therefore, this Water by running through the Earth, becomes a *Lixivium* of all thoſe Bodies which it meets with, and is capable of diſſolving, it appears evident, how ſeldom this can be pure, and that it muſt be very different according to the place in which it is found. If you take, however, that Water that is drawn from the pureſt Well, and therefore is the moſt ſimple of the ſort, and compare it with the pureſt Gold which is always exactly of the ſame ſpecific gravity, then its weight to that of Gold, is found to be as 250 to 4909, or as 1 to $19\frac{159}{250}$. This you find in the *Philoſophical Tranſactions* of the *Engliſh*, which they have confirmed by repeated Experiments. The ſame Water is found to be 850 times heavier than the common Air: And an *Engliſh* cubic inch, examined with the utmoſt care by the great *Boyle*, weighed 252. 256. 260 grains. *Boyl. Med. Hydroſtat.* p. 110. *Act. Leipſ.* 91. 196. That there ſhould here now be this difference of 8 grains, that is near a 32d part of the whole, is not ſo much to be wondered at, ſince heat eaſily renders Water lighter. To foſſil chryſtal Water was in Weight as 1 to $2\frac{1}{2}$; to Marble as 1 to $2\frac{7}{10}$. In giving an account, however, of the comparative gravities of Bodies, we ſhould take notice of the degree of Heat in which the Experiments were made: For as the expanſion of Bodies of the ſame kind ariſing from the ſame Heat, are in a reciprocal proportion to their denſities, Fluids, however, being more expanded than Solids; hence

Well-Water.

Metals are vastly less expanded by the same Heat than Water. For this reason, therefore, if the weight of Water is compared with that of Gold, or any other Metal in different degrees of Heat, the Observations will never be found to agree: But if two quantities of different Water are examined and compared with Gold in the same degree, then that which is found to be the heaviest, will always have dissolved in it some other Bodies which are heavier than the Water itself. Hence the heavier Waters are, the more they are always to be suspected of having something heterogeneous in them; and for this reason, the Physicians always condemn such Waters, as most prejudicial to health, on account of the foreign Bodies mixed with them, which are often very pernicious. There have been some Well-waters, however, found to be lighter than in the proportion abovemention'd: And these are always so much the purer, and more wholsome; except this should happen from any Spirits being mix'd with them. *Hippocrates*, in his Book *De Aere, Aquis & Locis* §. XVI. speaks of Waters *that boil easiest and pass quickest*. And again, §. XVI. he says, that *Rain-water, which is the lightest, sweetest, and clearest, is best for medicinal purposes*. And *Herodotus* has this passage, L. III. c. 125. *The* Ethiopians *live to the age of* 120 *years, and some of them more. Their food is boiled Flesh, and their drink Milk. They have a Water upon which nothing will swim, neither Wood, nor things that are lighter, but in it all Bodies sink to the bottom; and by means of this, they arrive to such a great age*. But where is there any such Water to be found now-a-days? Certainly no where: If there was, we might then compare our Water with it. But neither Nature or Art affords us any such thing, no not by the most careful and repeated distillation. When I formerly, therefore, read this Passage of *Herodotus*, which I absolutely believe to be true, I was induced to suppose, that the Wood in that part of *Ethiopia* was exceeding heavy, and at the same time the Water, in comparison of ours, very light. And, indeed, we know, that in *Asia*, *Africa*, and *America*, especially in the hottest parts of these Countries, there grow some sorts of Wood, which in hardness are equal to Iron, and in weight almost to Stone, and are hence called (*Sideroxyla*) Iron-Woods. Nay, how solid and heavy is our own Box, if it is but old and sound? Not to mention that sort of Oak called generally the Iron-Oak, and *Guaiacum*, if it is but good. And if we will but reflect upon that Wood in *America*, of which the Inhabitants make their weapons, we shall have no room at all to doubt, but that there were exceeding heavy Woods in those places which *Herodotus* makes mention of. And, indeed, modern Observations confirm almost every thing, which that great Man has asserted, notwithstanding some persons who have but little learning, and are unacquainted with Natural Philosophy, look upon many of them to be fabulous, and false. The lightest Water, however, that we are now-a-days acquainted with, either natural, or rendered pure by Art, is always heavier than any Wine or Beer, prepared with Water from Vegetables by Fermentation.

Fluidity of Water.

A second property of Water, which it has in common with other Liquors, is its Fluidity; which in this is very remarkable. For it is here so great, that the ultimate Particles of Water, by a gentle Heat, or small degree of motion, will recede from one another: So that Experiments made carefully, and on purpose, have determined how much Water in a certain degree of Heat, and a given time, will exhale from a known Surface not agitated by the Wind. In which

which examination, this is particularly obſerved, that, *cæteris paribus*, Water exhales ſo much the more, as it is more pure; and ſo much the leſs, as it is the more ſaturated with Salt. If it is pure, therefore, it has ſcarcely any tenacity in its parts, which upon being drawn, do not run out in long cohering Spirals, but are divided rather into dewy Particles. And when in diſtillation in any clean glaſs Veſſels, a warm watery Vapour ariſes with a gentle Heat, and ſticks againſt the cooler ſides of the glaſs head, it never runs down, and forms tenacious *ſtriæ*, like Oils and Spirits, but diſcovers its diſſipated Particles in appearance of a fine Dew. But very ſalt Water, on account of the Salt and *Bitumen* mix'd with it, does not ſuffer its Particles to be ſeparated ſo eaſily as ſweet. Hence Fountains, Brooks, Rivers, Lakes and Ponds, ſend up more Water, in proportion, than the ſalt Sea. The exhalation of this, however, which is very conſiderable, has been calculated by the ingenious Dr. *Halley*: For after, with pure Water, he had mix'd $\frac{1}{40}$th part of Sea-Salt, and thus brought it to the Saltneſs of the Sea, he put it into a cylindrical Veſſel $7\frac{8}{10}$ inches wide, and 4 deep, and then expoſing it to a degree of Heat equal to that of the hotteſt Summer, in a ſtill place where there was no Wind, it exhaled 6 ounces in 24 hours; and conſequently, in that ſpace of time, it had evaporated to the thickneſs of $\frac{2}{5}$ths of an inch; tho' the Water in that degree of Heat is ſcarce ſenſibly warm, and by no means emits any viſible Vapour. *Phil. Tranſ.* N. 189. p. 366. If Water, however, is ſet in a cloſe place, where the Sun never ſhines, nor any Wind blows through, and is kept there for a whole year, it then exhales only to the depth of 8 inches. *Halley. Ibid.* p. 183. N. 212. But I have experienced myſelf, as I formerly took notice, that Water being expoſed to the Wind, in a cylindrical Veſſel, was in a ſhort time, by the motion of it, diſſipated into the Air. This I learned, by ſetting a braſs Veſſel 8 inches high, in which there was ſome Water at bottom, in the open Air, and between two Walls when the Wind was very high. The ingenious *Kruquius* has obſerved, that the Rain, Snow, Hail and Dew, collected in the ſpace of one year, conſidered as Water, roſe to the height of near 30 inches, and that in the ſame time the ſame quantity exhaled from Veſſels that were placed in a ſtill ſhady place, but in the open Air: Hence then it appears, that by the Heat of the Sun, and the Winds, Water is perpetually carried off, diſperſed, and rendered volatile, and preſerved from ſtagnation and inſpiſſation; and hence we ſee the vaſt ſervice, and neceſſity of Winds. And again, which makes it as much as poſſible to our preſent purpoſe, hence we learn the great mobility of the Elements of the Water among one another, when by ſo light a cauſe, it ſuffers itſelf to be totally divided and reſolv'd in its ultimate Particles.

This very great fluidity of Water, however, depends intirely, and ſolely upon Fire, which acting upon it in a certain degree, gives it this fluidity. For if the pureſt Water we are acquainted with, is ſo expoſed to the Air, that it may be perfectly reduced to its temperature, it then loſes its fluidity, when *Fahrenheit*'s Thermometer is fallen to the degree 32. Three and thirty degrees, therefore, of Heat, or Fire, ſerve to keep Water in a ſtate of fluidity. And ſo long as Water has this degree of warmth, ſo long it retains a motion in itſelf, nay and exhales too, and conſequently keeps fluid by means of this Fire preſent in it. Depending ſolely on Fire, And that a pretty considerable one. But the natural cold of a very severe Winter, was observed at *Gedanum* to decrease to the first degree in the same Thermometer, as we formerly mentioned in our History of Fire; and in a natural way, the Heat of the Air seldom increases from that degree to the degree 80; whence it appears, which is pretty surprizing, that Water, tho' exposed to more than $\frac{1}{3}$ of the greatest natural Heat, becomes and continues Ice, whilst in the remaining part only, it becomes and continues Water. This certainly, was it not demonstrated by indisputable arguments, had never been believed. In Nature, therefore, there must be some weighty reason, that makes it necessary, that Water should be Water only in that degree of Heat, and should harden into the form of Ice, as soon as ever that is diminished.

Nor can its fluidity be farther increased. When the fluidity of Water, now, is once produced by this determined degree of Heat, it then continues exactly the same in every farther increase of it. Nor has it been possible, by any means whatever, to render Water still more fluid, tho' you make your Fire ever so strong. Water, therefore, always exists in its most fluid state, or becomes immediately Ice, and consequently, the Fire cannot by any action divide its Elements any farther, but only removes them from one another, which being accomplished, it at once becomes as fluid as its nature permits. This again, which otherwise would have been incredible, the incomparable *Newton* has made appear by a famous Experiment; for *Pendulums* oscillating in the very coldest, and hottest Water, discovered that they met in both cases with equal resistances. *Opt.* p. 312.

This, however, must be understood, to regard those changes of Bodies only, which our senses are capable of perceiving; and here we must consider only the lubricity of the Particles of Water, which we suppose affect one another with so small a cohesion, that it cannot, by Fire, be sensibly lessen'd: For otherwise, we know very well, that from the 33d degree of Heat, to the 212th, Water grows continually lighter and rarer, and consequently less resisting to the motion of the same Body, supposing it to continue of the same specific gravity. This increased rarity of Water we have determined already in our History of Fire. If we suppose then, that boiling Water takes up $\frac{1}{85}$th more space than it did before, how little difference can that make in the oscillation of a *Pendulum*, with regard to our senses? But then, besides, as the Body of the *Pendulum* too will grow hot in boiling Water, it will hence make this small difference still less sensible. And, indeed, if this was not the case, it is certain, first, that the resistance yielded by Fluids to the Bodies moved through them, depends upon the corporeal Mass of these Fluids, which is best express'd by their densities. Secondly, this resistance arises from the force with which the Particles of the Fluids, when they are at rest cohere with one another: Thus Wax, when it is cold and hard, will not transmit any Body through it, as it will when it is rendered fluid by Heat: Many express'd Oils, likewise, harden in the Cold; and even Water itself, when by its proper degree of Cold, it is frozen, loses for the future its power of letting Bodies pass through it. And thirdly, the quantity of this resistance depends likewise upon the magnitude, or smallness of those Particles, which together make up the Fluids, and into which they are at last resolved.

The Elements of Water small. But if we farther examine the ultimate Elements of Water, we find, that when they are singly and separately considered, they are exceeding small;

and that to ſuch a degree, that it has hitherto been impoſſible to diſcover their true ſmallneſs, ſo as to compare it with any known meaſure. For one of theſe Elements, when it is by itſelf, cannot, by any helps whatever, be rendered ſenſible; nor does it diſcover its ſize by concretion with other Bodies.

If we compare, however, the ultimate Particles of Water with thoſe of true elaſtic Air, the former ſeem to be much more penetrating than the latter, and diſpoſed to inſinuate themſelves into ſmaller Pores than theſe are capable of entering; as we have ſeen already in our hiſtory of Air. Does not Water paſs through the inviſible Pores and Interſtices of Wood, which never tranſmit the leaſt elaſtic Air? And in the *Apparatus* for pneumatical Experiments does not the Water ſoak through the Leather, under the edge of the Receiver; which perfectly intercepts the paſſage of the Air? It muſt be confeſſed, however, that this does not demonſtrate the true ſmallneſs of the corporeal Maſs which every ſuch Particle contains; for here we argue only from its penetrability, which depends more upon the figure of a Particle, than its true quantity of Matter. And if this conſideration is not properly attended to, we may fall perpetually into Miſtakes, by reaſoning from the penetrability of ultimate Elements to their true magnitude. Nor will it in this caſe be of greater ſervice to us to know the weight of theſe Particles; for from this, likewiſe, we cannot pretend to conclude certainly of their ſize. A grain of Gold, for inſtance, if it is formed into a perfect Sphere, will produce a Particle that will paſs through a ſmall *meatus*; but if you beat it out into a very thin plate, and then roll it up together, with how much difficulty will it paſs through a great one? But what particularly gives me reaſon to doubt whether the ultimate Particles of Air are not in reality leſs, with reſpect to their corporeal bulk, than thoſe of Water, is this, that the Elements of Air may be placed in theſe Interſtices that are left betwixt the contiguous Element of Water, without making the Water at the ſame time condenſable; which you remember I demonſtrated before in our Hiſtory of Air.

Perhaps leſs than thoſe of Air.

Tho' we cannot however certainly determine the ſmallneſs of the Particles of Water, yet this, in the mean time, we are ſure of, that there is no known Fluid, whoſe parts are more penetrating than thoſe of Water; except Fire, which penetrates every thing; Magnetiſm, if you ſuppoſe that to act like a Fluid upon Magnets and Iron; and Light, if you will have that to be different from Fire, and at the ſame time to have the nature of a Fluid. Setting theſe aſide, then, I aſk the Philoſophers, if they can produce any Liquor, which *cæteris paribus* will paſs through any paſſages that are impervious to Water? I am very ſenſible, indeed, that Oils will ſometimes ſoak through wooden Veſſels, in which Water might be contained; but then the Oil diſſolves the Oil, and Reſin of the Wood, and ſo they both run out together; whereas the Water, not being able to diſſolve the reſinous oily Subſtances, is very well ſecured, juſt in the ſame manner as we ſee Water won't run through Paper that is well ſoaked in Oil, though Oil itſelf drops through it readily. And hence it happens, that Syrup of Sugar, though a pretty thick Liquid, will penetrate through wooden Caſks that will hold Water; for Sugar diluted with Water is a *Lixivium*, which by its ſaponacious quality diſſolves the tenacious Subſtances of the Wood, which the Water cannot. Hence, too, ſaline *Lixiviums*, eſpecially from fixed Alcali's, can ſcarcely be contained in wooden Veſſels, which ſerve very well for pure Water.

Certainly more penetrating than others.

Water. Water, then, among all simple Liquors, that we are hitherto acquainted with, is the most penetrating, and most fluid.

Tho' there are many Bodies thro' which they cannot pass.

All Metals, however, though they are beat out into thin Plates, and then formed into Vessels, will hold Water, nor suffer it to pass through their Pores: All Gems exclude it, both the more precious and the less: No known Flints transmit it: Stones that are naturally hard, and hard, heavy, rocky Substances, perfectly resist its passage though them: Sulphurs are not penetrable by it; nor any Glass hitherto known, whether made from Flint, and an Alcali, or from Metals, if it is but well united, and has no Cracks in it: Some dense, hard, heavy, resinous Woods absolutely prevent its penetrating through them; though the lax, soft, light, watery, saline ones, are not capable of containing it, but suffer it to run through them; as do likewise Pumice-Stones, and other porous, spongy Stones: Our earthen Vessels made of Clay, and burnt Bricks, common Mortar made of Sand and Lime, and that made of the *Lapis Tophæus*, which vitrifies by drying, will hold Water likewise. Glass, however, which neither makes any alteration in Water, nor suffers any from it, affords us the best Vessels for keeping it. *Clavius*, the Mathematician, poured some Water into a Bolthead, and then sealed the mouth of its long neck hermetically, and marked with a Diamond the place to which the Water rose at that time; he then hung it up, and 80 years after, it was found in *Kercher*'s Study, just as full as it was at first; and perhaps it is so still, tho' it is now, since the Water was first put into it, 120 years.

Tho' agitated by Heat.

If Water is contained in a Vessel perfectly close, that will not melt when it comes to be hot, and the Water cannot pass through when it is cold purely on account of the smallness of the Pores of the Vessel; then, if it is agitated by Fire, it will still remain incapable of making its way out. This we see evidently in all our distillations made in proper Vessels: This the Experiment of *Christopher Clavius*, just mentioned, plainly evinces: This we see clearly in *Papin*'s Digester, and in the Æolipile, which being thrown into the Fire when full of Water, confines the Vapour of the Water, though agitated with a violent *impetus*, and only transmits it through the mouth when it's open'd. I know some great Masters in the Art are of another opinion, imagining, that the very ultimate Elements of Water are attenuated by Heat; so that after a great number of distillations, they acquire so great a subtlety as to be able to transpire through the Substance of the Glass. See the famous *Stahl*, in his *Fund. Chem. Dog. & Exp.* p. 38. § 7. But what he mentions there is upon the authority of other persons; and certainly it is a very difficult matter to lute the Vessels so accurately together, that nothing shall be able to insinuate itself through the cement. *Joachim Becher*, indeed, asserts, that Water, by a great number of repeated distillations, may be brought to have a surprizing, corrosive faculty. *Stathl.* 18. p. 120. § 6. But for my own part, in the great number of Experiments I have been engaged in, I don't remember ever to have seen the least sign of any such penetrability or acrimony. In the mean time, however, I have been abundantly convinced, that there is nothing more difficult in the chemical Art, than to repeat a distillation a great many times in an Elaboratory that is hot, and full of Vapours, without losing something of what you are distilling, and having something foreign mixed with it.

But

But it has been farther obſerved, that Water being contained in a ſtrong Veſſel, which it was not able to penetrate, could not, by being compreſſed by a vaſt force and weight, be made to paſs through its Pores, but remained totally included in it. Pleaſe to think only what a prodigious compreſſure there is in *Papin*'s Digeſter, and yet not a drop of the Water is forced through. The ſame thing was tried formerly in the Hydraulic Machine ABCD. This conſiſted of a hollow Cylinder AB, made of Braſs, and cloſely ſoldered up. At B only it opened into the Tube BC, which was ſoldered to it, and at C was produced upwards at right Angles to the height D of ſix feet, ſo that there was a free communication betwixt the Cavity AB, and that of the annexed Tube BDC. At A there was a Cock E, a little above the top of the Cylinder AF, by which you might keep in the Liquor in the Veſſel AB, or let it out at pleaſure. This then being open, the Veſſel AB, by pouring Water in at D, was perfectly filled; after which, the Cock being turned, more Water was poured into the Tube BC, which, according to the laws of Hydroſtatics, preſſed the Water in AB ſo forcibly, that the Veſſel was diſtended, and the Copper Plate AF was forced outwards, and raiſed up, though there was a great weight ſet upon it, and yet not one drop of Water ſweated through. But when the Water came to be raiſed almoſt as high as D, then by the prodigious preſſure, the ſoldering was burſt, and the Water run out at the Cracks. From theſe inſtances then, Gentlemen, it plainly appears, that Water, though it is compreſſed by the greateſt force, will not paſs through thoſe Pores, through which, by the fineneſs of its parts, it would not have inſinuated itſelf ſpontaneouſly.

Or by preſſure.

Pl. IX. Fig. 1.

There is a plauſible Experiment indeed mentioned by the *Academy del Cimento*, in their Hiſtory of Experiments, p. 203, 204. which ſeems to make againſt this aſſertion. For a hollow metal Sphere, being perfectly filled with Water, and then accurately cloſed, they put it into a ſtrong preſs, and upon compreſſing it very ſtrongly, they obſerved the Water to ooze through the Pores of the Metal. But here, as a Sphere is the moſt capacious of all Bodies, that are iſoperimetrical, it cannot, by the force of the preſs, be changed into any other figure, upon the incondenſable Water, without the cohering parts of the Metal receding from one another, and its ſubſtance being rendered thinner; and as the Water at the ſame time being compreſſed, acts as it were like an Augre upon the Pores of the attenuated Plates, it is poſſible, that the metalline, elaſtic *Lamina* may be ſo diſtended upon the Water which is not condenſable by any force, and conſequently of infinite reſiſtance, that the Water may be preſſed through the Pores of the Metal, which when the preſſure is over, may by its contractile force reſtore itſelf, and cloſe up the Pores again.

We are perſuaded, therefore, that as on the one hand the ſingle Elements of Water cannot be increaſed by any cauſe, except Fire alone, which ſeems to exert this power univerſally upon all Bodies; ſo on the other, that they cannot be leſſened but by the abſence of Fire, or Cold, or which is the ſame thing, by being left to themſelves, or freed from Fire. But this ſenſible diminution, now, of the Elements of Water, conſidered as they conſtitute Water, does not extend itſelf lower than to 32 degrees of Heat, for then Water continues Water no longer, but is converted into Ice. And that contraction of the Elements of Water, which happens after they come to be Ice, cannot be obſerved any longer, becauſe the Air, being expelled by the cloſer adunation of thoſe

By Cold alone they become leſs.

thoſe Elements, begins to form itſelf into elaſtic bubbles, which then by their elaſticity expand the Ice, more than the Cold contracts it. Hence, however, we underſtand a Paradox, which the Maſons affirm they have often obſerved, *viz.* that cold Water ſoaks through walls more eaſily than hot. For when we were treating of the dilating power of Fire, it appeared, that Water is more condenſed by Cold than Stones; ſo that the Pores of Stones are leſs contracted by the ſame Cold than the Elements of Water, whence it may happen, that Water, in its greateſt degree of Cold, may paſs through thoſe *Meatus's* which were too ſmall for its Elements, when it was hot.

Not to be attenuated by Fire.

This then being conſtantly obſerved to be the caſe, we conclude, that Fire, let its force be applied and continued in what manner you will, can never divide the Elements of Water into ſmaller Particles, but can only with its utmoſt effort extend them into a larger Bulk, and then ſtrongly agitate them among one another; which ſeems to be the limits of the efficacy of Fire upon Water. Rain-water, which was catched upon the Obſervatory of our Academy, I diſtilled in very clean Veſſels, and with a gentle Fire, and after having kept it ſome Years well ſtopped, I found it exactly the ſame, without the leaſt difference, whether chemically examined, or hydroſtatically.

But always kept in motion by it.

Since 33 degrees of Heat now diſſolves Water in ſuch a manner, as to render it fluid, hence we are certain, that the particles of Water are always in motion, ſo long as by this Heat it continues to be Water: For this Heat, in which Water is turned into Ice, is more than $\frac{1}{3}$ of the greateſt natural Heat; and certainly a Fire ſo great as is able to melt hard Ice, muſt neceſſarily be capable afterwards of keeping its Particles in motion. Hence, therefore, we ſuppoſe, that Water, though conſidered together as at reſt, has its Particles kept in a conſtant agitation. Nay, and the ſolution of Salts, too, in Water, ſeems to evince, that its Elements are in continual motion; though this ſolution, indeed, appears rather to be attributed to attraction, than repulſion: In the mean time, however, it don't ſeem likely that the whole Maſs would be diſſolved, unleſs the agitated Elements of the Water were kept conſtantly moving from one place to another, and by this means were ſucceſſively applied to the ſolvend Salt. By the help of Microſcopes, likewiſe, we are able to perceive a motion in the Particles of Water. And laſtly, it is plain, Water muſt be rarely at reſt, in any Veſſel whatever, as every thing almoſt on which it can ſtand, is continually affected with a tremulous motion.

And immutable.

Hence, therefore, are not the ultimate Elements of Water perfectly immutable? Certainly they ſeem ſo firm and conſtant to the Figure, which once they are formed with, that no power of Art or Nature has yet appeared capable of altering it. And this will always hold equally true, whether you conſider them ſingly and ſeparately, or as they are collected together, and compoſe one Body. For ſince from every Operation it returns conſtantly the ſame as when it was applied, neither becoming denſer or rarer, heavier or lighter, thicker or thinner, it plainly demonſtrates, that both the bulk and figure of its Particles have remained the ſame: For if by the force that acted upon them, their figure had been changed, then the contact of the Elements had been changed likewiſe, and conſequently, there muſt have been ſome alteration produced in the Interſtices between theſe Elements, whence would ariſe ſome difference in the denſity and gravity of the whole Body. Suppoſe, for inſtance, the Elements

ments of a Body to be ſpherical, and that theſe afterwards, by being compreſſed together, are changed into Cubes, then the Interſtices between the ſpherical Elements, in the firſt caſe, being the greateſt poſſible, would produce the greateſt lightneſs, and rarity, which being quite filled up by the Cubes, in the laſt, the Body would acquire its greateſt denſity and gravity: But nothing of this nature is ever obſerved in Water. In the Æolipile expoſed to a very ſtrong Fire, the Water, by the violence of the Heat, the reſiſtance of the Veſſel, and the ſtraitneſs of the paſſage through which it is let out, is prodigiouſly agitated, divided, and rarified; and yet the Vapour received into a Veſſel gives you always the very ſame Water that was put into it.

These Elements, therefore, ought by no means to be looked upon as a kind of little flexible Eels, moving about in ſinuous convolutions, as the ſubtil *Deſcartes*, and the famous *Stairs*, have imagined: But on the contrary, the ultimate Particles of Water ſeem to be exceeding rigid, perfectly inflexible, and of an adamantine hardneſs. Are they therefore perfectly ſolid Spheres? This ſeems ſufficiently probable. If the Air, therefore, that is intercepted betwixt theſe Elements ſhould reſide there in a ſpherical form too, then the Space taken up by the Water, would be to that taken up by the Air, as 100 to 7, nearly as 14 to 1, according to the computation of the ingenious *Cruquius*. Nor flexible.

But again, by various, and unexceptionable Experiments of the Academy *del Cimento*, it has been made evident, that the Elements of Water are not compreſſible by any force whatever. p. 197 to 207. *Du Hamel* likewiſe informs us, that a Sphere of Gold, when it was perfectly filled with Water, could not be compreſſed. That a Leaden Sphere, indeed, full of Water was compreſſible by the Hammer, *Colbertus* tells us, *Phyſic. General.* Part I. p. 4. Lord *Verulam* relates too, that a Tin Sphere, being filled with Water, and then ſtrongly compreſſed, upon making a hole in it, made the Water fly out. *Boyle* aſſerts, that it threw it to the diſtance of three feet. Exper. 20. and *Stairs* affirms the ſame, p. 396. Theſe laſt Experiments therefore ſeem to invalidate the Opinion of the Academy abovementioned: But here there are two things that ought to be carefully conſidered. In the firſt place, in the filling of theſe Veſſels, the Air may eaſily inſinuate itſelf, and lie concealed betwixt the Sides of the Veſſel and the Surface of the contained Liquor; and if this is the Caſe, then when it afterwards comes to be compreſſed, it will preſs out the Water wherever there is a vent, till it is reduced to the common denſity of the Atmoſphere. And ſecondly, as I hinted before, the Particles of the Metal being diſtended upon the Water, and endeavouring to contract themſelves, muſt, upon any Hole being made in the Veſſel, immediately force out the Water. Theſe inſtances, therefore, are not ſufficient to prove any compreſſibility, or elaſtic Spring, in the Water, which the *Florentine* Experiments ſeem intirely to deſtroy. Hence, then, Water, in reſpect to compreſſion, and the denſity that ariſes from it, appears to ſuffer nothing at all from the different weight of the Atmoſphere, let the variation be ever ſo great. And here certainly the Works of the Author of Nature appear very wonderful, whilſt we ſee one Element, as Air, formed with almoſt an infinite Elaſticity, whilſt another, as Water, is not elaſtic at all. In making all theſe Experiments, however, what a prodigious deal of caution is neceſſary? For if there is but the Nor compreſſible.

least common Air, besides what is in the Water itself, intercepted and detained between the concave Surface of the Vessel and the convex one of the Water, which may easily be the case, as we see by the Bubbles formed upon the polish'd Surfaces of smooth Bodies immerged in Water; I say, if there are any such Bubbles as these, though they are first exceeding small, yet afterwards, by being united together, they may form there a considerable quantity of Air, which, upon being compressed, will exert a very great expansive force, which one may be easily led to ascribe to the Water itself. But we must be very careful, likewise, that, during the time that the Experiments are making, the Heat of the Water is neither increased nor diminished; for as the expansion of Water upon Heat, and its contraction upon Cold, is very considerable, by this means, likewise, the event may prove fallacious. But in the third place, we may here take notice farther, that though the Air which is lodged in the interstices left between the Elements of Water, has there no actual elasticity, yet, when it is expanded by a certain degree of Heat, is forced out thence by a hydrostatical force, and becomes united together, it then acquires an elastic power, in the same manner as it does in the Air-pump, when it is absolutely drawn out of it; if this then should happen to prove the case here, the Air which before being dispersed through the Water, did not appear elastic, now it is separated, and not immediately absorb'd again into the Water out of which it was express'd, will exert a true elastic force. Except therefore all these cautions are carefully attended to at once, an error may easily happen in these Experiments: For which reason it always ought nicely to be examined, whether there are any such Bubbles in these Vessels, or no.

Water exceeding simple.

The fourth property which the order of our Subject leads us to take notice of in Water, is its exceeding great simplicity: For if it is pure elementary Water, it does not discover the least diversity in its parts, so that it is every where found to be exactly the same; and by what has been already laid down, it appears to be immutable in its bulk, figure, density, weight, and other Properties. The Alchemists now observing this constant simplicity of Water, fell into an opinion, that all Bodies, in particular the more simple ones, were produced from Water alone, as their original Matter, by means of a seminal faculty in their Seed, and a quickening Fire. Hence *Paracelsus Archid.* x. c. 3. Water is the proper Element or Sea, that is, the true Mother of all Metals. And *Helmont* throughout his whole Works endeavours to advance and inculcate this Doctrine. And for this reason they asserted farther, that all Bodies, when they are perfectly and radically dissolved, by the universal Solvent, are at last reduced into a homogeneous, elementary Water, their particular, seminal power being quite destroyed. Consult *Helmont* in every part of his Writings. This Opinion, however, seems rather founded upon History and Disputation, than any Experiments which have been related in such a manner, that a sober man can fairly give credit to them. For after *Moses*, the most ancient Writer, had delived a tradition, that the Spirit of God, brooding upon the face of the Waters, had communicated to them a prolific virtue, the wisest of the ancient *Persians* looked upon Water as the principle of Bodies. Hence the same doctrine came to be in vogue among the *Egyptians*, from whom *Thales* the *Milesian* carried it into *Greece*, by which means it at last came amongst the Chemists. Hence the followers of *Van Helmont* acknowledged only

only two ſimple, natural Bodies. *viz.* Water perfectly ſeparated from every thing foreign, and heterogeneous, and Mercury freed too from every thing heterogeneous, and from the taint of its own inherent, original Sulphur, whoſe ſimplicity then would be greater than even that of Gold. Mercury, however, itſelf they aſſerted to be the offspring of Water, from which it originally has its riſe, and into which it may at laſt be reſolved. Hence they ſuppoſed Water to be the univerſal nutriment by which all Bodies are ſupported, which no Art whatever is capable of making any alteration in, but only the innate faculty of created Seeds.

As a fifth property of Water, we reckon its mildneſs. And this quality it is endued with to ſuch a degree, that if it is reduced to the Heat of a healthy Body, and then applied to any of its parts, which have the quickeſt Senſe, it not only don't excite any pain, but it don't ſo much as raiſe any other ſenſation than what is cauſed by the natural humours, and the parts feel when they are perfectly ſound. If, for inſtance, it is applied to the *Cornea* of the Eye, than which there is ſcarce any part ſooner affected with pain from any thing ſharp, it does not cauſe the leaſt uneaſineſs. To the Membrane of the Noſe, which is made up of Nerves that lie almoſt bare, it is neither troubleſome, nor affects it with any new ſmell; nay, if you apply it ſoftly to the Nerves, when they are ſtretched with an inflammation, and from any very light cauſe grow ſo exceeding painful, it produces no manner of inconvenience. In crude Ulcers, which can't bear the leaſt touch of the ſofteſt thing without uneaſineſs, warm Water cauſes no irritation at all: Nay, foment even the bare and half-deſtroyed Nerves of an ulcerated Cancer with warm Water, and inſtead of increaſing the ſharpneſs of the Pain, you will aſſwage it; whereas if you apply any thing elſe to them, it will make it worſe. The organs of ſmelling it does not affect with any ſmell, thoſe of taſting with any taſte, thoſe of ſeeing with any colour, or the nerves with any ſenſation. Among all the humours of the human Body, it is found to be the mildeſt, even the Oil itſelf not excepted, which, let it be ever ſo ſoft, by its tenacity gives the Nerves a kind of uneaſineſs. And among thoſe Elements which Art is capable of extracting from theſe humours, Water, when it is pure, is always obſerved to be the moſt mild. And laſtly, it demonſtrates its excellent mildneſs, by being able to dilute things acrid, in ſuch a manner as to deprive them of their natural acrimony, and render them harmleſs, with reſpect to the human Body. A drachm of the Liquor drawn from Vitriol, for example, by the extreme force of Fire, called by the Artiſts the pureſt Oil of Vitriol, drank by a perſon with an empty ſtomach, would prove a violent poiſon, burning up his throat, *œſophagus*, and ſtomach; and yet if the ſame is diluted in ſix pints of Water, it will do no harm, though you drink it all. And in other inſtances the ſame thing nearly holds true.

Exceeding mild.

In reſpect, therefore, of both theſe qualities, warm Water is eſteemed one of the principal Anodynes, and Paregorics in Phyſic, and is hence recommended by *Hippocrates* as the ſofteſt Fomentation for the ſharpeſt Pains.

Hence an Anodyne.

The ſixth property which we obſerve in Water, is its diſſolving power, by which it is able to diſſolve certain Bodies in ſuch a manner, that when they are diluted in it, you will have a Fluid, in which the diſſolved Bodies ſhall be ſo equably diſtributed, that in every part of the Water there ſhall be a

The diſſolving power of Water.

 proportional

proportional part of the ſolvend. As this ſpeculation, now, is of conſiderable conſequence, ſo it will be moſt readily underſtood, by examining in order thoſe Bodies upon which Water is capable of acting in the manner deſcribed; and theſe are as follows.

First upon ſimple Salts.

Firſt, all true, ſimple, foſſil Salts, whether exiſting in a liquid or ſolid form. Hence *Sal-Gem*, Fountain Salt, Sea Salt, Borax, Nitre, *Sal-Ammoniac*, and the alcaline Salt of Chalybeat Waters, as it is juſtly accounted by the famous *Hoffman:* As likewiſe the foſſil, acid Salts, which are rarely found in a ſolid form, but being almoſt always liquid, are referred to the Acid of Sulphur, called the Oil or Spirit of Sulphur *per Campanam*; to the Acid of Alum forced out by an extreme Fire, called Oil of Alum; to a ſimilar Liquor, drawn in the ſame manner, from Vitriol, called Spirit or Oil of Vitriol; all which three ſorts of Acids, being perfectly depurated, and reduced to their greateſt ſimplicity, ſeem hardly at all to differ from one onother. It is exceeding difficult indeed to free them intirely from all their Water, and when you have done it, they immediately attract more into them out of the Air, as greedily as fixed, alcaline Salts do, when they are dried in the ſtrongeſt Fire. When you have ſeparated it from them, however, very nicely, they may be kept ſome time in the Cold, in form of ſolid Chryſtals; but as ſoon as ever they attract any moiſture out of the Air, they melt again, or if they are expoſed to a ſomewhat greater degree of Heat, for then, like Ice, they perfectly become fluid. Hence, however, we ſee, that theſe acid Salts, when they are quite freed from their Water, are capable of acquiring a ſolid form, though they retain it with a great deal of difficulty. The other ſimple, foſſil, acid Salts, are the acid Spirits of Nitre and Sea Salt; and theſe are always fluid; for they are of ſo volatile a nature, that they themſelves fly off with that degree of Heat, that is neceſſary to ſeparate their Water. All theſe foſſil Salts, now, may be diſſolved in Water, according to the Law abovementioned.

In a different manner,

In the ſolution, however, effected in this manner, there is obſerved a very conſiderable and manifold diverſity. For in the firſt place acid Salts, that are almoſt always liquid, and therefore are already diluted with ſuch a quantity of Water, as to render them fluid in a certain degree of Heat, may be diſſolved in any quantity of Water whatever, be it ever ſo ſmall: If you take, for inſtance, a pound of the ſtrongeſt Oil of Vitriol, and mix it with only one drachm of Water, you will ſo accurately divide the Elements of the Oil of Vitriol, that it ſhall be all perfectly diſſolved in this one drachm of Water. And this is the caſe of all other acid Salts, that we are hitherto acquainted with. But on the contrary, thoſe foſſil Salts that are of a ſolid form, will not ſuffer themſelves to be diſſolved, except you apply to them a certain quantity of Water. If you make uſe of leſs than is neceſſary for this ſolution, then, ſuch a part only of the Salt will be melted, as that quantity of Water will take up, the remainder ſtill continuing ſolid. When theſe Salts, however, are once perfectly diſſolved in a proper quantity of Water, they may afterwards be farther diluted in any quantity whatever. Take, for inſtance, an ounce of dry *Sal Gem*, and diſſolve it in three ounces of Water, and you will have a ſimple *Lixivium*, to which, if you add only one ſcruple of Water, the *Lixivium* will be perfectly and equably diluted by it. And this property, certainly is very remarkable, inaſmuch as there is no end to this dilution; for when a foſſil Salt is once

diſſolved

diſſolved in Water, it may afterwards be diluted in the ſmalleſt or greateſt quantity of Water, in ſuch a manner, that in every portion of the ſolvent Water there ſhall be a proportional part of the diſſolved Salt. But in this diſſolving power of Water it is obſerved, in the ſecond place, that if the Water poured upon the Salt is ſhook about with it, the ſolution is ſooner effected, and more Salt is diſſolved; whereas, if it ſtands quiet, it is longer about, and the Water takes up leſs. In the third place, hot Water diſſolves Salt in a great deal leſs time than Cold, and takes up, and retains a great deal more. Hence Water that has only 32 degrees of heat in it, performs its office ſloweſt, and diſſolves leaſt Salt of all; whilſt boiling Water, which has 212, does it quickeſt, and diſſolves moſt. And this is always obſerved to happen in proportion to the degree of Heat and Cold. For if you diſſolve Salt in boiling Water, 'till the Water is perfectly ſaturated, and then remove the Veſſel from the Fire, you will obſerve, as the Water grows gradually colder and colder, it will continually precipitate more and more Salt to the bottom, 'till at laſt, when it is reduced to the 32d degree of Heat, it will have diſcharged a very large quantity of Salt in a ſolid form; and if then by a ſtill greater degree of Cold, this ſalt Water begins to freeze, there will in that caſe be yet more Salt ſeparated from it, ſo that in the ſharpeſt Cold of all it will be nearly all expelled, and ſo long as that Cold continues, will remain with the Ice, of a ſolid conſiſtence. But again, the ſalt Water, which when acted upon by ſo ſharp a degree of Cold, diſcharg'd the greateſt part of its Salt, will be much ſooner thaw'd again upon the application of Salt to it, than common Water will without, in the ſame degree of Cold: For as Salt, on the one hand, by being mixed with Water, keeps it from freezing, 'till the Cold is increaſed a good deal below that point in which pure Water would have froze: So, on the other, if you apply Salt to Ice in that very ſame degree, preciſely, in which if the Salt had been mixed with the Water, it would have been juſt upon freezing, it will reduce this Ice to Water, though without it, the Ice would have required ſeveral more degrees of Heat to diſſolve it. By this ſurprizing property, then, we ſee, that Salts have a power to prevent the aſſociation of the parts of Water, and their concretion into Ice, and that by the application and interpoſition of their own Particles. Hence the Water of the Sea is a good while longer before it freezes than freſh Water, and requires a much greater degree of Cold. In the fourth place, the concretion of Salt, before diſſolved in Water, called chryſtallization, appears from what has been ſaid to ariſe, firſt, from the want of a ſufficient quantity of Water to dilute it; ſecondly, from the Liquor's being at reſt, in which the Salt is diſſolved; and, thirdly, from Cold: For theſe three are the inſtruments by which chryſtallization is brought about. But in the fifth place, we obſerve farther, that the diſſolving power of Water operates much ſooner upon one Salt than another; as we ſee *Sal Gem* is ſooner diſſolved, in the ſame Water, than Borax: and the ſame quantity of Water too will diſſolve more of one Salt than another, as we ſee likewiſe in the ſame Salts. And ſixthly and laſtly, when Water is ſo perfectly ſaturated with one kind of Salt, that if you add any more it will fall undiſſolved to the bottom; yet even then it will be capable of diſſolving a good deal of another ſort, and that without letting go the former. Saturate, for inſtance, Water of a certain degree of Heat with *Sal Gem*, ſo that it won't diſſolve the leaſt grain more, and it will, nevertheleſs, take up a ſmall

quantity

quantity of Nitre; and yet the *Sal Gem* will remain perfectly diſſolved in the Water as before. Nay, and when it is thus ſaturated with theſe two Salts, it will ſtill be able to diſſolve ſomewhat more of another. If the Philoſophers and Chemiſts, therefore, would properly conſider theſe *Phænomena*, it would open a way to farther inquiries into the nature of the Solution that Water exerts upon Salts, than have yet been made.

Secondly, upon compound Salts. In the ſecond place, pure Water diſſolves thoſe Salts that are called Metalline, or Terreſtrial Salts; by which we mean the Chryſtals or Vitriols produced from Metals corroded by Acids; and that, whether theſe Acids are Foſſil ones, as in Vitriol and Alum; or Vegetable ones, as in Verdigreaſe. All theſe Vitriols, now, it appears by chemical Experiments, are compounded of a ſolvent Acid, a Water diluting this Acid, and a corroded Metal, united by a certain Law, and in a certain proportion into one Glebe. Whilſt all theſe Bodies are thus diſſolved in Water, the ſame ſix conditions juſt now mentioned, will hold good in theſe likewiſe.

And upon thoſe of Animals and Vegetables. But in the third and laſt place, Water has a power alſo of diſſolving the Salts, both of Animals and Vegetables, whether native, or produced by Art. Acid, Rough, Salt, Alcaline, Compound, Ammoniacal, Fix'd, Volatile, Semi-fix'd, and Simple ones, thoſe ariſing from a Salt and Oil, combined together, and thoſe produced by Fermentation, Putrefaction, and Combuſtion, are all diſſoluble to Water. But here again, there is obſerved the ſame variety in the ſolution, as we obſerved above. And among all theſe different kinds of Salt, Tartar is diſſolved with the greateſt difficulty.

Theſe things confirmed by Experiments. All theſe things, now, I'll demonſtrate to you by various Experiments. Firſt, then, in this Glaſs, I have an ounce of pure Water, into which I drop four drops of Oil of Vitriol, and upon ſhaking it together, the Liquor through the whole grows equally acid. 2. Here again, I have an ounce of Oil of Vitriol, into which I drop four drops of Water, and upon ſhaking the Veſſel, the Liquor, as before, becomes uniformly acid. Hence then it appears, that acid Salts, whether mixed with Water in a greater or leſs quantity, are moſt equably divided by it, and moſt intimately diſperſed through it. 3. With an ounce of Water, I mix half an ounce of dry Sea-Salt, part of which diſſolves, and the remainder lies undiſſolved at the bottom. 4. To a very ſtrong Brine of Sea-Salt, I add any quantity of Water whatever, and they very equably mix with one another. 5. If the ſame is performed with Nitre, *Sal Gem*, Borax, *Sal-Ammoniac*, Salt of Tartar, a dry alcaline Salt, a volatile alcaline *Sal-Ammoniac*, with Alum, or Vitriol, the effect will be perfectly the ſame, as in the third and fourth Experiments: All which I have here ſet before you. Theſe Salts, therefore, in order to be perfectly diſſolved, require always a certain determined quantity of Water, nor can Water diſſolve ſolid Salts, but to a limited portion of them. All theſe Salts, now, that I here made uſe of, were firſt very carefully dried, and reduced to a very fine Powder. If we could, by any Art now, perfectly free acid Salts from all the Water that is mixed with them, it is very probable, that their Particles being then united and concreted into a ſolid form, would in a certain degree of Heat require a determined quantity of Water to reduce them again to a ſtate of fluidity: For if the ſtrongeſt Oil of Vitriol is expoſed to a great degree of Cold, it requires a certain portion of Water to prevent its ſhooting into ſolid Chryſtals; nor will that which is

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diluted with Water thus congeal in the Winter, but only that which is exceeding pure. It is not an eaſy matter, however, to give you an inſtance of exhibiting pure acid Salts in a ſolid form, without the concurring aſſiſtance of a very great degree of Cold, and hence Perſons have generally imagined, that theſe acid Salts may be always diluted with the leaſt quantity of Water; but this, you ſee, muſt be underſtood with ſome reſtriction, agreeable to what we have now obſerved. And thus much for the proof of the firſt propoſitions.

Into three ounces of the pureſt diſtill'd Water, I here put one ounce and one drachm of Sea-Salt, all which, if they ſtand at reſt, will diſſolve in time, tho' ſlowly; but if they are ſhook ſtrongly together, it is all diſſolved preſently. To the ſame quantity of Water, in each of theſe Veſſels, I add the ſame quantity of Salt, but one of them I keep here in the Cold, whilſt I ſet the other upon the Fire; and the Salt in the warm Water diſſolves much ſooner than that in the Cold. With twelve ounces of diſtill'd Water, I here mix five ounces of Sea-Salt, and upon boiling them together, they are intirely diſſolved: I add now as much boiling Water as was loſt by boiling, and you ſee in this degree of Heat, there is a perfect Solution. I cover the Veſſel that nothing may exhale, and ſet it by to cool, and the Salt concretes again in the Cold, and from the degree of ebullition, quite down to the degree 32, this *Lixivium* of Sea-Salt, which was as well ſaturated as it could be rendered by boiling, forms and depoſites every moment more and more Salt. Hence then we learn, that the ſame quantity of Water in the Summer time, takes up more Salt than it does in the Winter; in a hotter Climate diſſolves more than it does in a cold; and conſequently, moſt of all in the Torrid Zone, and leaſt about the Poles: But as putrefaction, *cæteris paribus*, prevails in proportion to the degree of Heat to which Bodies are expoſed, we ſee it is wiſely provided, that in hot Countries there ſhould be ſo much more Salt diſſolved than in cold ones, which beſt reſiſts it. Boiling Water, then, will diſſolve as much Salt, as Water can poſſibly take up: Water that is in the very next degree to freezing, leaſt of all. But even Ice itſelf congealed from Salt-water in every increaſing degree of Cold down to O in *Fahrenheit*'s Thermometer, diſcharges continually more and more Salt, ſo as at laſt to retain but an exceeding ſmall quantity, in the greateſt obſerved natural Cold. All theſe Obſervations, then, make it evident, that in the Elements of Water there is a natural diſpoſition, which, when they are acted upon by Fire, makes them liable to be ſo ſeparated from one another, that the Particles of Salt may be diſpoſed in the Interſtices between them: And that on the other hand, when the Heat is withdrawn, and they are left to themſelves, they then ſpontaneouſly attract one another in ſuch a manner, as to leſſen theſe intercepted ſpaces, ſo that the Particles of Salt can remain there no longer, but upon the nearer approach of the aqueous Elements are expelled from between them. The diſſolving power of Water, therefore, with regard to Salt, depends partly upon the Salt and Water, and partly upon the quantity of Fire that is united with them both. And hence, tho' moſt of the Chemiſts, indeed, would have it otherwiſe, it is evident, that it is impoſſible to determine how much Salt may be diſſolved in a given quantity of Water, unleſs the degree of Heat is firſt accurately adjuſted in which the Solution is performed. And for this reaſon, it ſeems certain, farther, that Water, without the aſſiſtance of any Heat at all, is not able to diſſolve the very leaſt quantity of Salt, that is, that Salt will not

The quantity of Water neceſſary to dilute Salts.

be

be diluted by the very coldeſt Ice. And here, again, it is very remarkable, that Salt, by being mixed with raſped Ice ſhould make it thaw, and yet by the very ſame means ſhould excite ſuch a prodigious degree of Cold: This appears every where evident, but moſt of all ſo in thoſe Experiments of *Fahrenheit's*, which we related to you, p. 99, which certainly evince, that Salt has a power of heating the coldeſt Bodies, and of expelling Cold from them into the neighbouring Bodies and Spaces; which again, is a wonderful Law of Nature. But as I am not treating profeſſedly of this ſubject now, I muſt proceed, tho' I have a good many more things that I could add, which, perhaps, I may do hereafter: What I have offered, will in the mean time afford you matter of ſpeculation and farther inquiry. Give me leave, however, to propoſe a few more Experiments which I have made relating to our preſent buſineſs. When the common Air was 38 degrees warm, I took of the pureſt drieſt Sea-Salt reduced to a fine powder 2 ounces, which ſuffered themſelves to be diſſolv'd in 6 ounces 3 drachms of pure diſtill'd Rain-water; ſo that here 4 parts of Salt required 13 parts of Water. One ounce of *Sal Gem*, prepar'd in the ſame manner, required 3 ounces 2 drachms of the ſame Water, the proportion here being the ſame as the former, *viz.* 4 to 13. One ounce of pure dry powdered *Sal-Ammoniac*, was diſſolved in 3 ounces 2 drachms of the ſame Water. Nine drachms of pure dry Nitre, reduced to Powder, took up 6 ounces of the ſame diſtill'd Water; ſo that there were 3 parts of Nitre, to 16 of Water. Half an Ounce of very dry Borax, required more than 10 ounces of Water to diſſolve it intirely; hence the proportion, as 1 to 20. One ounce of Alum was diſſolved in 14 ounces of diſtill'd Water. One ounce of *Epſom* Salt, in 1 ounce 2 drachms: One ounce of Salt of Tartar, in 1 ounce and $\frac{1}{2}$. Three ounces of Water, ſhook ſtrongly, and for a good while, with $\frac{1}{2}$ an ounce of the *Arcanum Duplicatum* of the Duke of *Holſace*, diſſolved it perfectly. And laſtly, by ſhaking them together for ſome time, 3 ounces of Water diſſolved intirely 1 drachm and $\frac{1}{2}$ of common green Vitriol. Hence, then, we infer, that different Salts require a very different quantity of Water to diſſolve them: That ſome are diſſolved ſooner than others: That thoſe which ſpontaneouſly melt in the Air, diſſolve ſooneſt, and in a very ſmall quantity of Water; which too ſeem of a more active nature: And that theſe, when they are expoſed to the Fire, part with the Water in which they are diſſolved, with ſo much the more difficulty, ſo that Salt of Tartar, and Oil of Vitriol, cannot be freed from their Water without a very great degree of Heat. To theſe 3 ounces 2 drachms of Water, now, which has diſſolved in it 1 ounce of Sea-Salt, nor is capable of taking up any more of this Salt, I add $\frac{1}{2}$ a drachm of Nitre, and this diſſolves in it. Again, with theſe 6 $\frac{1}{3}$ ounces of Water, which contain 1 ounce of diſſolved Nitre, and are perfectly ſaturated, I mix $\frac{1}{2}$ an ounce of Sea-Salt, and it diſſolves intirely. Hence, therefore, Water, when it is ſaturated with one ſort of Salt, ſo that it cannot take up any more of that, is nevertheleſs ſtill capable of diſſolving ſome more of another. Fountain-Salt, *Sal Gem*, Sea-Salt, *Sal-Ammoniac*, Nitre, and Borax, being reduced to their particular Brine, may be intirely and intimately mix'd with one another. In the Solution, however, of a metallic Vitriol by Water, it ought particularly to be taken notice of, that this cannot be perfectly dried before this Solution, but it will be altered in its Nature: Nay, and whilſt it is diſſolved in this manner, it always lets fall to the bottom a good deal of of indissoluble Ochre; and hence by repeated Solution and Chrystallization of Vitriol in Water, the whole substance is at last converted into Ochre, and a pinguious Liquid, that cannot be easily dried. The easier, therefore, the sooner, and with the less quantity of Water, Salts are dissolv'd, the more strongly they seem to retain their Water when they have once received it. But in the Solution of Metals, now, by Water, there are some *Phænomena* that are very singular, and well worth our consideration. Metals have some Salts, by which they may be dissolved; and when they are found dissolved by these into vitriolic Glebes, they then suffer themselves to be diluted in Water: And this Solution is always soonest effected, and is most perfect, when these Glebes abound with that Salt, which such a particular Metal is principally dissolved by; for then pure Water will so perfectly dilute such a Glebe, that the metallic Particles will be most equably distributed through the Water. But on the other hand, when in Vitriols, part of the solvent Salt is wanting, then Water poured upon them, will dissolve the Metal so much the less, so much slower, and more imperfectly, especially if you add too great a quantity; for then there is always some part of the Metal precipitated to the bottom. But when Metals are dissolved in a good quantity of their solvent Salts, and then diluted with Water, by a gentle exhalation they are reduced into solid vitriolic Glebes called Magesteries, Salts, Vitriols, Sugars, and Chrystals of Metals. In all these now, the Metal, its solvent, and pure Water, are always combined together in a certain proportion, and form pellucid, brittle Masses, dissoluble in Water, fusible in the Fire, and hence convertible into a fine Calx, which lose their transparency, as soon as ever the Water is drawn from them. By this Art, now, Metals are rendered potable, without much inconvenience, and with a medicinal effect that may be pretty certainly determined, as they are thus rendered dissoluble in Water. For in the first place, these Bodies will act by the Acid which dissolves the Metals, and then adheres to them. Secondly, by vertue of the metalline Mass dissolved by this Acid, and now in the Vitriol; for this metalline part will then act by the properties common to all Metals. And thirdly, in which their principal efficacy consists, these Vitriols will act by that singular vertue which is proper and peculiar to every particular Metal, and which is generally inimitable by any other. But fourthly, these Bodies likewise acquire a farther power, arising from the union of these three together, thus all united by the mediation of Water, in particular, into one Mass, which now acts by their whole joint efficacy. Of this kind now, thus produced by Water, are Vitriols of Gold, Mercury, Lead, Silver, Copper, Iron, and Tin.

This rule, however, must not be extended to all Semi-metals, as if Semi-metalline Particles, reduced by their solvent Acids into Masses appearing saline, might be afterwards diluted, and dissolved in Water like Salts, and true Metals. The purest metalline part of *Regulus* of Antimony, for instance, is perfectly dissolved in the strong Spirit of Sea-Salt that adheres to the corrosive sublimate of Mercury, in the distillation of Butter of Antimony; for what else is this Butter of Antimony, but a true vitriolic Salt of *Regulus* of Antimony, made by a combination of it with Spirit of Sea-Salt? Hence, therefore, from our History of metalline Salts, a Person would be apt to imagine, that this Butter, likewise, might be dissolved in Water; but how much would he be disappointed, when he came to make the Experiment? For as soon as ever the Water

Water don't dissolve all metallic Salts.

comes to this icy Glebe, the solvent Acid immediately lets go the dissolved *Regulus*, mixes itself with the Water, and gives you again intirely the semi-metalline corroded *Calx* that lay conceal'd in the Butter. This rule, therefore, must not be carried beyond its proper limits.

Water dissolves Alcohol.

Water dissolves Alcohol, not spontaneously, but if they are shaken together; for if Water is gently poured upon Alcohol, it passes through it, and falls to the bottom, whilst the Alcohol swims at top. Nay, it will not readily so dissolve Alcohol, but that after you have shaken them, the Alcohol will still in some measure cohere together, and float about in the Water in pinguious *striæ*: If the concussion, however, is continued for a good while, it will at last be perfectly diluted, and equably distributed through the whole Water. This tenacity, now, of the parts of the purest Alcohol, appears no where more elegantly than in an Experiment I formerly shewed you, p. 258, when I took a chemical Vial full of Water, and inverting it, immerged the mouth into Alcohol, for then you saw the Alcohol ascend through the Water without mixing with it, rise into the Belly of the Glass, and collect itself together at top. Since, therefore, pure Alcohol is a vegetable Oil reduced by the efficacy of a proper fermentation into these Spirits, which burn, and are miscible with Water;

Therefore fermented Oils.

Hence we learn, that even Oils themselves, after they have first been chang'd in this manner, may be intirely mixed with Water, let them be ever so pure, tho' sooner, indeed, and more easily, if they are diluted in some quantity of it already; for common Spirit of Wine mixes more readily with Water, than the purest Alcohol.

Water and Salt don't dissolve Alcohol.

In the mean time, however, it is particularly remarkable, that Water, when it is perfectly saturated with Salt, will by no means mix with Alcohol; nay, if you shake them together ever so strongly, and for ever so long a time, you will never reduce them to one uniform Fluid, but will find on the contrary, that they repell one another much more powerfully than any other two known Liquors in Nature. In this Vessel here, I have some Oil of Tartar *per deliquium*, in this other some Alcohol, both of them pure transparent Liquors: These, now, I mix together, and you see they continue perfectly distinct, the Oil of Tartar subsiding to the bottom, whilst all the Alcohol swims at top. But I'll shake these now with all the force I am able, and what is the consequence? Why the Oil again collects itself together, and the Alcohol rises united above it, nor so much as the least drop of either of them remains mixed with the other. Nay, farther, I put these two Liquors into a tall Bolthead, and made them boil, in order to try whether by this means I could not make them mix together, but I found it was to no purpose, for both of them continued perfectly separate from the beginning to the end, even in the act of ebullition, but the Alcohol being raised by the strength of the Fire, was separated from the Water, which remained at the bottom with its Salt.

Water sometimes attracts Alcohol, and deposites Salt.

But there is still something farther very extraordinary in this affair, and that is, that if Water is thoroughly saturated with a Salt that may be very easily separated from it, then if you mix the purest Alcohol with this *Lixivium*, the Alcohol will unite with the Water, and the Salt will be expelled and precipitated to the bottom in form of a dissolved Salt. In this Glass I have the strongest *Lixivium* that can be made with *Epsom* Salt and Water, which you see is quite

quite clear, nor has the leaft fign of any Salt in it. Into this, now, I pour fome Alcohol, and it fwims at top: But I fhake them as you fee together, and now the Liquor grows turbid, opake, and whitifh, and lets fall fome little Chryftals of Salt, by this means feparated from its diffolvent Water, which is now united with the Alcohol. And in the *Offa Helmontiana*, where there is as much volatile alcaline Salt of *Sal-Ammoniac*, diffolved in Water, as it can poffibly take up, and then an equal quantity of the pureft cold Alcohol is poured upon it, the Liquors being fhaken together, inftantly coalefce into a white folid Glebe, from which in a little time there is feparated fome Water attracted into the Alcohol.

But another thing to be obferved in this diffolving power of Water is this, that if it is mixed with Alcohol, that has a diftilled Oil diffolved in it, then the Oil will be feparated from the Alcohol. This you'll fee, if you'll pleafe to attend to the following Experiment. I have here fome exceeding pure Alcohol, in which I have diffolved fome choice Oil of Cinnamon, and you perceive how equably clear it is, without the leaft fign of any Oil fwimming in it, or falling to the bottom. Into this mixture, I now gently drop fome Water; and don't you obferve how the Liquor immediately grows white, and from a tranfparent one, becomes opake? But you obferve farther too, that the Oil, which before was fo perfectly diluted, as to become imperceptible, difcovers itfelf now, and collects itfelf together. Hence, then, it appears evident, that Water, being mixed with Alcohol, renders it unfit for the Solution of thefe Oils: That Alcohol unites more eafily, and in a more kindly manner with Water than with thefe: And that thefe Oils, when they are diluted with Alcohol, do neverthelefs continue real Oils, tho' they do not, during that time, appear in form of Oil, but of Spirits. Refins too, may be diffolved in Alcohol, fo as not in the leaft to appear; but if you mix Water with this Liquor, it inftantly becomes very white, difcovers again the latent Refin in the Alcohol, and yields you the very fame quantity of Refin that was diffolved: This is true in every kind of Refin whatfoever. Thefe refinous Subftances, therefore, may be diffolved in Alcohol, may be recovered from it again by the help of Water, may be diffolved again, and precipitated as before, and this may be repeated as long as you pleafe. This I learned by a great number of repetitions of thefe Operations in Refin of Scammony. But let us take Camphire a little into confideration: What kind of Body do you look upon this to be? You'll be apt to anfwer, a Refin. Shew me then any other Refin in the World, that may be fublimed dry, without any *refiduum*, or any alteration in its parts: In this particular, therefore, it is different from all Refins: This, however, may be perfectly diffolved in Alcohol, and upon the affufion of Water, exactly like other Refins, will be recovered into true folid Camphire, intirely the fame as it was before. Upon the whole, then, it appears, that Water attracts Salt of Tartar more powerfully than it does Alcohol: Whilft on the other hand, it attracts Alcohol more ftrongly than that does Oils, Refins, and Camphire.

Water diffolves the Alcohol out of Oils, Refins, and Camphire.

But Water, again, diffolves every compofition that is properly called a Soap, or a faponaceous Body, and that, whether it is artificial, or natural: Nor does it at all fignify, whether it is fixed or volatile. For every *Sapo* is compounded of an Oil and an alcaline Salt, fo united together, that they may be diluted in Water in fuch a manner, that there fhan't be the leaft appearance, either of the

It diffolves Sapo's, and faponaceous Subftances, and by this its Power is increafed.

the Oil or the Salt, but the whole mixture ſhall appear homogeneous. The particular property now of ſuch a Subſtance is this, that if it is intimately mixed with Oils, oily Subſtances, Reſins, reſinous Subſtances, Gums, and gummy Subſtances, Gum-Reſins, or any other tenacious Bodies formed from theſe, it will render them miſcible, and diſſoluble in Water, ſo that they may by this means be waſhed off from the Bodies to which they adhere. Water, therefore, not only diſſolves true Soaps, but by being aſſiſted by them, acquires a power of diſſolving thoſe Bodies, which otherwiſe would have been beyond its efficacy: The diſſolving Power, therefore, of Water, by the help of Soap is vaſtly increaſed.

Water diſſolves Air. One would ſcarcely have believed, however, that Water had a power of diſſolving Air, unleſs this had been abſolutely demonſtrated before in our Hiſtory of Air. See p. 299, 300. But this in the mean time is effected only in a particular manner, and to a certain degree, but no farther; and indeed, with this circumſtance, that the Air, whilſt it continues thus diſſolved, no longer retains that elaſtic quality which is proper to it. See the places juſt cited. In this reſpect, therefore, Water diſſolves Air, as it does Salts, that is to ſay, in ſuch a manner, that the ſmall Particles of Air diſpoſe themſelves between the interſtices left between the Elements of Water, as thoſe of the Salts do; and whenever all this Air is perfectly ſeparated from its diſſolvent Water, by Froſt, the removing the preſſure of the Atmoſphere, Fire, the Sun, or the Mixture of certain Bodies together, there is then immediately juſt ſo much Air imbibed by the Water as was diſengaged from it.

And earthy Bodies, firſt prepared. In the laſt place, Water is capable of diſſolving many earthy Bodies, when they are firſt prepared; tho' whilſt they were alone, they could never be diluted, and diſſolved by it. Oyſter-ſhells, the Claws, and other ſhelly parts of Lobſters, and Cray-fiſh, the Shells of Snails, and River and Sea-fiſh, Stones, the *Calculi*, and ſtoney concretions in Animals, their Horns, Hoofs, Bones, and the like, when they are firſt perfectly corroded by their proper ſolvent Acids, may be afterwards intirely diſſolved in Water: Nay, and Chalk, Corals, Pearls, Mother of Pearl, calcined Stones and Flints too, have long been inſtances of the ſame thing.

Other Bodies it cannot diſſolve. Having thus then given an account of the Bodies that Water is capable of diſſolving, it may be properly enough inquired, which then are thoſe that are capable of ſtanding out againſt this diſſolving power? Why, to this queſtion we ſhall then only be able to anſwer, when we are certain that we are maſters of ſome Water that is abſolutely pure, without the leaſt Mixture of Salt; for Bodies are very often diſſolved by the vertue of latent Salts, and the effect is falſly aſcribed to the Water itſelf; whereas, was this Water quite pure, we might then be able to judge, whether this vertue belonged to the Water alone. In Metals, in particular, the thing is exceeding difficult, inaſmuch as Iron, when wetted with the pureſt Rain-water, is converted into a Ruſt, and Copper into a Mould. The famous *Joel Langelotte*, indeed, has in his Writings aſſerted, that Gold may be diſſolved by attrition alone: And the ingenious *Homberg* affirms, that ſimple Water, by being rubbed for a long time with Metals, nay, even Gold itſelf, is capable of perfectly diſſolving their Subſtance into a potable, medicinal form. Theſe Experiments I have read and examined; but as theſe have been made in the Elaboratories of Chemiſts, where the Air is impregnated with all kinds of volatile Salts, I have always doubted, whether these Solutions should not properly be attributed to these Salts; especially, considering that the rubbing in these cases was continued for the space of whole months, in which time, tho' but a very small quantity of Salt was applied at once, yet the aggregate of all together, must be pretty considerable. The most ancient, indeed, of the Alchemists, were of opinion, that all things are produced from Water, and at last are resolved into it; and tell us, that Bodies must be always resolved by principles consentaneous to their origin; and hence have acknowledged Water to be the universal *Menstruum:* But they have never let us into the method of practice that would confirm their Doctrine. Pure Earth, however, perfectly free from every kind of Salt and Sulphur, Water will not dissolve; nor will it attenuate and dilute Glass, Gems, Chrystals, or Stones that are perfectly simple. Hence a great many Bodies of this kind, or compounded of these, it leaves intirely untouched. Hence, therefore, we infer, that Water is not a universal Solvent, but that it is limited to those Bodies which we have enumerated.

Water insinuates itself into the Pores of Bodies.

Having thus, then, carefully examined the properties of Water, we easily perceive, that it will readily insinuate itself into the invisible, nay, the smallest Pores of a great number of compound Bodies. For as it is very heavy, and consists of Particles that are exceeding subtil, its very great lubricity, and its easy separability into its Elements, will dispose them to penetrate with the greatest ease into the smallest interstices. But the very efficacious power that it has of dissolving such a vast number of Substances, very frequently effects too the resolution of the matter that stops up the Pores of Bodies, and by this means, likewise, it procures itself a passage into them; especially, as its ultimate Elements are exceeding firm and immutable, and hence have a true mechanical vertue, as well as that singular one, which depends upon their contractility.

Hence increases their weight.

When, therefore, by this power it has insinuated itself into the minute Pores of Bodies, and perfectly penetrated through their whole Substance, it is no wonder that by this addition of new matter, it should increase their weights. And this augmentation in many of them, which have a pretty great attractive power, with regard to Water, is very considerable; as in almost all Salts, the fixed alcaline ones in particular; most Soaps we are acquainted with; even pure fermented Spirits; and many Solids. Hence those Persons who sell by weight, find a considerable advantage in disposing of such kind of Goods in damp cold Weather, when they buy them in hot and dry. And by this means the Chemists have been sometimes deceived, who taking notice of these increments, and decrements of the weights of Bodies, have frequently ascribed them to fictitious causes, when in reality, they depended only upon this addition of Water.

And bulk.

But as it thus increases the weight of Bodies, so likewise it does frequently their Bulk. Hence, therefore, we perceive, that it does not only take possession of their vacuities, but that it exerts likewise a power by which it separates the solid Elements from one another. This appears to be true by numberless Experiments, but never more evidently than in one made and proposed by the *Academy Del Cimento.* Experiment 184. which because the Book is scarce, you'll give me leave to insert here.

A Cone

Pl. IX. Fig. 2. A Cone AB was made of solid Steel, and formed as exactly as possible, and its altitude divided into some equal parts. There was then another Cone CD made of a piece of Wood cut longitudinally out of a Tree, which was hollowed in such a manner, that its internal conical Surface was fitted exactly to the Convex Steel Cone AB, when the wooden Cone CD was dry. This wooden hollow Cone was then made thoroughly wet, and upon this it was swelled so much inwards, that it would no longer admit the Cone AB into its Cavity, which it easily received before: But at the same time too the Cone CB, which when it was dry, went into another hollow Cone, was so swelled outwards, that it could not now be thrust into it. Thus then it appeared to ocular demonstration, that the substance of the Wood was expanded by the Water in all its dimensions. Hence, therefore, there are often produced very extraordinary and surprizing effects, by Water's insinuating itself into dry Bodies, which by this means become bigger, and by expanding themselves, are the causes of incredible alterations.

And then becomes concreted with saline Bodies. After Water now is thus intimately mixed with Bodies, that are of a vastly different nature from its own, it is then in a wonderful manner capable of being concreted with them into a Mass, in which one should secretly suspect there was any Water. This we see evidently to be the case, for instance, in common Sea-Salt, by the following method. Take three pound of this Salt, and cautiously decrepitate it with a gentle Fire, till it don't crackle any longer. Then put this decrepitated Salt into a clean earthen Vessel, and setting it upon a strong Fire, make it just ready to melt, and in this state reduce it to a Powder, mix with it three times its weight of Bole, and with a great degree of Heat, draw off an acid Spirit of Sea-Salt; of which you will have some ounces. Separate this Spirit, then, according to *Homberg*'s method, into an Acid concentrated into a Chalk, and a Water; and by this means you will procure a true elementary Water, drawn from Salt, which having pass'd a calcining Fire, one would have supposed had parted with all its Water. But the Water which is very surprizing, is here so concreted with these saline Elements, that the dissolution of them is almost insuperable, nor to be effected without this extreme torture of the Fire. And the same is likewise true in *Sal-Gem*, Fountain-Salt, and Nitre: Not to mention Alum and Vitriol, which too, if they are first calcined with a gentle Fire, and then reduced to a very dry Powder, will, if they are urged with a strong Fire, yield an exceeding acid Spirit, which may be afterwards separated into an Acid, and a good deal of Water.

And Sulphur. With regard to the driest Sulphur, too, I have often been in doubt, whether that likewise in its substance don't contain a large quantity of Water. Whilst it burns, certainly, it affords a Flame and an acid Spirit; but this Spirit, which is always in a fluid form, may by Art be separated into a pure Water, and an Acid equal to the most condensated Oil of Vitriol. That Acid, therefore, which united with the Vegetable Oil composed the Sulphur, at that very time contained Water in it, and consequently Sulphur, which is an exceeding dry Body, and perfectly combustible, is partly made up of Water, as a constituent Element. I am well appriz'd, indeed, that it may be imagined, and not without reason, that the Water which lies concealed in Oil of Sulphur *per Campanam*, and is procurable from it, may possibly arise from the Air, whilst the Sulphur is burning; for the moister, and more cloudy the Weather is, when this

this Oil is made, the more there is always of it. But ſuppoſing that this is true, yet Oil of Vitriol, and Sulphur, have always Water in them, whenever they exiſt; and hence, as Oil of Vitriol enters into the compoſition of Sulphur, Water muſt do ſo too. For this reaſon, therefore, we conclude, that Water is in reality a conſtituent part of all Sulphurs and Salts, and there lies concealed, tho' it may be extracted thence by Fire.

And earthy Bodies.

But it appears much more incredible, that ſoft fluid Water ſhould enter into the compoſition of the hardeſt drieſt Bodies, and then adhere to them ſo tenaciouſly, as not to diſcover the leaſt ſign of its being there, nor to be ſeparated from them without the extreme force of Fire. Nay, and even then, we are not abſolutely ſure that all their Water is expelled out of them. For the ſeparate Elements of Water, which are exceeding ſolid, no ways compreſſible, immutable, and conſiderably heavy, when they are once very firmly united with Bodies, become at length concreted with them in ſuch a manner, as ſcarcely to be ſeparable from them afterwards by any Art, or violence. This ſingular property of Water, indeed, we have curſorily conſidered already in the beginning of this Chapter, whilſt we were mentioning the univerſal concurrence of Water in almoſt all the works of Nature. We ſhall now, therefore, by undeniable inſtances make it appear, that the hardeſt, and heavieſt Bodies, owe the coheſion of their parts, in particular, to Water alone, which like a kind of ſtrong *Gluten*, conſolidates them with ſo indiſſoluble a union, and binds the Elements with ſo firm a concretion, that no glutinous matter whatever is capable of doing it more efficaciouſly. And the Water itſelf being here concreted with theſe, and connecting them with one another, forms together with them one and the ſame ſimple cohering Body, appearing to us to be perfectly ſimple. This property of Water, now, ſhould, I think, be particularly taken notice of by the Chemiſts, who upon Examination would find, that this conglutinating power of Water ought not to be leſs regarded than its diſſolving one: And yet this laſt is very frequently taken under conſideration, and diſcourſed of, the former very rarely: In the firſt place, then, let us examine *Gypſum:* This is a very ſoft fine *Calx* of burnt Alabaſter, that may be blown away with a breath; and yet if you mix with this a proper quantity of Water, it becomes a ductile Paſte, which preſently acquires a ſtoney hardneſs, nor parts with its Water again without a great deal of difficulty. But conſider, again, the fat Potter's Clay which we inſtanced in formerly: This, when it is perfectly dried, affords a Subſtance, that may be reduced to an impalpable Powder, that flies about upon the leaſt breath of Wind; nor if it is kept dry, or burnt only with a moderate Fire, will ever become concreted together; but yet, if you work this with a proper quantity of Water, it will become a pliable Paſte, which dried by a gentle Heat, and then burnt in a proper Kiln, yields us Veſſels that vie with Stones in hardneſs, and are capable of holding Water. Limeſtones, or the boney Teguments of Fiſh, burnt to a *Calx*, produce a looſe Powder, that by its volatility is troubleſome to the Lungs, nor ever ſpontaneouſly grows hard; and yet work it well with a due portion of Water, you will have a Paſte, which expoſed to the Fire, burns into a Stone. If you mix Sand and Lime together, will theſe conſolidate? Never. Add Water to them, and you have a Mortar, which will ſo faſten and cement Bricks together, that the union will continue for ages undiſſolved. And as for the Glues with which we join Bodies together, made of Starch, Flower, and the glutinous Subſtances of Animals and Fiſh, theſe all are rendered fit for the purpoſe by the mediation of Water. If all theſe things, then, are properly conſidered, the opinion of theſe Chemiſts don't ſeem ſo abſurd, who aſſert that Water is concreted with the very hardeſt Bodies. Who will venture to deny, that Water helps to produce the ſolid natural Bodies, who evidently perceives this to be the caſe in artificial ones? Or who will be obſtinate enough to exclude Water from compound Bodies, who ſees this neceſſary to the formation of ſome of the moſt firm ones?

And the moſt ſolid parts of Animals.

But laſtly, let us take a view of the drieſt, hardeſt, and thoſe that appear the moſt ſolid parts of Animals: I mean their Hair, Hoofs, Horns, Teeth, Bones, Ivory, and the Spines of Fiſh; ſhan't you be ſurprized, now, if I aſſert, that the terreſtrial Elements of theſe ſeveral parts coaleſce into a proper hardneſs, by means of the conglutination of Water? But this is certainly the caſe: For if any of theſe, after they have been laid by for years, and are become drier than a Pumice-Stone, are put into a glaſs Retort, and by a ſtrong Fire ſeparated into a volatile part, and a fixed one, the volatile part will be found far to exceed the other. And this volatile part, now, will be almoſt all liquid, except the Salt; and this liquid part will be reſolvable into an Oil, Salt, and large proportion of Water. Hence therefore it appears, that Water is moſt intimately united with theſe hardeſt parts, and ſerves to conſolidate them together; for when by the extreme force of the Fire the Water is all expelled, there remains nothing but looſe Aſhes, or brittle Fragments, that cohere ſo ſlightly, that they are very eaſily reduceable to Powder. If theſe Fragments now, which are always black, are afterwards expoſed to an open Fire, they become white, and moulder away, and upon rubbing fall into Aſhes. But if you calcine a Bone, till it is perfectly white, with heat quite through, and keep it whole, though exceeding brittle, and cohering very weakly, then, if you throw it into Water, you will hear the Water ruſh into it with a hiſſing noiſe, as if violently attracted into the dry Bone, and it will again reſtore it to its former weight and hardneſs, the coheſion being by this means recovered. Hence, therefore, we infer, that though Water does not ſupply the ultimate matter of which the ſolid parts of Animals conſiſt, yet, as it performs the Office of a *Gluten* to unite the contiguous Particles together, it ſo long makes a part of the concrete, increaſes the bulk, and keeps the parts connected together with a proper union.

Nay in Oils,

But as for Oils, now, what perſon living could ever have imagined, that theſe are not only not free from Water, but that they are in a great meaſure made up of it? And yet the famous *Homberg* has proved by very exact Experiments, that diſtilled Oils may, by a chemical *Analyſis*, be in a great meaſure reſolved into the pureſt Water. *Hiſt. de l'Ac. roy. des Sc.* 1703. p. 37. *Du Hamel. Hiſt. de l'Ac. roy.* p. 372. Here, then, we ſee, that in a matter particularly inflammable, and looked upon as a true *Pabulum* of Fire, the greateſt part of the compoſition in reality is Water.

And Alcohol.

Nay, and *Van Helmont* aſſures us, that the pureſt, ſimpleſt Alcohol itſelf is, by the attraction of Salt of Tartar, half converted into elementary Water. In burning it, certainly, there is a great deal of latent Water diſcovers itſelf, as we took notice before in our Hiſtory of inflammable Matter p. 189. and following.

following. Whoever, then, is thoroughly apprized of these things, will make no doubt of the extensive distribution of Water, through vast numbers of *Species* of Bodies, and its most firm concretion with them.

But here again we must take care and keep within bounds, if we would not err from the truth: For what has been above delivered with some other considerations has given rise to an opinion among the Chemists, that Water alone is the Matter from which are produced all sensible Bodies. For some of the principal of them have laid it down in their writings, that Water being first rendered exceeding pure by a long continued Frost, and then never thawing again, but by an increasing Cold being condensed, and rendered heavier, would at length be converted into true mountain chrystal. And this they boldly assert to be confirmed by observation in the icy Mountains of *Helvetia*, which look northward, where the Ice never thawing for ages, is said to be thus transformed. Upon which head you may consult *Paracelsus*, and the *Academy del Cimento*. In the mean time, however, this is certain, that Water 40 degrees colder than the greatest observed natural Cold, thaw'd again immediately. Nor can the constriction effected by Cold ever so far condense Ice, as to make it come up in weight to Chrystal, much less to the solidity of a Diamond. It is not at all probable, therefore, that Gems are ever produced from frozen, condensated Water, but that these spring from their proper Seeds, as well as all other Bodies. The great *Verulam* says, indeed, that no nutrition is carried on without Water, p. 656, and that nothing grows without it: But this is true particularly of Animals and Vegetables. In Metals the case appears to be intirely otherwise, unless by Water you will understand Mercury; for the Adepts used to call Mercury the Water of Metals, nay and simply, Water, or their Sea. But who can ever believe, that Water can ever be rendered 14 times heavier than it is, in order to be converted into Mercury? Nay, and in Animals and Vegetables too, though its certainly true, indeed, that Water contributes vastly to the Matter of their Nourishment, and the intimate connexion of their constituent Elements, so that hence they partly consist of true transformed Water; yet it never has appeared, by any certain Experiments, that Water is capable of producing all the parts of these Bodies. I am well apprized of the Experiment of *Van Helmont* on the Willow supported by Water alone, which he so carefully describes, p. 88. 32; and the illustrious *Boyle*'s account of the Gourd, and other Vegetables, sprung from Water alone, and increased to a very considerable weight. *Orig. Forms*. p. 165. Whence these great Men have been led to think it evident that the most simple elementary Water, being applied to the living Seeds of these Bodies, is, by their seminal power, transmuted into all the Elements both of Animals and Vegetables; so that hence their whole Substance has its rise from mere simple Water. But this doctrine *Van Helmont* advances and urges, because all Animals and Vegetables, when they are dissolved and cohobated with the Liquor *Alcahest*, are always changed at last into a mere simple Water, equal in weight to their former Body. As for this *Alcahest*, however, of *Van Helmont*, I confess I know nothing of the matter, nor have I heard of any person who since him has pretended to be Master of this wonderful Liquor, and to have performed the same Experiments. But be this as it will, by a more accurate inquiry into Nature, it is since evident, that Water, indeed, is the principal Vehicle to convey the Matter of Nourishment to the Bodies both of Animals

Water however does not produce every thing.

mals and Vegetables, the Water at the ſame time not being the Matter itſelf, but being filled with various heterogeneous Particles that are: For the pureſt Rain-water always abounds with a great number of Corpuſcles, very much reſembling the nature of Vegetables: And the more any Water contains of a rich muddy Matter, the more weight it will give the ſame vegetable growing in it for the ſame time. But the greateſt part of the Water that enters into plants ſoon exhales out of them again, which perhaps would not have been carried up into the Air, if it had not been received into them; and farther, the pinguious Matter that is mixed with the Water, is found to be conſumed, whilſt the Vegetation of the Plant is thus carried on in Water, Upon this head ſee the curious Experiments of the famous Dr. *Woodward*, *Phil. Tranſ.* No. 253. p. 193. which were afterwards repeated in the *Royal Academy of Sciences* at *Paris*. We cannot, however, deny, but that Water is ſometimes intimately united with the ſolid parts of Bodies, ſo far as it becomes concreted with them into the ſame Maſs; ſo that in reality it not only performs the office of a Vehicle, but likewiſe concurs in the compoſition of ſome parts both of Vegetables and Animals. And hence the ancient Chemiſts aſſerted, that Water is the univerſal Wine which all Plants, Animals, and Foſſils drink. In this ſenſe therefore we may venture to ſay, that Water is the Matter from whence all things ariſe, and from which, by the incubation of a pregnant Spirit, they are all produced.

A repulſive force between Water and ſome Liquids.

But there are ſome Bodies which refuſe any conjunction with Water, and if it is brought in contact with them, repel it, but yet without any motion in their proper Subſtance. Oils, for inſtance, ſo ſtrongly reſiſt any union with Water, that if you forcibly mix them together, they will diſengage themſelves again, collect themſelves into orbicular or ſpheroidal Bodies, and repel the Water from their Maſs thus united under the ſmalleſt poſſible Surface. Balſams, Colophonies, and Reſins melted with a gentle Heat, have likewiſe the ſame property. In theſe, as I remember at preſent, there is only this difference, that the more ſubtil Oils grow, the leſs they are averſe to this union, the thicker they are, the more: And hence, when they come to be rendered exceeding thin, they at laſt become eaſily miſcible with Water, and then will remain mixed with it for a long time, and that, though the Oils are exceeding pure. This, however, muſt be underſtood of Water that does not ſpontaneouſly lie concealed in Oils; for concerning this Water we have treated already.

And Solids.

But ſome ſolid Bodies, likewiſe, repel Water, thoſe eſpecially that are exceeding ſolid, or have a very ſmooth ſhining Surface. Thus we obſerve this property in the Furr of Beaſts, the Feathers of Birds, Webbs of Spiders, and Bags, and Silk of Caterpillers, and Silk-worms; particularly if the Animals are in health. I confeſs, indeed, in all theſe there is an unctuous matter diſpoſed all over their Surface, that has ſomething of the nature of an Oil, and on this account repels the Water, for which reaſon, when they are boiled with a ſharp Lye, and this is ſcour'd off, they repel it leſs than they did before: But ſtill it is obſerved, that a very ſmooth ſurface will have the ſame effect. Examine plates of Metal, for inſtance, when they are perfectly poliſhed, and you will find, that Water will not only not adhere to them, but that it will fly from them, whereas they would eaſily retain it if they were rough. Dry Ivory and Stones imbibe Water with their rough Surface, but when they are very nicely poliſh'd, they repel it. This, you'll ſay, perhaps, is owing to the Pores being ſtopped

up

up by the Polish, nor do I deny, but this may help, but even to the very external Surface it won't adhere, now it is polished, to which it would when it was scabrous. Is this, therefore, the reason that the Bodies of Fish, which are so soft, and dissolve so easily, are every where covered with smooth shining Scales, and a pinguious subcutaneous Membrane, that thus they may be able to withstand the effects of the Water, in which they are to live, and in which they so soon dissolve? And does it hence happen, that as soon as ever Fish are dead, their Scales are relaxed, and this oily Substance decays, the Water soon macerates their Bodies, which, had they lived, would have continued firm for a long time? *Act. Lips.* 87. p. 160. *Perault. Ess.* T. III. p. 297.

Having thus, then, examined the general properties of Water, we must now add a few things concerning the different sorts of it, for the service of the Chemist. In the first place, then, let us begin with Rain-water; and this certainly one may properly call the *Lixivium* of the Atmosphere, in which are contained all the *Species* of Corpuscles, that were floating about in it. Of what kind, now, these are, and what great variety there is of them, we have already treated particularly in our History of Air: Let these things, therefore, be consulted from p. 282 to 292. There it appears, that in this Air is dispersed every kind of volatile Bodies. But Bodies are either spontaneously volatile, or become so by Fire, Fermentation, Putrefaction, Mixture, Separation, or Effervescence: And hence Salts, Spirits, Oils, *Sapo's*, Earths, and even Metals themselves, are found there. These, however, will be distributed there in various manners, according to the diversity of the exciting cause, which for the most part is the Fire of the Sun, subterraneous, culinary Fires, or mechanical ones, made use of by Artificers. But this variety that is observed in Rain-water won't depend only upon the exciting cause, but upon the diversity of the Soil too, from which the Fire raises the Particles, and mixes them with it. Nor will the difference in the seasons of the year produce a less alteration in this Water: For we find, that the Vernal, Summer, Autumnal, and Winter Rains differ very much, both in the Matter they contain, and the Effects they produce. Vernal Rain-water, for instance, is particularly disposed to Fermentation: For this is replete with those Bodies which the Winter Cold had locked up in the Earth, and the succeeding warmth now resolves, dissipates into the Air, and mixes with the Rain. But the various alterations of the Weather, likewise, make a very considerable difference too in the Rain that falls at different times. Thus that which comes down after a very long Drought, appears by every character to be quite of another nature from that which falls after the weather has been rainy for a considerable while. To these causes add the Meteors that are frequently observed in the Heavens. The Water that falls with Thunder differs from the rest: Not to mention the Winds that carry the Water of the Air from one place to another; by which means it happens, that when Rain succeds high Winds that have blown for a good while from one quarter, this is full of the Exhalations proper to places at a very great distance, and brought from thence by the Winds. These various Corpuscles, now, the Winds put in agitation, bring together from opposite places, mix with the Rain, and thus bring about a wonderful Mixture, greatly beneficial often to the Corn and Ground. And hence, as frequent observation teaches us, if the Rain that falls in very hot weather is catched in clean Vessels, and kept in them for some time, it will spontaneously putrify into a fetid, pu-

The nature of Rain-water various.

trid Liquor; though, as far as I remember, no body has ever obſerved Rain-water to grow acid. For my own part, at leaſt, after a great number of trials made in the examination of Water, I have never, I confeſs, diſcovered any ſuch thing. But when this Water has thus ſpontaneouſly grown putrid, it may be eaſily rendered wholeſome again, and may be drank without being offenſive; for if you give it only one boil on the Fire, the Animals that are in it will be deſtroyed, which, with the reſt of the impurities, will ſubſide to the bottom, and then if you make it moderately acid, by adding to it a ſmall quantity of an Acid that is very ſtrong, it will be fit for uſe. This is found to be of excellent Service under the Equator, and between the Tropics, where the Waters putrify ſo horribly, and breed ſuch quantities of Inſects, and yet muſt be drank. And for the ſame reaſon, a ſmall quantity of Spirit of Vitriol mixed with Water will prevent its growing putrid, and breeding any Animals, and at the ſame time it will continue wholeſome and good. But again, by all the Experiments I have made, I have never been able to raiſe Rain-water into a fermentation, and ſo convert it into inflammable Spirits. I have found, however, that in Rain-Water catched in a high, pure place, in clean Veſſels, there ſwim about little pregnant Seeds of a very fine, green, river-weed; for upon keeping this Water in very pure Glaſſes, there firſt appeared ſome very ſmall Corpuſcles, diſcovering themſelves by their green colour, which gradually increaſing, at laſt extended themſelves to a conſiderable breadth, and upon examining them with a Microſcope, I found them to be perfect little Plants. If you rather believe, that in this caſe the Seeds fell out of the Air into this Water, the thing will be the ſame; for then as the Rain falls through the Air, they may come down with it. The inviſible Seeds, likewiſe, of a great many kinds of Moſſes being interſperſed in the Rain, occaſion abundance of little Plants too of this kind ſpringing up in this Water. But much the moſt numerous, that thus grow in Rain-water, are the *Funguli*, which upon examination with a Microſcope are found to be much the fineſt of all, and in the greateſt abundance; but the collection of theſe to the naked Eye appears diſagreeably, and looks like a Slime. Theſe then are the principal Vegetables that properly belong to Rain-water, and which by no caution, hardly, can be kept out of it. In one part of the Year, however, they are in greater plenty than they are in others, and hence, in this reſpect, they produce ſome variety. But farther, Rain-water catched in the Spring and Summer Seaſon, has been found tainted, likewiſe, with the impregnated little Eggs of Inſects, and has diſcovered to the Microſcope little Animals produced in it, eſpecially when it has been cheriſhed for a good while by the heat of the Sun, and being openly expoſed to the Air. In a little drop of Water, thus circumſtantiated, what numberleſs Animals have often appeared, as we learn from the induſtrious *Lewenhoek?* You begin, therefore, to be ſenſible, with how little reaſon Rain-water is looked upon to be pure. But in Rain-water there is nothing more ſurprizing, than that if the very pureſt of it is perfectly ſhut up in a Veſſel, it in a ſhort time begins to form ſmall, white Clouds, which increaſing in number, and magnitude, grow continually more and more opake, and at laſt degenerate into a fine, tenacious *Mucus*, and change the Water into a ſlimy Fluid. Hence, therefore, it comes to paſs, that when it ſtands quiet a good while, it is obſerved to form itſelf into numerous filaments, to depoſite a feculent Matter, and alter in Colour, Smell, and Taſte,

and

and after having paſſed theſe changes, to acquire at laſt the rancid ſmell, and nauſeous, nay ſometimes intolerable taſte of a vapid, mucilaginous Water. This, then, O ye Chemiſts, is the true Nature of Rain-water, ſo far diſtant from a pure ſimplicity, and ſo tainted with various impurities! And yet this is the lighteſt ſort of all that we have amongſt us; whilſt at the ſame time all others, in almoſt every place, are ſomewhat heavier. And, indeed, this is Water truly diſtilled by nature; for it is raiſed from the Surface of the Earth, by the gentle warmth of the Air, and carried to ſuch a height as no chemical diſtillation can poſſibly imitate; and it returns out of the ſame Air, without being in the leaſt rendered impure by any Veſſel. On this account, therefore, the Chemiſts can ſcarcely by diſtillation prepare any Water purer than that which Nature thus yields us: This appears very evident, if we will but carefully conſider the Water which the Chemiſt diſtills; the Veſſel in which he performs his Operation; the Fire he makes uſe of; the ſmall height to which he raiſes the Water; and the Air through which he carries on his diſtillation: I ſay, if we will but conſider theſe things, and compare the natural diſtillation with this artificial chemical one, we ſhall not wonder, that diſtilled Rain-water is not lighter than the natural, but hydroſtatically the ſame, as I have learned by undoubted Experiments. Among all the varieties, now, of Rain-water, that of Snow is found to be the lighteſt. *Boyl. Med. Hydroſt.* p. 134. And this Snow-water, the higher the place it is catched in, as it comes down, the purer and freer it will be from the groſſer and heavier Particles, inaſmuch as it won't be mixed with theſe as it falls. And again, if after it has been for a long time very cold and dry, the Water aloft is formed into ſnowy Flakes by a ſharp Froſt, then this Snow will be the pureſt of all, eſpecially if at the ſame time too the weather has been very calm, ſo that the purity of the Air has not been diſturbed by the admixture of a variety of volatile Corpuſcles. When the Snow, therefore, has fallen upon a ſandy, barren Mountain, a great way diſtant from any commerce of mankind, and has perfectly covered the Surface, and is riſen to a conſiderable height, then if you very gently take off only the upper part, this Snow will be as pure as it is poſſible, either artificially or naturally, to procure it: For in this there will be ſcarcely any Salt, Air, Oil, or other Bodies. Hence this Snow, when it is melted, yields a Water different from all other. The Water, indeed, of this Snow is the pureſt of all we are acquainted with, is exceeding immutable, capable of being kept for many years, and is a ſingular remedy for inflammations of the Eyes. From ſuch pure Snow as this the Alchemiſts long ago aſſerted might be extracted, by a ſecret method, a very red Body, which lies buried and concealed, by an igneous power, in its inmoſt receſſes. And that this Snow, when it falls upon the ſame place for ſome ages together, leaves every time a very fine Cruſt, which in a *ſeries* of years riſes to a conſiderable *Stratum*, and renders the Soil there extremely fruitful, the famous *Olaus Rudbekius* proves by abundance of arguments, in that infinitely laborious Work, his *Atalantis*. p. 128. Thus much, then, for the method of obtaining the very pureſt Rain-water. But farther, this Rain-water being digeſted for a conſiderable time, putrifies, ſtinks, and if it is then diſtilled, yields oily Spirits, that are in ſome meaſure inflammable. And being digeſted, putrified, diſtilled, and concentrated, it has afforded a very fragrant Spirit, which very gently diſſolves the Body of Gold, without any effervescence. *Act. Lipſ.* An. 90. p. 86. When it is put into Caſks, and by the heat of the weather has putrified between the Tropics, it afterwards loses its stink and putridness, settles, and grows very clear. *Phil. Trans. Abr.* Vol. II. p. 326. The most impure Rain-water, now, of all, is that which falls in very hot and windy weather, and is catched in places about cities that are low and fetid, where Animals, Vegetables, and other Substances, by the vast number of people are perpetually dissipated into the Air; especially if at the same time that Air is foggy, thick, and stinking, so as to affect the Nose with a very disagreeable Smell, and the Lungs with a noxious Vapour; which Stink, as it often comes without any visible cause, so it disappears again in the same manner, without leaving the least mark behind it, and perhaps afterwards returns again as it went. We have likewise observed, that when it has been exceeding hot and dry for a long time, and there succeeds great Thunders, with large showers of Rain, the Water that then falls, if it is collected in pure Vessels, produces a Froth, which seems truly to contain something of a very fine kind of nitrous Salt. And Rain that has come down with terrible Whirlwinds, has been sometimes found to be fetid, and if it fell upon any garment, in the space of four and twenty hours, filled it full of Animals *Phil. Trans.* No. 127. p. 652. Abrid. V. p. 171. Hence, then, we may easily see the reason why this Water is so greatly conducive to the fertility of the Earth, both as it contains a very subtil Matter, which furnishes Particles both for the solid and liquid *Pabulum* of Plants, and at the same time is the most proper Vehicle to carry to them all those Substances which are necessary to their nourishment. If the Water, now, collected from melted Snow, and mentioned before as the purest, is distilled once with a gentle, clear Fire, in tall, clean Vessels, this may be looked upon as the very purest of all, especially if this distillation is performed in a place that is free from Smells and Vapours. After having tried a great many different methods, I have not found any one by which I could render Water more pure than by this. I know, indeed, that some chemists, when they wanted Water exceeding pure, have distilled it very gently off of fixed alcaline Salts; and by this means, it is true, they have fixed all the Acids in the Alcali, and easily retained in it both the oily and the terrestrial Particles, but then, at the same time, there is somewhat of a lixivious quality communicated to the Water. Others, therefore, have distilled these Waters off of *Sal Gem*, Sea Salt, Nitre, and the like; but the Water they obtained by this means was always more impregnated with heterogeneous Particles. Nay, though you distill it successively with different sorts, you won't make it at all purer, as I learned by performing the distillation alternately, with alcalious, acid, and compound Salts. This purest Water, now, when it boils on the Fire, has that fulminating quality which we formerly described, and concerning which we took notice, that it did not depend upon the Air, nor does it ever lose it, though it be ever so pure, and has been distilled some number of times. But it remains farther, that we lay before you those Marks, which in such a manner belong to this purest Rain-water, that they serve to distinguish it from every other sort. In the first place then, if this pure distilled Water is mixed with other Waters less pure, there immediately appears a whiteness upon the mixture, though they both were very clear before. If the best common, or Venice Soap is dissolved in this Water, the solution is perfectly equable, without any small soapy Fragments; whereas, if if you diſſolve it in Water leſs pure, you will obſerve ſuch little Maſſes appearing half diſſolved, like Milk that is half curdled. If it is poured upon wax, that is to be expoſed to the Sun, or thrown upon Linnen that is to be whiten'd, it gives them an exquiſite whiteneſs, whereas that which is impurer leaves them not ſo clear. Of all Waters, this grows hot and cold again the ſooneſt: But by boiling, it never becomes better. If into this Water, when it is cold, you throw the pureſt Gold or Silver, when they are perfectly melted, either ſeparately, or together, they paſs quietly through it, and fall to the bottom, divided into little grains: This the Aſſayers call Granulation, and it is of excellent ſervice in a great many chemical Operations. Iron, Tin, and Lead, in fuſion thrown into this Water, in the ſame manner, fly from it with a very violent motion, and a great noiſe, ſo that the mixing theſe with it is much more dangerous. But what a ſurprizing quality has Water, with reſpect to melted Copper? Certainly, if you throw this into Water, the Copper, Water and Veſſel will be agitated with an incredible noiſe and fury not to be reſtrained, to the imminent danger of all around it. Nay, it has been confirmed by very fatal inſtances, that upon a ſmall quantity of Water's being poured upon this metal, when it was in fuſion, every thing about it has been torn to pieces, with an *impetus* almoſt quicker than that of Gun-powder. This ſurprizing property, now, I am of Opinion, cannot be underſtood, or explained, from any common principle of Bodies. In the laſt place, Rain-water, when it is ſimple and pure, may be looked upon as the Mercury of Animals, and Vegetables; for then in point of ſimplicity it is not inferiour to the Mercury of Metals. Then, according to *Van Helmont*, it is the firſt Element, out of which all things are produced, and the laſt into which they are all reſolved. But this doctrine, as we took notice before, muſt be allowed only with proper reſtrictions.

All Spring-water owes its origin intirely to Rain-water. For the Heat raiſes the Water from the Surface of the Earth, and the Waters, into the Air; and then the Air, when it is thus replete with watery Vapours, being ſtopt againſt the cold, broad tops of high mountains, applies it to them, by which means it is there collected into drops, exactly in the ſame manner as in our diſtillations. Theſe drops afterwards uniting together, run down the ſides of the mountains, either in little ſtreams on the ſurface of the ground, or elſe ſinking down into ſome ſubterraneous paſſage, there form a kind of reſervoir, and deſcend from thence. When theſe places, now, are higher than thoſe where theſe Waters find an out-let, there the Fountain plays up ſo much higher in proportion, as theſe collections of Water are higher than the mouths where they burſt out. Hence, then, we ſee the reaſons why there are no Springs, except in the neighbourhood of mountains? Why there are moſt Springs where the Mountains are moſt in number, higheſt, and moſt ſolid: And why in Vallies ſituated between Mountains, Springs are moſt frequent, and riſe higheſt. Hence, likewiſe, we underſtand, that Spring-water can never be more pure than Rain-water, ſince the purity of the former depends intirely upon the latter. And how, indeed, is it poſſible it ſhould be more limpid than that Vapour from which, when it was aloft, it took its origin? For, certainly, Water can by no method be purified more than by being carried to ſuch a height in the Air. This Rain-water, however, thus collected into

Spring Water.

Spring-

Spring-water, if it happens to fall into places that are full of Flints, then, being detained in their Interstices, and running through them, it there deposites all the heterogeneous Particles it was before tainted with, and at last, having been purified through these Meanders, it becomes pure Water, clearer than Amber. This then is the method which Nature makes use of to bring Water to its greatest clearness, and simplicity; and this is the Water mentioned by *Virgil* as *exercitata cursu*, and described by him as purer than Amber: Nor do I know any other contrivance whatever, by which it can be rendered more pure. But we know, likewise, that our common Sand or Gravel is nothing but a collection of very pure Chrystals, or little Flints. And the figure of these, now, is so vastly irregular, that it is scarce possible to find any two that are perfectly alike. Hence they can never be so placed among one another, as not to leave some empty Spaces between them; and for this reason, if the Water that distills from the Mountains happens to light upon these sandy Gravels, it then running through the small Interstices of the Sand, becomes a good deal more pure than it was before. And hence, too, even Rain itself, falling upon the Surface of sandy Mountains, and then strained through very clear Sand, runs down in form of very pure Water. This Spring-water, however, when it runs through such places as contain Substances that are easily dissoluble in Water, it then in its passage dissolves such Bodies, and carries them along with it. Nor does it at all signify, then, whether it runs through Rocks, Sand, Hills, or Mountains, for it will still retain these dissolved Particles. And hence it comes to pass, that Brooks, Rivers, and Springs acquire the Nature of that Matter, which lies in the Channels through which the Waters pass. For this reason, therefore, nothing can be asserted concerning the particular disposition of Spring-water, till we are acquainted with the nature of the subterraneous Passages through which it runs. A reflexion upon Alums, Salts, *Sapo's*, and Vitriols, makes this sufficiently evident. Thus sometimes it comes out under the name of Chalybeate Waters, called the *Acidulæ*, though the egregious *Hoffman* has made it plainly appear, that these are of an alcalescent, volatile Nature, and are replete with an embryonated Spirit. And often, you see, it appears in sulphureous Baths, vastly different from the former, though they both owe their origin to the same Spring-water. Some Springs again are wholesome, and have a medicinal vertue; whilst others are pernicious and poisonous. Nay, there are some which are endued with a petrifying quality, as is observed in the petrifying Cave in *Burgundy*, about a mile distant from *Quingey*, where the Water, as it drops down, petrifies into statues of all kinds of figures, *Journal des Scav.* 1688. p. 432. And yet what is particularly surprizing, these petrifying Waters don't generate Stones in the human Body. *Mem. de l'Ac. roy. des Sc.* 91, 92. From all these instances, then, it evidently appears, that nothing can be asserted of the clearness, weight, and vertues of Spring-water, that will hold universally true; but we must examine every one particularly, if we would rightly understand its nature. And indeed there is no consideration makes this plainer, than this, that if you boil any sort of Spring-water whatever, for some time, and then let it stand to cool, it will always deposite some *Fæces*. But whilst we are thus examining all the circumstances of Spring-water, there is nothing more particular and extraordinary than that you shall have none of this Water in some places, though you dig to a prodigious depth.

A surprizing instance of this we have given us by the famous Dr. *Plott*, in his description of *Staffordshire*, where he tells us of a Well that appeared by letting down a Line to be 2600 feet deep, tho' it did not then touch the bottom; and yet in all that depth, there was no Water to be met with. How prodigious solid must the bottom of that Well be, to prevent any Water's bubbling up through it? And how very strong and solid must the sides of this Well be from the Surface of the Earth to the depth of two thousand six hundred feet? Consult the famous Author, and *Journ. des Scav.* 1680. p. 14.

River-water should come next under our consideration: But as all Rivers that run with a constant course, owe their origin intirely to Water collected from the Air by Mountains, as we have just now mentioned to be the case of Springs, hence the matter of them both originally will be perfectly the same. In this respect, therefore, every thing that has been said of Spring-water, may be applied to River-water. And the principal difference, indeed, that there is between them, is this, that Spring-water almost always runs underground, whereas River-water being generated on the Mountains, trickles down the sides of them, collects itself into little streams, which gradually uniting together, form Rivulets, and at last terminate in large rapid Rivers, always exposed to the open Air. Hence, therefore, whatever falls from above, whatever is brought by the Wind, whatever is added by Vegetables that fall into them, whatever is brought thither by Animals, or deposited there by Fishes, or amphibious Animals, all these things are collected in Rivers, mixed with their Water, and lodged in them, and there may be macerated, putrified, and at last dissolved. River-water, therefore, besides containing every thing which we mentioned before of Spring-water, may have all these Bodies mixed with it likewise. If you please now to consider, that these Rivers thus coming from the Mountains, let them run ever so far, at last discharge themselves into a Sea that is lower than those Mountains, then you will easily perceive the reason why they never stand still, but constantly keep on their course towards the Sea. Hence, likewise, we understand, that Rivers, whilst they are continually running through so many different places, as Woods, populous Cities, *&c.* their Water must in every one of these become perpetually of a different nature. For this reason, then, again, we must not pretend to pronounce absolutely concerning the particular nature of River-water, but consider here, likewise, what alteration it continually receives by this addition of new Bodies. The Rain-water, certainly, that comes down from the Clouds, mixes itself with this River-water: As we see likewise Animals, Vegetables, and Fossils, in different places, and times, are dispersed through it likewise. What wonder, therefore, is it, that some Water taken in by the *English* at St. *Iago*, and put into Hogsheads, should be so altered, that when they were about the Island *Borneo*, it should, by the Heat of the Weather, emit a Vapour, which upon a Candle's being apply'd to it, catch'd into a bright Flame? The Water at that time was exceeding fetid, but after it came to settle, it grew very sweet again. *Philos. Trans. Abridgm.* T. V. p. 271. *Thames* Water, put into Casks, stinks, and comes to itself again, And *New London* Water stank prodigiously in eight days time, but being carried to *Virginia*, it again became sweet. *Phil. Trans.* N. 127. p. 652. And again, the same *Thames* Water being put up into Hogsheads, and carried into hot Countries, within the space of 8 Months, was changed into a Liquor abounding

River-water.

with inflammable Spirits, ſo that the Vapour of it took Fire like Spirit of Wine. At that time too it ſtank; but upon the admiſſion of the freſh Air to it on opening the Veſſels, the ſtink was all gone in four and twenty hours; but if the Veſſels with their Water were well ſhook about, it went off in five hours in ſuch a manner, that it was not at all troubleſome: And yet this ſtinking Water when it is drank, is born by the human Body without any inconvenience. *Tranſ.* N. 268. p. 838. *Tranſ. Abridg.* T. III. p. 547. *Mem. de l' Ac. Roy. des Scav.* T. I. p. 404. If Sea-water, now, is drawn off by diſtillation, and is then mixed with River-water, it uſes to prevent this putrefaction, as appears by the Experiments of *Du Hamel* upon *Menſtruums*, p. 412. But again, in the Kingdom of *Congo*, there is found a Water, the froth of which, if it lights upon Straw, and is then expoſed upon the Shore, concretes into a tenacious matter, which when it comes to the Fire, grows hard like Iron. *Act. Lipſ.* 1687. p. 650. And the Water of the *Rhone*, if it is firſt ſuffered to ſtand and ſettle, and is then put up into earthen Veſſels, will not putrefy by Heat, tho' it will very much if it is put into wooden ones. *Act. Lipſ.* 1683. But farther, upon a careful Examination by Experiments, it has been obſerved, that Rain, Snow, Spring, and River-water, hydroſtatically compared, ſcarce differ one thouſandth part of their weight; and that, tho' ſome Water from the *Ganges* was tried among the reſt. *Boyl. Med. Hydr.* p. 104. Hence we can ſcarcely underſtand, or think credible, what is told us by another Author, *viz.* that there is a Water in ſome part of *Africa*, which upon an accurate hydroſtatical Examination, appeared in the Bulk of one pound to be four ounces lighter than the Water in *England*. *Boyl. Uſeful. of Phil. Experim.* Part II. p. 114. I wiſh this ſurprizing Experiment had been more exactly deſcribed, and confirmed by proper authority: The thing certainly is of conſequence enough to deſerve it: For if this was found to be always the caſe, then what *Herodotus* tells us of the Water of the long-lived *Ethiopians*, would appear to be perfectly true. But not to grow too prolix, I think what I have ſaid ſufficient to let us into the nature of River-water: For it appears to me very evident, that the impurities of ſuch a vaſt number of Bodies as are mixed with this Water, ſupply that matter which cauſes it, when expoſed to a great Heat in wooden Veſſels, to ſuffer and undergo all thoſe alterations of Fermentation, and Putrefaction, which we have juſt now mentioned; which, therefore, are to be aſcribed to the contents of thoſe Waters, and not to the Waters themſelves.

Standing-water.

But we muſt ſtill add a few things concerning the Waters which ſtagnate in Lakes, Ponds, and Ditches about Towns; for theſe likewiſe are frequently made uſe of by the Chemiſts. If we conſider this ſort about our City of *Leyden*, we find it to be a *Lixivium* of all the Privies and Common-ſhores that are continually diſcharging themſelves into theſe publick Ditches. At the ſame time too, vaſt quantities of materials made uſe of in dying our Wool, Hair, and Silk, are here diſſolved likewiſe; by which means what a ſurprizing and confuſed Mixture muſt hence ariſe? Certainly, Alum, Tartar, Vitriols, the Subſtances that give the Colours, and *Aqua Fortis*, are perpetually running in great abundance from the Dyer's Coppers into this Water. And yet all this Water, now, is either diſcharged into *Harlemer Meer*, or only gently flows backwards and forwards. Why, therefore, ſhould it ſeem at all ſtrange, that a good many Articles in dying ſhould be brought to greater perfection here by the help of theſe Waters, than

than in other places, where they are attempted in the ſame manner without them? That this is the caſe, abundance of Experiments confirm. This ſtagnating Water, now, is a good deal heavier than pure natural Water: For 12 ounces of this Water being put into a glaſs Baſon, and expoſed to a gentle Heat, when the Water was exhaled, diſcover'd at the bottom a great many little Inſects of various kinds, and beſides, a large quantity of earthy Matter, yellowiſh, and of a limy nature, together with Mud; which being mixed with *Aqua Fortis*, produced a very ſtrong Effervescence. Various kinds of theſe Waters, now, being examined hydroſtatically by a glaſs *Index* immerged into them, there appeared to be a conſiderable difference in their weights, which reduced to a Table was as follows. Firſt, pure Rain-water, catched as it fell, was found by this Inſtrument to be lighteſt of all, and therefore this was made uſe of as a ſtandard for the reſt. Secondly, Water taken out of the river *Sale*, was one Line heavier than the former. Thirdly, the medicinal Waters at *Hall*, were two Lines heavier. Fourthly, the Spring-water there was four Lines heavier. Fifthly, the Spring-water in the Houſes was ſix Lines heavier. Sixthly, that Water being put into an open Veſſel, and let ſtand a good while in a Cellar, was ſix Lines and a half heavier. And Seventhly, the Water that ſtagnated thereabouts in the Ditches and Lakes, was found to be heavieſt of all, *viz.* to be ſeven Lines heavier than the firſt Rain-water. All theſe Experiments made with a great deal of caution, and accuracy, are faithfully related by the egregious *Hoffman*, in his *Exercitationes Phiſico-Chemicæ*, which can be never ſufficiently recommended. How careful, therefore, ought we to be in making Experiments with Water, which appears to be ſo various; ſince every ſort of it, in regard of its different contents, muſt ſo far conſtantly produce different effects? We ought, therefore, to be acquainted with the methods by which its purity may be diſcovered, before we make uſe of it for theſe purpoſes. One of the beſt ways then of trying whether Water is pure, is by a Solution of Silver made in *Aqua Fortis*, and then diluted with the pureſt Water we can procure: For if you then drop ſome of this Solution of Silver into any Water you want to examine, if it don't thereupon grow turbid, opake, or white, you may ſafely enough depend upon its being very pure, except, that it may contain ſome Spirit of Nitre, or *Aqua Fortis* in it. In the ſame manner the beſt Oil of Tartar *per deliquium*, diluted in a good deal of pure Water, ſufficiently demonſtrates the purity of the Water under Examination, if upon being mixed with it, it produces no alteration in it; for if there is any thing elſe in it beſides alcaline Bodies, it immediately diſcovers it by a ſudden change of its Colour. But there is nothing in this caſe more eaſily affected than a Solution of Sugar of Lead in the pureſt Water you can get; for if any heterogeneous Water is dropped into this, its impurity appears in an inſtant. Conſult the *Acad. del Cimento*, p. 237, where you will find various valuable Experiments. Such Marks, now, as theſe, that thus ſerve for the Examination of Waters, are of infinite ſervice in chemical Inquiries, where there is an incredible nicety required, ſince the very leaſt admixture of any foreign Matter will often render the whole Operation ineffectual. How often have the Chemiſts, to their great diſappointment, experienced the truth of this, when they have been engaged in raiſing the *Arbor Dianæ*, or in the chemical Production, and variation of Colours?

Ice, the natural state of Water.

Upon an Examination, now, of what has been ſaid, we are obliged to conceive of Water as a kind of *Species* of Glaſs which melts in a Heat of 33 degrees, and grows hard in a Cold that is a ſmall matter greater: For it then becomes a hard, elaſtic, brittle, pellucid, inodorous, and inſipid Maſs, that may be poliſhed into durable *Lens's* and *Meniſci*, for Microſcopes, and Burning-glaſſes. This Glaſs, it's true, is volatile; but in other reſpects, is the ſame as the common. And if we regard it now with proper attention, it is pretty ſurprizing, that from ſo ſoft and fluid a Body as Water, there ſhould in a ſhort time be produced ſo hard and ſolid a one as Ice: And that from Corpuſcles, which whilſt they were in a ſtate of Fluidity, had no ſigns of elaſticity, there ſhould, now they are conſtringed together, ariſe a Maſs that is exceeding elaſtic, and which being formed into a Ball, rebounds like Glaſs, or an elaſtic Metal. And this hardneſs, now, and elaſticity, thus produced in Ice, increaſes continually in the ſame proportion as the Cold increaſes, ſo that when at laſt that comes to be very intenſe, Water becomes hard like true Glaſs, and acquires a prodigious elaſticity. But this Glaſs ariſing from Water, diſſolves again in 33 degrees of Heat, and then becomes immediately volatile. Some ingenious Men, indeed, have aſſerted, that by a ſtrong and laſting Cold, the Particles of Water may be ſo united together, as to be converted into Chryſtals and Gems, that would not melt in a common Glaſs-houſe Furnace: But that this opinion is not ſufficiently confirmed by proper Experiments, we have taken notice already. If you ſuppoſe, however, that this may be true, then Water, by this transformation, would be capable of receiving ſuch a quantity of Fire into it, as to make it red hot, and ſhine in the dark like Metals, Stones, and other ſolid Bodies. But ſo far as we are hitherto acquainted with Water, it is found impoſſible, by any aſſiſtance of Art or Nature, to increaſe the Heat of it to more than 214 degrees, unleſs at the ſame time you compreſs it with a greater power than common. If, indeed, we could compreſs Air a thouſand times more than it is compreſſed by a common Atmoſphere, in this caſe, poſſibly, one might heat it nine thouſand degrees farther; which Heat would then be much greater than that of melted Iron. But in the laſt place, as ſoon as ever frozen Water is diſſolved by the warmth of the Air, all its hardneſs, elaſticity, and brittleneſs, are at once perfectly deſtroy'd.

When it thaws, it becomes a Solvent.

And no ſooner is Ice acted upon by the very leaſt degree of a Heat that is able to thaw it, but it immediately becomes a *Menſtruum*, a moving cauſe, and the moſt univerſal Vehicle, which diſſolves, in particular, the more active Bodies, mixes them together, applies them to one another, by uniting itſelf with many Bodies that are too acrid, renders them more mild, puts all Bodies in agitation, and ſo produces the moſt remarkable phyſical changes, and operations.

In Animals the Vehicle of Aliments.

In Animals, certainly, all Nutrition is carried on intirely by the help of Water. Not, indeed, that the Elements of Water are converted into the very Elements of the animal Body, for this is not ſo univerſally agreed on, but without the aſſiſtance of Water, the true nutritious Particles can ſcarcely be convey'd to thoſe parts of the Body that want a ſupply of Nouriſhment from them. As Water, therefore, alone, is a proper Vehicle for this purpoſe, hence, of conſequence, Nutrition cannot be brought about without it.

But neither is there any such thing as Life itself in Animals, without the concurrence of Water; for this is the softest, most fluid, and finest part of all our Humours, and penetrates most effectually into all, even the minutest Vessels of the Body. If this is too much diminished, Life itself is soon at an end, the Blood and other Fluids being by no means capable of carrying on the Circulation: Nor is there any known Liquor in Nature that will by any means be able to supply its defect. Hence, therefore, every vital action depends upon Water, as it is this that renders the other Humours fit to circulate through their proper Vessels. Whoever by a very gentle Heat has separated the Water from any animal Juices, either the thickest, or the most diluted, has always found, that this constituted much the greatest part, and disposed the remainder to pass through the Vessels designed for them. And again, if you examine any solid part of the Body, you will find, that likewise owes almost all its aptitude to the actions of Life, to Water alone, which being once removed, it becomes incapable of them immediately. The Instrument of Life,

Nay, and Health itself, which is the greatest perfection of Life, and the exercise of all the actions necessary to it, depend upon, and are effected by Water, more than any thing else. The increase of the Body is brought about principally by Water. Water is the cause of a great many diseases, and a great many are removed by it. Death itself is often occasioned by an excess of Water, but much more frequently by the defect of it. And lastly, Water performs the most happy Cures. And Health.

And that Water is equally serviceable to the Life, Health, Nutrition, Increase, and other Actions of Vegetables themselves, is very evident from what the famous Dr. *Woodward* has given us upon this subject, in the *Philosophical Transactions*; which has been since confirmed by the ingenious Dr. *Hales* in his *Vegetable Statics*. The whole fruitfulness, certainly, of the Earth, arises from Rain and Snow, by which a fertile Crust is gradually spread over the most barren Sands, and there produces a very black and fruitful Earth: This we learn from the elegant Observations of *Olaus Rubekius*, whom we have mention'd already. But in *Egypt*, and *Lybia*, where the ground is not much moistened by Dew, or Rain, nor any Rivers arising from Mountains, there, when the Sands are once barren, they always continue so; particularly, because the Storms of Wind there raise up the Sands in vast Clouds, and thus destroy the first Rudiments of this fruitful Crust. *Verulam*. p. 655, 656. As also in Vegetables,

And lastly, Fossils themselves, so long as they remain in the metallic Veins, in appearance of a liquid Juice; nay, and Metals, whilst they continue in form of a thick, pinguious, ponderous Fluid, and go by the name of a metallic *Gur*, so long they exist in form of a saline unctuous Fluid, and they may then be dissolved in Water, nay, and actually contain in them a diluent Water. Upon this head you may consult the Writers upon Metals, and particularly *Agricola*, who is far the chief of them. Certainly, all saline, vitriolic, metallic, concreted Juices confirm the truth of this; for all these make it evident, that Water is the principal Agent among them, that dilutes, moves, changes, and increases them, and mixes them one amongst another. And in Fossils.

From what has been said, then, it evidently appears, how surprizingly and universally Water is useful. The most tender, and beautiful Colours of Bodies, certainly, are formed by the concurrence of Water, witness the finest Colours The uses of Water for other purposes.

lours of Flowers, not to mention numberleſs other inſtances. The particular ſcents of Bodies are chiefly mixed, preſerved, and perfected by the admixture and temperament of Water: For in this Vehicle, which is much the propereſt for this purpoſe, they are moſt gratefully diſtributed. And as for the elegant variety of Taſtes, what does this depend upon but Water, which by a due interpoſition, applies them to the Tongue, and the Palate? The ſingular, the nutritive, medicinal, medicated, and poiſonous qualities of Bodies too, by the concurrence of Water, are rendered active, tho' they were not ſo before. But again, that the very great hardneſs and firmneſs of Bodies depends often upon the interpoſition of an aqueous *Gluten*, we have already demonſtrated. Certainly, Bricks, Tiles, Stones, Bones, Horn, Hair, and Hoofs, were it not for the Water that is in them, would ſoon be diſperſed into a very ſoft Powder. Nay, and moſt of the phyſical actions that Bodies exert one amongſt another, are performed by means of Water, and would ceaſe without it. And as this is true of Operations that are excellent in themſelves, and are the origins of a great many other actions; hence thoſe of courſe muſt depend principally upon Water. An inſtance will make this plain: The Effervescences produced between Salts and Salts, Salts and Oils, and Salts and ſolid Bodies, happen then only, when theſe Salts are ſo diluted with Water, as to be reduced to a ſtate of fluidity, and ſo brought into action: For when they are perfectly freed from all their Water, and left quite ſolid, they then generally are but little active. But we know what a vaſt many changes and operations ariſe purely from Effervescences; which therefore all neceſſarily require the concurrence of Water, in order to their being effected. But if we conſider Fermentation, too, the fruitful Spring of ſo many, and ſo great phyſical productions, this certainly, can by no means be brought about without Water. Nay, on the contrary, if Vegetables are deprived of their own Water, they can never poſſibly be raiſed to a Fermentation, but will continue unaltered for a long time: But as ſoon as ever a proper quantity of Water is added to them, and they are expoſed to a ſuitable degree of Heat, and the Air has free admiſſion to them, a fermentation ſpontaneouſly ſucceeds and produces all its effects, which are ſo very conſiderable. The putrefaction of Animals, Fiſh, and Vegetables, never happens neither in Bodies that are dry: For theſe likewiſe, if they are intirely freed from their Water, and thus rendered perfectly dry, may be kept for a vaſt while in a dry Air without corrupting, whereas, if they are moiſtened with Water, they are ſoon converted into an intolerable putrid Matter. There are numberleſs other ſeparations of various Bodies, which are brought about by Water very eaſily, but can be no ways effected without it: Thus the ſeparation of Salts from Earth and Oils, and the extraction of Alcohol from Reſins, and reſinous Subſtances are performed by Water. And on the other hand, the union of a great many Bodies too, depends intirely upon Water, and cannot be obtained without it; of which we have given you a great number of evident inſtances already. Precipitation, again, which among the chemical Operations is ſo conſiderable a one, is performed principally by the mediation of Water. The Sublimation, too, of the precious Oil, procured by diſtillation from Aromatics, Balſams, Barks, Flowers, Leaves, and Seeds, depends intirely upon the aſſiſtance of Water alone: For take away this, and there is no phyſical or chemical Contrivance by which this beautiful Oil can be obtained pure, and

without

without an empyreumatical Taint. But again, Water is the *medium* by which we can certainly distinguish and direct the degrees of Heat from the degree 32, to the degree 212, which it is very difficult to do by any other method. I don't deny, indeed, but that Oil will do the same, nay, and farther too, quite to 600; but in these cases, Water continues always the same, whereas Oil growing continually thicker and thicker, does not afterwards retain the equable increments of the ascending Heat. This now is of vast use in the chemical Art, nor was this known to the ancient Chemists; if it had, they would not have taken such a vast deal of Pains to find a method of raising and keeping up an equable degree of Heat, equal to the vivifying Warmth of a brooding Hen; for this now-a-days may be easily come at, directed, and continued by the help of Water, and a Thermometer. Concerning all these effects of Water, however, that have been mentioned, this is to be remarked, that they will be very different, according to the various degrees of Heat that are applied to it, so that upon every increase of Heat, the effect of Water will constantly vary: But as this is sufficiently evident, I shall not take up your time in explaining it.

But Water now is never observed to be more active, than when by boiling, it is raised into Vapours in a close place; for if Bodies are exposed to such a floating Vapour, and are perfectly moistened by it, they are thence surprizingly penetrated, altered, corrupted, and dissolved. By Experiments, however, that have been made on purpose in this affair, it is certain, that Vapours exhaling from Water by means of a gentle Heat, have this different effect upon Bodies exposed to them, that those that rise from Salt-water make them putrify less, than those from fresh, which destroy them a vast deal sooner; so that hence the putrifying power of the Vapour of fresh Water, by the assistance of Heat, was very evident. The ancient Physicians, therefore, very justly remarked, that a moist and hot Air has a pestilential Quality, and soon dissolves human Bodies. And by the Moderns it has been observed, that the *Europeans* who first settled in *America*, almost all died of a malignant distemper, which in form of a putrid Fever, very soon resolved their Bodies. And this happened particularly to those Persons who lived in the places which were woody; for there the Air is always exceeding moist, and abounds with warm Vapours exhaled by the Trees, and other Vegetables, in incredible quantities. For if you compute, according to the calculation of the ingenious Dr. *Hales*, in his *Vegetable Statics*, the Surface that all the Leaves of a pretty large Tree make up in the Summer time, it will be evident, that there must be a prodigious deal of Water continually exhaling from the Woods in so hot a Climate. And hence, when these Woods were set on fire and destroy'd, and the Country was laid open to the Air, the same places became very healthy. See upon this head the curious Observations of that famous Physician *Ludovic. Testi*, concerning the wholsomeness of the Air of *Venice*. *Act. Lips. Sup.* Pl. III. p. 167.

The Vapour of hot Water active.

That Water rarifies when it is by Frost congealed into Ice, was first observ'd by the famous *Galilæo*, and consequently, that Ice is rarer and lighter than the same quantity of fluid Water. Hence it comes to pass, that Ice always swims upon Water, the specific gravity of Water being to that of Ice, as 9 to 8. *Experim.* of the *Acad. del Cimento.* 25. 28.

Ice rarer than Water.

5

This

From aerial Bubbles.

This rarity, however, of Ice, is owing to Spaces full of Air-Bubbles, which, whilst the Water is freezing, are formed in it, and being considerably large in comparison of the Water, are the cause that the Body of the Ice appears lighter. For in our History of Air and Water it has been abundantly demonstrated, that in cold Water there is a pretty large quantity of Air lodg'd in the Vacuities left between its Elements; which Air, however, not coming at any other aerial Particles, is not collected and united together, nor has any elastic force. But when the Water comes to be constringed by the Cold, by reducing itself into a narrower compass, and lessening its Interstices, it presses out the Elements of Air, unites them together, and hence forms elastic Bubbles, that expand themselves, and become lighter. And as the strength of the Cold grows gradually greater and greater by the association of new ones, these Bubbles grow continually bigger and bigger, and thus increase the proportion of Air, to the bulk of the Ice.

Hence breaks Vessels.

These now at last being rendered very great, the Air acquires such a prodigious expansive power, that it bursts almost all Vessels, let them be ever so strong in which it is confined; even such as it could scarcely have broken, if it had been dilated by the Heat of boiling Water. Some of the most ingenious among the Philosophers, indeed, have imagined, that this accident happens from the solid parts of the Metal's contracting themselves upon the Ice that is formed within, and consequently, not from the expansion of the Ice outwards, but from this contraction inwards, the Vessel, and the Ice, being in the mean time both condensed by the Cold. But to this ingenious conjecture, the Gentlemen of the learned Academy *del Cimento*, oppose the following evident Experiment. They took a new hollow Sphere of pure Gold, and filled it perfectly full of Water, and having closed it, exposed it to a freezing Cold. At the same time too, having fixed the Sphere, they fitted upon it an exact metal Ring, a little less than a great Circle of the Sphere; which being placed loose upon the Sphere, encompassed it round almost at its center. They then mark'd the place exactly in the Sphere where the edge of the Ring rested; and afterwards, when the Water was frozen, they found, upon examination, that the Surface of the Sphere was so remov'd from the center, and grown so much larger, that the Ring was considerably raised from the great horizontal Circle of the Sphere towards its *Vertex*, the expansion of the Sphere being much greater than the contraction of the Ring, as appeared by comparing it with another Ring that was of the same size, and was not exposed to the Cold.

Ice formed of Water, deprived of Air.

But Water, now, from melted Snow, or that which has been a good while boil'd, freezes more slowly, and at the same time becomes much more solid, rarifies less, and forms much fewer Bubbles whilst it is freezing. *Acad. del Cimento*, p. 163. And very pure Water, kept a good while in the Air-pump, and exposed to a freezing Cold in *Vacuo*, freezes there much sooner than it would have done with its Air in it, and standing in the open Air in the same degree of Cold. The Ice too from Water thus deprived of its Air, has been found to be much harder, heavier, more equable, and more pellucid, than common Ice: So that hence it is certainly evident, that it is the Air which is lodged in the Water, and is collected by the freezing Cold, that produces this rarity and lightness. Nay, upon making some Experiments very carefully in this manner, there was Ice produced, that would not swim upon Water. *Ibid.*

Ibid. 171. If in exceeding cold Weather, you pour a fine Powder of Sea-Salt, *Sal-Gem*, Fountain-Salt, or *Sal-Ammoniac*, that is equally cold, upon rasped Ice or Snow, and then rub them together, the very moment they are mix'd, the Salt will begin to dissolve, and at the same time there will arise a greater Cold than was in either of them before, and that always to a certain degree, let the degree of Cold in them before they are mixed be what it will: At least, as far as we have been hitherto able to discover. And this artificial Cold, by a repetition of the same Experiment, may be increased at pleasure. Alcohol of Wine, in the same manner, being poured upon, and mix'd with Ice, increases the Cold. If the pure saline acid Spirits of Sea-Salt, Nitre, *Aqua Fortis*, or *Aqua Regia*, are rubb'd too with Ice, they generate Cold likewise, which will be always so much the intenser, as they are stronger. But of this we treated largely in our History of Fire, whilst we were relating *Fahrenheit*'s Experiments for producing the greatest Cold that has hitherto been known.

The most perfect Ice.

If a Person, therefore, should in the coldest Weather take the most pure Water, and in the carefulest manner deprive it of all its Air in the most perfect *Vacuum*, and let it freeze there, and afterwards by this contrivance of *Fahrenheit*'s cool the Ice as much as possible; then one might procure the hardest, densest, purest, most pellucid, and heaviest Ice, and by this means the physical character of Ice might be determined evidently to the Senses. In the mean time, however, as far as we can judge from what has been experienced, such Ice would dissolve again with a Heat of 32 degrees.

Not changed by Cold into a Body that remains hard in the Fire.

Hence it evidently follows, that the greatest degree of known Cold does not convert pure Water into any kind of Stone, Chrystal, or Gem, tho' this artificial Cold is 40 degrees more intense than the natural one in those places, where it is asserted, that frozen Water is changed into mountain Chrystal. With us, certainly, no increase of Cold in Ice has made it melt with more difficulty, when it has been exposed again to the usual degree of Heat that dissolves it.

Water not changed by time.

The purest Water, now, being poured into a very clean Vessel, and hermetically sealed up in such a manner, that it had not the least communication with the external Air, continued a whole age without any sensible alteration: So that in all that time, it neither hardened into a solid form, nor generated Earth, or any thing else in it, tho' this was tried in the Air at *Rome*, which is pretty warm. *Boyl.* V. I. p. 62. *Du Hamel.* T. IV. p. 109.

Contains something more subtil than Air.

Again, if by the help of the Air-pump, you deprive Water as much as possible of its Air, and then whilst it remains so, shake it about in a Vessel, it will emit an infinite number of very small Bubbles, that spring up like sparks of Fire, and have not much the appearance of Air rising out of the Water. Do these very small Bubbles, therefore, when they are united together, form those fulminating non-aerial Bubbles, which appear in Water whilst it boils upon the Fire, after all the Air by long boiling has been expelled out of it? *Du Hamel. Demonstr.* p. 395.

Lies often wonderfully concealed where there is a great deal of it.

But there is nothing now that is more apt to impose upon us, than the quantity of Water in the Air: For the Particles of Water being ranged in a certain position, with regard to one another, are capable of producing very thick black Clouds; and yet the same Water, in greater quantity, and more dense, but disposed in a different manner, shall be so pellucid, that there shall not be the leaſt appearance of it. Thus, if we ſhut our lips pretty cloſe, and blow our breath out very ſtrong, it will ſcarcely appear; but if with an open mouth we breath it out gently, it forms a very viſible little Cloud, if it meets with the cold Air. In the ſame manner, ones moiſt Breath, in the Summer-time, is not diſcernible, though you ſee it very plainly in the Winter. But of this we treated fully in our Hiſtory of Fogs and Clouds. Here, therefore, we only give this hint to the Chemiſts, that, ſince it ſo much concerns them, they would learn to make the moſt accurate Hydroſcopes poſſible, and ſtudy, by the help of them, to find out a method of diſcovering the quantity of Water in the Air, whenever they have a mind. The uſefulneſs of ſuch a knowledge, not to mention any thing elſe, appears evident from the neceſſity of knowing what temperature of the Air is moſt convenient, if you would prepare Oil of Sulphur *per Campanam*, or Oil of Tartar *per Deliquium*, in the beſt manner.

A Wave of Water.

If ſtanding Water is not at all ruffled with Wind, it forms a Surface, that diſpoſes it parallel to that of the Earth. If you then throw a heavy Body upon the Surface of this Water, whether it be a great one, or a ſmall one, or whether it falls upon it gently, or with force, this Body, by thus falling into the Water, will with ſome *impetus* drive out ſo much of it upon its ſtagnating Surface, as is equal to the bulk of the Body. This expulſion, therefore, of the Water will ſucceſſively continue ſo long as any part of the Body continues above the Surface of the Water, but when once it is quite covered, it then deſcends equably, nor is afterwards taken notice of. The Water, now, that was raiſed by the Body immediately returns back again into the place that is left by it as it ſubſides, by which means there is formed an undulatory Circle upon the Surface of the Water. And this, from the point where the Body falls as a Center, is propagated in greater and greater Waves, always concentric to one another, to a conſiderable diſtance. And theſe Waves are always formed by this Law, that in the ſpace of 8½ ſeconds, they run through a *radius* of 12 feet from the Centre of their motion; whereas ſound runs 1080 feet in one ſecond in the Air; ſo that a Wave of Air is to a Wave of Water formed in the ſame time, as 765 is to 1, which is pretty near the proportion of their ſpecific gravities, according to the computation of the famous *De la Hire*. Though ſuch circular Waves, now, ariſing from different cauſes and centers, happen to interſect one another, yet each of them ſtill continues on concentrical to its proper center; nor are they confounded with one another. And if they happen to meet with a reſiſting and reflecting obſtacle, after their reflexion they proceed on with the ſame celerity as if they had met with no reſiſtance at all. And, which is ſtill a much greater Paradox, and really ſurprizing, whether the Wind is with or againſt them, it makes no difference at all in the propagation of the Waves. See by all means on this head the *Memoirs de Phyſique*, &c. Ann. 1693, p. 133. Theſe things I thought worth while to take notice of, that they might afford matter of ſpeculation to our Chemiſts, who are continually forming notions about the harmony of the univerſe.

Can Water be converted into Earth?

If you diſtill the pureſt Water with a gentle Fire, and in a very clean Veſſel, to a perfect dryneſs, it will leave a ſlight ſpot at the bottom of the Glaſs. And this will always happen, repeat the Operation ever ſo often, with the

the ſame Water, but in freſh Veſſels. Nay, and if you pour it back again into the ſame Veſſel, and then diſtill it again, upon every ſuch diſtillation the Cruſt will grow a ſmall matter bigger, till at laſt it becomes pretty conſiderable. This Experiment, by the indefatigable induſtry of the great *Robert Boyle*, was carried on to the two hundredth time, and he tells us in his laborious Treatiſe of *Original Forms*, that when Water had been thus cautiouſly diſtilled 200 times in a glaſs Veſſel with an Alembic, an ounce of it at laſt produced ſix drachms of a white, light, inſipid Earth, that was fixed, heavy, and indiſſoluble in Water. *Orig. Forms*, p. 259. to 273. Upon the authority of this account, the greateſt Philoſophers have laid it down as certain, that Water, by ſimple repeated diſtillation, may be abſolutely tranſmuted into true Earth. And hence the illuſtrious *Newton* deduced, that Water thus converted into Earth, might at laſt be made red hot. *Opt. Lat.* p. 319. Q. 22. With proper deference, however, to theſe great Men, give me leave to tell you, what I have been able to diſcover upon a careful examination into this matter. I took ſome Rain-water that was catched upon our obſervatory, in Veſſels that were very clean, and ſo placed, that no Rain could be beat into them that firſt fell any where elſe: A great quantity of this I put into a large Cucurbit, and with a very gentle Fire of an Athanor, to avoid any Smoke, I diſtilled it into a very clean Receiver to a perfect dryneſs. There remained then a white ſpot at the bottom of the Glaſs, but incredibly ſmall in proportion to the quantity of Water: And at the ſame time, though I had with the utmoſt care luted the Veſſels together with a Lute made of Linſeed-flower and Water, I found that in this diſtillation there was a good deal of the Water loſt. Hence I confeſs I can no ways poſſibly underſtand how thoſe famous Gentlemen could by any means prevent all the Water's perſpiring through the luting of the Veſſels, before the ſame could be diſtilled two hundred times. But ſuppoſing this, whilſt we are repeating theſe diſtillations, at the ſame time that the Water paſſes in form of Vapour out of the Cucurbit through the Alembic into the Receiver, the empty part of the Cucurbit, the Alembic, and the Receiver are full of the common Air of the Elaboratory where this Experiment is made: But this Air is always full of Duſt floating about in it, occaſioned by the Fires, the draughts of Air, Wind, and people's moving backwards and forwards. That this is the caſe appears plain from any glaſs Veſſel diſpoſed in the very uppermoſt parts of ſuch a place, which will be ſoon covered with Duſt. If we conſider this carefully, therefore, it will be very evident, that in every diſtillation there muſt by this means be a ſmall quantity of Duſt added to what was collected before. And if this Operation is repeated too hundred times, there muſt, on account of the Water's being poured back again, be four hundred ſuch collections of Duſt. I don't at all deny, therefore, but that ſome of the powder ſo produced is owing to the feculent Corpuſcles themſelves in the Water, though the greateſt part of it I think ought to be aſcribed to the Duſt in the Air. And when, upon a juſt calculation, founded on experiment, I compute the quantity both of the Duſt ariſing from the impurity of the Water, and that collected from the Air, I confeſs I cannot certainly ſee that any Earth was really generated from the ſimple Body of the elementary Water in theſe Operations. And, indeed, there is ſtill ſo much the more reaſon to doubt of it, as Mr. *Boyle* repeated the Operation himſelf but three times, and afterwards took it upon the authority of a Chemiſt, that by two hundred diſtillations, an ounce of Water had yielded ſix drachms of Earth. I don't at all queſtion, therefore, but every body that is pleaſed with this kind of inquiries will think that there is ſomewhat of conſequence in the opinion, which I here candidly ſubmit to the examination and correction of the publick. That Water may be concreted with other Subſtances into a ſolid Body, ariſing from this union, I am obliged to believe, for reaſons I have given already: But that the Elements of Water, by mere diſtillation, have ever, without the interpoſition of a third Body, been ſo united as to be converted into mere Earth, I have not yet ſeen ſufficiently demonſtrated by Experiment, and have learnt by frequent inconveniencies, that we are too apt to neglect in our chemical proceſſes, thoſe heterogeneous Bodies that ſecretly inſinuate themſelves, during the Operation. Thus then, Gentlemen, I have laid before you all thoſe things which the modern doctrine furniſhes, with certainty, concerning the third univerſal, chemical inſtrument, Water. Whether, now, that Water into which the *Alcaheſt* is ſaid ultimately to reſolve all Bodies, is the very ſame with that which we have been treating of, I am not yet, I confeſs frankly, able to determine. This doubt thoſe perſons only are capable of reſolving, who are ſo happy as to be let into ſuch myſteries, the admiration of which is all that is left for us.

Of EARTH.

Definition of Earth.

Both the Philoſophers and Chemiſts have made uſe of the term Earth, in treating of the Principles or Elements of which compound Bodies conſiſt. For by this word they deſigned to expreſs one of thoſe Elements, which in conjunction with the reſt makes up theſe compounds, and qualifies them in a good meaſure for performing the Operations both of Nature and Art. And if we examine very nicely into the proper ſignification of the term, as made uſe of by them, we ſhall find, that by Earth they meant a ſimple, hard, friable, foſſil Body, fixed in the Fire, but not melting in it, nor diſſoluble in Water, Alcohol, Oil, or Air.

Explained.

That the Idea of Body is included in that of Earth, no body, to be ſure, will deny, as its Maſs is extended into the three dimenſions of Body, is perfectly impenetrable, and always gravitates with its own proper weight. But it ſeemed a more difficult matter to determine, whether or no it ought to be ranked in the claſs of Foſſils: Upon a careful examination, however, of the characters we formerly laid down of the three natural Kingdoms, I ſhould think it ought principally to be referr'd to foſſil ones; for more or leſs Earth is always intermixed with almoſt every Foſſil that we are acquainted with. This I confeſs in Metals is demonſtrated with more difficulty; but in the reſt it is diſcovered very eaſily, and that in ſuch quantity, that it can ſcarcely be ſeparated from them, and then, not without a great deal of trouble. The weight of it, beſides, is ſo great, that it exceeds that of Water, Salts, Oils, and vegetable and animal Spirits; and by this means it inſinuates itſelf into the innermoſt parts of the Earth, ſo that it is found, and may be dug out of its deepeſt receſſes. And laſtly, pure Earth never diſcovers in its Maſs the intermixture of any other Elements, or ſcarcely any variety. Hence, therefore, it appears, that Earth could hardly be reduced more properly to any kind of Bodies, than that of Foſſils. Suppoſing, then, Earth to be a foſſil Matter, what

what an exceeding ſimplicity do we diſcover in it? Certainly, ſo great a one, that you'll ſcarcely, in the whole compaſs of Nature, find a Body that is more ſimple. For pure Earth, or, as it is called, Virgin Earth, appears ſo uniform, and homogeneous, that even Metals themſelves don't ſeem to be more ſo. And when it is perfectly ſeparated from every thing elſe, then, notwithſtanding its exceeding fineneſs, it is hard and conſiſtent. I confeſs, indeed, there are harder Bodies; but this, nevertheleſs, poſſeſſes a conſiderable degree of hardneſs. The Matter of Earth, in the mean time, appears friable, ſo long as it continues under the obſervation of our Senſes; as it always readily ſuffers it ſelf to be reduced to a finer Powder, in which reſpect it differs widely from true Metals and Gems. In this particular, however, conſiſts its greateſt difference, that it remains ſo fixed and immutable in the moſt intenſe Fire, that when it is intirely alone it is not poſſible to put it in fuſion.

The moſt perfect procured by diſtillation.

If a perſon catches pure Rain-water, and diſtills it carefully, he will find ſome *Fæces* left at the bottom, as we took notice juſt now in our laſt article upon Water. If the fæculent Matter thus collected is perfectly dried, and then thoroughly burnt, it will yield ſome Aſhes, which being very accurately freed from all the Salt that is in them, produce a fine pure Earth, which goes by the name of Virgin Earth. For whether this Matter is generated from the Water itſelf, which is ſuppoſed to be changed in this manner; or whether, which is more probable, it is collected from the Air, it produces this very ſubtil Powder. For the Air, as we obſerved before, though it is quiet, and contained in a cloſe place, abounds even then with a large quantity of an earthy, and kind of aſhy Duſt. This appeared evidently in our Hiſtory of Air, by the conſideration of looking obliquely upon the Rays of Light, in a dark Room, and is confirmed by laying a piece of black Silk open there, which will ſoon be covered with a kind of duſty Cruſt; which conſiſts chiefly of a fine Earth, which was floating about in the Air. A very conſiderable part, therefore, of this Powder is Earth, which, by an infinite number of Cauſes, being rendered exceeding fine, and put into motion, becomes capable of being carried aloft in the Air, particularly, if it happened to be expoſed to Wind. There, afterwards, it intimately mixes itſelf with the falling Dews, Fogs, flying Clouds, Water, Rain, Snow, Hail, Hoar-Froſt, and other things, to which it is applied, and with which it becomes cloſely united. Nor does the fixed nature of the Earth, generated in the diſtillation of Rain-water, which, as Mr. *Boyle* obſerved, would bear the intenſeſt Fire in a crucible, without being changed, or flying off, make at all againſt what we have aſſerted, though a perſon, indeed, might be apt to think with himſelf, how can ſuch a quality as this be conſiſtent with a Powder's floating about in the Air: But it is one thing, certainly, for a Body to be at reſt in a Fire, tho' a very intenſe one, that is equably applied to it, on all ſides; another to be taken away with an unequable motion of the Air, though without a Wind. When a very fine Powder of Earth is placed in a Teſt, and urged upwards, downwards, and on all ſides, and from the center, by the very ſame Force, it ſtagnates, if I may ſo expreſs myſelf, in a homogeneous Liquid, and by this means continues at reſt; but if the puff of a Bellows happens to fall upon this ſame Powder, it inſtantly diſperſes it about: And as Clouds replete with Water are driven about, and the very Waves of the Sea are carried up, and hurried along by the Winds, ſo we know likewiſe, that the Sands of *Egypt*

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and *Lybia* are raiſed into the Air in ſuch a manner, that they were ſufficient to overwhelm *Cambyſes*'s whole Army. Gold-Leaf, and very thin Plates of other Metals, bear the greateſt force of the Fire, for a conſiderable time, in the Cupel; and yet are blown away by the Breath, or a very gentle Wind, and diſſipated into the Air. We ought to conſider, likewiſe, at the ſame time, that Bodies that are perfectly terreſtrial, ſo long as they are intirely ſimple, and unmixed, often continue fixed and unmoved by the Fire, though upon their being mixed with other Subſtances, they become ſo volatile, as to ſuffer themſelves to be carried up into the Air, by a moderate Heat. There is nothing, you know more fixed in the Fire than Gold; and yet if you mix it with *Regulus* of Antimony, and then carefully rub it for a conſiderable time with the beſt Sublimate of Mercury, you make ſuch an Alteration in it, that it will fly off with a gentle Fire. And ſo pure Earth, if it is perfectly ſeparated from every thing elſe, will remain fixed in a Crucible, in the ſtrongeſt Fire; though if you mix it with other Bodies, you may diſſipate it into its ultimate Particles. This we need no other proof of, than the burning of Wood under a high Chimney. Does not the Smoke of this fix a black Soot to the very uppermoſt part of the Chimney, which, being chemically examined by Fire, yields a large quantity of Earth, which was carried up ſo high by the Oil and Salt that were mixed with it? And yet this Earth, now, when it is purified, and by itſelf, you may burn with the ſtrongeſt Fire, and it will in the midſt of the Flames remain perfectly fixed. Thus then you underſtand where and by what method one may procure the moſt ſimple Earth, *viz.* by diſtillation of the pureſt Rain-water. But yet even in this caſe, the *Fæces* that are thus produced, will contain in them every thing that was, together with this Earth, floating about in the Air, and at the ſame time is not volatile enough to aſcend in that degree of Heat with which the diſtillation is performed.

And by combuſtion, from the Aſhes of Vegetables.

If Vegetables are burnt in an open Fire, they moulder away into white, fixed, fine Aſhes, which with the leaſt puff may be blown into a volatile Powder, and be carried by the Wind to a very great diſtance. Nor has there ever yet been diſcovered any one Plant that upon burning would not produce ſuch Aſhes. If you take, now, theſe Aſhes, and waſh them a good many times, and very carefully, with the pureſt Rain-water, you may by this means perfectly free them from all the fixed Salt that remained in them: And as the Fire before had carried off all the Oil, and volatile Salt, the Earth will at laſt remain in the Water by itſelf. Theſe Aſhes, then, which will not have the leaſt Saltneſs in them, muſt be ſhook well together, with ſome very pure Water, and when this is become turbid, it muſt be poured off into a clean Veſſel, and then more Water muſt be put upon the *Reſiduum*, and ſtirr'd together, and decanted as before, and this muſt be repeated till all the Aſhes are thus waſhed from the little Stones, Sand, bits of Glaſs, and other little, ſolid, heavy Particles, which are not capable of being diluted in the Water. All this turbid, decanted Water, then, muſt be put into one Veſſel, and ſuffered to ſtand till all the Aſhes have ſubſided to the bottom; and then you muſt very carefully pour off the Water, leaving at the bottom a very fine Mud, which if the Salt is perfectly ſeparated, by being dried with a gentle Fire, will give the true elementary Earth, produced from Vegetables by the Chemical Art. This Earth, now, is found to be perfectly inodorous; quite inſipid; of a white colour; very ſoft,

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and ſcarcely ſonorous; hardly diſſoluble by any means, in Air, Water, Fire, Alcohol, or Oil; ſo fixed in the Fire, that if it is pure, it can ſcarcely be converted into Glaſs; capable, like Flower, of being work'd with Water into a Paſt that is ſo ductile, that with care it may be formed into a Veſſel, which is able to bear almoſt the very greateſt Torture of the Fire without any damage, will not vitrify in any degree of common Fire but remains unchanged, and will contain in it all kinds of Metals, whilſt they are in fuſion. This is that Earth which the Aſſayers make their Teſts with, for trying their Metals, when they want to diſcover what quantity of Gold or Silver is mixed with other foſſil Bodies. Of this are formed the Cupels, in which the Foſſil Glebes are mixed with melted Lead, by which means they leave their Gold and Silver fus'd into a globular Figure, whilſt every thing elſe is diſperſed and carried off. Of this too are made the Mufflers under which theſe Cupels are placed, to prevent any Dirt's falling into them, and through which there paſſes a pure and very ſtrong Fire. This is that Earth which being kept ever ſo long with melted Lead in an intenſe Fire, is never fuſed itſelf, or made to vitrify with it. And laſtly, this is the Earth of which is formed that *Myſtica Vannus* of *Vulcain*, not of *Bacchus*, through the Pores of which the crude and imperfect Bodies, that vitrify with Lead, are ſtrained, as it were, and run out, whilſt not the leaſt Particle of Gold or Silver is admitted through them, which collect themſelves, and unite into a globular Maſs, in the center as it were of the Teſt, though its whole Concave Surface and Body are every where, and equally porous. This Earth, therefore, when it is formed into ſuch a Veſſel, is the true Sieve of Metals, when they are fuſed with Lead. All theſe Characters, then, belong properly to that very pure Earth, which is procured from the Aſhes of burnt Vegetables, by the Chemical Art.

As likewiſe from Smoke and Soot.

The very ſame ſort of Earth, likewiſe, may be obtained from that part of Vegetables, which in burning aſcends from the Fire, in form of Flame, Sparks, Smoke, and Soot: Nor does it at all ſignify of what kind they are, or whether they are green or dry, acrid or mild. For if the Smoke that fixes upon the very uppermoſt cold parts of the Chimney, and there forms itſelf into ſooty Flakes, is collected, and expoſed to a very ſtrong Fire, in a clean iron Frying-pan, it will fume, take fire, flame, and at laſt conſume into white Aſhes, which being freed from their Salt, if they contain any, by the method aforementioned, yield an Earth, which in every property exactly reſembles the former, nor can by any means be diſtinguiſhed from it. Hence therefore we learn how volatile Earth may become, when it is mixed with other Bodies, and rapidly agitated by Flame; to what a great degree of volatility it may by this means arive; to what a height it may be carried, and ſo be diſperſed and ſcattered through the Air. When the black Smoke ariſes from Vegetables, and floats along in form of Clouds, the Earth likewiſe being there rendered volatile, moves together under the ſame appearance. But laſtly, when Soot is collected, and diſtilled in a clean glaſs Retort, with various degrees of Heat, and at different times of the diſtillation, it yields a Phlegm, Spirits, a volatile Salt, and another Salt, that riſes only with the laſt degree of Fire, and various ſorts of Oils; and in the end there remains at the bottom ſome black *Fæces*, which being burnt in an open Fire, produce Aſhes, which when by the help of Water they are perfectly depurated from their Salt, give exactly the

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very ſame Earth as was procured by the foregoing Methods. Theſe laſt Experiments, therefore, evidently demonſtrate, that the force of Fire agitates the very Earth with the Water, Oil, and Salt, and carries it aloft; and that this is perfectly of the ſame Nature with that which remains in the fix'd Aſhes of burnt Vegetables. This indeed is very ſurprizing, and at firſt may ſeem hardly credible, but yet it is abſolutely certain, and diſcovers to us a quality of Earth which before we were not acquainted with. If this Earth, now, which in burning is ſo volatile in the Soot, as it was firſt in the Smoke, by diſtillation, or combuſtion, is perfectly ſeparated from all the watery, oily, and ſaline parts that are united with it, it then becomes equally fixed with that which is procured from the Aſhes of the ſame Vegetable when it is burnt. Earth, therefore, when it is perfectly pure, and alone, is exceedingly fixed in the Fire, tho' by being intimately combined with Oils and Salts, it may be very eaſily rendered volatile. How full therefore muſt the Air be of a true terreſtrial Matter, eſpecially about thoſe places where great quantities of Vegetables are continually burning?

And by Diſtillation.

But again, take any kind of Vegetable that we are hitherto acquainted with, put it, as Nature produces it, into a clean glaſs Retort, make a very gentle Fire under it at firſt, gradually increaſe it to the greateſt degree, ſo that every thing may come over ſucceſſively into the Receiver that will riſe by thoſe different degrees of Heat, and then this Vegetable will be divided into two diſtinct parts; one, which will ſuffer itſelf to be carried up into the Receiver in form of a diſtilling Subſtance, whilſt the other remains in the bottom of the Retort, and will bear the utmoſt force of the Fire without aſcending, being a fix'd black Coal, which will continue ſo for a long time, as *Van Helmont* very juſtly obſerved formerly, and Dr. *Hook* has ſince confirmed by Experiment. The Chemiſts, indeed, commonly tell us, that the Water, Spirits, Oil, and volatile Salts, come over into the Receiver in form of Liquids, as the volatile parts, whilſt the Earth, fix'd Salt, and a ſmall quantity of fix'd Oil remain at the bottom of the Retort. But how far this is true, we muſt here examine. The volatile, firſt part, therefore, is always of various ſorts, *viz.* Water, Spirits, an Acid Salt, an Alcaline one, and different kinds of Oils. Theſe all now being mixed and united together, produce a Matter very much reſembling the Smoke of Vegetables, and the Soot that ariſes from it; with this difference, however, that when theſe are raiſed by an open Fire, then many more and groſſer parts are carried up, than when the ſame Subſtance is expoſed to the Fire in a cloſe Veſſel. And hence it comes to paſs, that the very ſame quantity of vegetable Matter yields a good deal leſs Aſhes, when it is burnt openly, than it leaves Coal and Aſhes procurable from it, in the bottom of the Retort, when it has undergone the utmoſt force of the Fire. If you take now all the parts together that were raiſed by diſtillation into the Receiver, and diſtill them again in a clean Veſſel, 'till the *reſiduum* at the bottom is perfectly dry, there will then always remain a black Coal; for tho' you urge it every ſo long with the ſtrongeſt Fire, you will never be able to render it volatile: Fumes, indeed, you may conſtantly force out of it; but the Coal itſelf will always continue fix'd in the Veſſel, and exceeding black. When you have attempted this, therefore, a good while in vain, take it out, and you will find it light and fungous: Then put it in a clean open Veſſel upon a common Fire, and it will burn, and flame, and by this means will have all its blackneſs conſumed, and will then leave a white Earth, which being perfectly freed from its Salt by the methods before mentioned, will be the very ſame virgin Earth, as was procured by the former Operations. Hence, therefore, it appears evidently, again, that in the diſtillation of Vegetables, the Earth riſes with the Water, Spirits, Salts, and Oils. If you take now the Oil diſtilled in this manner, and in a clean Retort, urge it through all the ſucceſſive degrees of Heat, gradually increaſed, you will have an Oil in the Receiver purer than the former, and much more penetrating. If you then repeat this Operation for a great number of times, the Oil at length will become ſo fine, that it will come near to the ſubtilty of Alcohol; but in every diſtillation, a great part of it will be diſſipated into the Air, and its proper Spirit, which gave it its peculiar ſmell and taſte, will intirely diſappear. In the mean time, likewiſe, in every diſtillation, there will, at the bottom of the Retort, be generated a black Coal, which never yields any Salt, or can be rendered volatile: And when this again is burnt in an open Fire, it produces white Aſhes, and a conſiderable portion of Earth, always of the ſame nature. Nor is there any end of this, repeat the diſtillation ever ſo often, 'till at length you may collect ſo large a quantity of it, that the greateſt part of the Oil will be converted into a pure ſimple Earth; as you may ſee in Mr. *Boyle, Of the Mutability of Principles.*

Corollaries from theſe obſervations.

Hence, therefore, it is certain, that this Earth may be procur'd from any part of Vegetables whatſoever; and that amongſt all the ſorts thus produc'd, there is not the leaſt difference that our ſenſes are capable of diſcovering. Hence too, we learn, that all this Earth, when it is abſolutely pure, is ſo fix'd in the Fire, that it can bear its utmoſt efforts almoſt without any alteration; but that, nevertheleſs, when it is mix'd with other volatile parts of Vegetables, it is together with them carried up by the Fire, and is in that reſpect ſo long volatile: This we ſee, both in the Soot that is generated by burning them in an open Fire, and the parts that riſe in diſtillation in a cloſe Veſſel. And again, we obſerve farther, that there is not any volatile part of Vegetables that renders Earth more volatile, and more eaſily ſo, than the Oil: And that among the different ſorts of Oil, procurable either by Art or Nature, there is not any one that carries up more Earth with it in diſtillation, than that laſt thick pitchy one, that is forced out by the ultimate action of the Fire. And to this, indeed, it ſeems owing, that theſe Oils are ſo very heavy, the large quantity of Earth which they contain, thus increaſing their weight: And hence ariſes likewiſe their very great tenacity. This is particularly confirmed by this Obſervation, that theſe Oils, when the Earth is ſeparated from them by diſtillation, grow immediately very thin, lighter, and exceeding volatile.

Earth in fixed alcaline Salts.

But we ſhall again diſcover a wonderful origin of pure Earth, if we now take carefully into conſideration, the other part of the Aſhes of burnt Vegetables, namely, that fix'd alcaline Salt, which in the Water was waſhed away from the Earth that we juſt now examined. Any body, indeed, would be apt to imagine here, that there was no Earth at all remaining in this Salt; for the Earth we ſaw in the preceding Operation, was left undiſſolved, whilſt the Salt was diſſolved in the Water, and paſſed pure through very thick filtering Papers in form of a *Lixivium:* Upon inquiry, however, we ſhall find to the contrary. To this purpoſe then, take this *Lixivium*, and firſt of all, by ſuffering it to ſtand quiet for a long time, let all the terreſtrial *fæces* ſubſide to the bottom; and by this means, it will be ſo depurated, as to become as limpid as Water: Let it then be filtered through *Hippocrates*'s Sleeve, and let this be repeated till it is grown as clear as Chryſtal. This Liquor then, if you examine it with a Microſcope ever ſo nicely, will not diſcover the leaſt ſign of any terreſtrial matter. Take then this very pure *Lixivium*, and put it into a clean Veſſel, and in a quiet place as free as poſſible from duſt, reduce it to the conſiſtence of a thick Oil; and then in a clean iron Pot, evaporate this thick Liquor to a dryneſs, keeping it continually ſtirring with an iron Spatula; and by this means you will procure an exceeding pure fixed alcaline Salt. When this is done, put this Salt into a good clean Crucible, and with a Tile cover it over as cloſe as poſſible, and in this condition commit it to a very ſtrong Fire till it is melted: Then pour it out into a warm braſs Mortar, and with a hot Peſtil rub it immediately into a fixed alcaline ſalt Powder. Let this Powder then be put into a large glaſs Baſon, and be thus expoſed to the Air in a place free from duſt, and the Salt in a very ſhort time will be intirely diſſolved into a Liquor perfectly fluid, whilſt to the bottom there will fall a white terreſtrial Powder, which being thoroughly waſhed from the Salt that adheres to it, will appear to be nothing but mere Earth, ſuch exactly as the other, which remained in the Aſhes. If you take now this Oil of Tartar *per deliquium*, and dry it, calcine it, and expoſe it to the Air as before, it will diſſolve again, and you will have a new Oil *per deliquium*, and always ſome Earth remaining; and if you repeat the Operation a vaſt number of times, at length the greateſt part of the fixed alcaline Salt will be reduced to a mere ſimple Earth, that in burning was united with that other Principle, which in conjunction with it, formed the alcaline Salt; which ſaline Principle being now by many calcinations and ſolutions ſeparated from its Earth, and ſet at liberty, flies off, and is diſſipated into the Air, and leaves the Earth alone. If you collect, however, all this Earth together, and weigh it, you will find it a good deal lighter than the Salt was at firſt; this decreaſe in its weight, evidently evincing, that a great part of the Salt was rendered volatile, and thus carried off. As this Experiment, therefore, conſtantly ſucceeds in this manner, we cannot but conclude, that this Earth, thus diſcovered, did really exiſt before in the fixed alcaline Salt from which it is by this means procured, and that in ſo latent a form, that it ſuffered itſelf, during that time, to be perfectly diſſolved in Water, which otherwiſe is ſo repugnant to the nature of Earth. And hence, therefore, it likewiſe appears, that the pureſt Earth, when it is united with ſome other Principle, is totally diſſoluble in Water, tho' it is by no means ſo when it is alone: Unleſs, perhaps, you will rather believe, that the very Salt itſelf, not terreſtrial before, may, whilſt it undergoes theſe calcinations and ſolutions, by an actual tranſmutation, be converted into true Earth. This opinion, however, is not founded upon any Argument or Experiment that I am acquainted with, and therefore ſeems intirely precarious: And beſides, it ſeems to me to be inconſiſtent with the ſettled conſtancy of Nature, which for ſo many ages has always been obſerved to act in the ſame manner, and by the ſame means; inaſmuch, it has never yet appeared, that any one Element has prevailed upon another, but that being properly adjuſted together, they have all conſtantly remained in the very ſame proportion.

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And as for the other Opinion, that Earth, by being united with ſaline Principles, may be rendered capable of being diſſolved by Water into a Liquor, in which nothing at all earthy ſhall appear, this is every where warranted by the chemical Art. In Glaſs, is not Earth intimately concreted with an alcaline Salt, and thus produces with it a perfect tranſparent Maſs? Which nevertheleſs, according to *Van Helmont*, may be again reſolved into an Alcali, and an Earth precipitated from it. Do not all Metals, when united with their proper diſſolvent Acids, appear in Water in the form of a very pellucid Salt? Which, notwithſtanding, may be thence again procured opake, intire, and without alteration: 'Tis needleſs to mention Chalk, Stones, Oyſter-ſhells, Earths, and other Bodies; all which, by being combined with Salts, ſeem to be converted themſelves into very pure Salts, which yet by various methods, may be again reſolved into their ſolvent Liquors, and an Earth which is ſeparated from them. How evidently is this evinced by chemical Precipitations? From the abovementioned Experiments, therefore, it is certain, 1. That the common fix'd alcaline Salts, procured from the Aſhes of burnt Vegetables, do conſiſt in a great meaſure of true, ſimple, elementary Earth, which whilſt they are forming, enters into their compoſition. 2. That this Earth is ſo concealed, intermixed, and diſſolved in theſe Salts, ſo long as they exiſt in a fixed alcaline form, that it does not give the leaſt indication of itſelf by any ſign whatever, and therefore ſo long cannot be diſcovered; as it will by Water, or the moiſture of the Air, be ſo diſſolv'd, as to be converted into an exceeding ſimple limpid Liquor. 3. That this Earth of Vegetables can only be ſubtiliz'd to this degree, by the moſt violent action of an open Fire, which whilſt it is thus conſuming Vegetables, ſo intimately unites this Earth, attenuated at the ſame time with another alcaline ſaline Principle, that from both of them thus conjoined, there is generated an Alcali, which is a proper creature of the Fire. And this, now, as we juſt mentioned, will only happen in the open Air; for a Coal, made from green Wood, being included in an iron Box, was in this manner expoſed for ſeveral hours to a very ſtrong Fire, and nevertheleſs continued a very black Coal, nor would yield any fix'd alcaline Salt, tho' upon being afterwards taken out, and burnt to Aſhes in an open Fire, its Aſhes then afforded ſome. Hence, therefore, it appears evident, that this Salt does not in reality pre-exiſt in Vegetables, but is then only introduced into Nature, when the Fire has united Earth to that other Principle, which may be thus combined with it in the open Air, but not in a cloſe Veſſel. And that this fix'd alcaline Salt is generated only in the open Air, and by the power of the Fire alone, is not leſs certainly confirmed by this conſideration, that if any Vegetable whatever, is only ſo far burnt, either in the open Air, or a cloſe Veſſel, as to be converted into a black Coal; then, if you reduce this black Coal to Powder, and boil it in Water, it will not, in the *Lixivium*, afford any fixed alcaline Salt: And yet if afterwards you take either this Coal, or its Powder, and burn it in an open Fire, by boiling its Aſhes, you will be able from them to procure it. The Earth of Vegetables, therefore, being vaſtly attenuated by the extreme force of an open Fire, is after the conſumption of the Oil, intimately united with the other ſaline part, and thus produces a fixed Alcali. Nor has this Salt ever any other origin that we are acquainted with. 4. Fixed alcaline Salts, therefore, are not ſimple Bodies, but are compounded of two perfectly distinct Principles, intimately united together. 5. And it is likewise exceeding probable, that this burning of Vegetables, after it has attenuated the Earth, combines it with that native Salt, which was naturally in the Plant, and existed there in form of a *Sapo*, made up of this Salt and an Oil united together. And hence we suppose the action of the Fire consumes the greatest part of this Oil, and then converts the Salt, the Earth, and a tenacious black Oil, into a black Coal, in which the saline part lies so concealed under the Oil and Earth, that it does not appear there as a Salt dissolvable in Water, but remains secure from the action of this *Menstruum*, till by a longer continuance, and greater strength of Fire, the black Oil of the Coal is destroy'd, and thus this Oil, which served as a *vinculum* to bind together the Earth and Salt, is removed: And thus we imagine, that at length this saline part, which before was of itself considerably volatile, becomes fixed and united with this ultimate, subtil Earth, being now perfectly freed from its principle Oil. And hence it seems to come to pass, that this fixed alcaline Salt itself, if it is kept for a long time in a very intense Heat, will at last become volatile, and perish in the Fire, tho' if it is mixed in a certain proportion with Ashes or Earth, it will be converted into Glass, which is considerably fixed there, and is very durable. 6. Hence, therefore, we never find any simple Salt in Vegetables, which of itself is naturally fixed, that which is so, owing its fixity intirely to the Earth, with which the Fire has combined it; for if Vegetables are exposed for a great length of time to the alternate vicissitudes of moisture and dryness in the Air, or if they first perfectly putrify, then, if they are afterwards burnt, they won't produce any fixed alcaline Salt in their Ashes. 7. And hence these fixed alcaline Salts, generated in the manner just explained, may, by the contrivance abovementioned, be again resolved into those two Principles, from which they were first formed by the action of the Fire, namely, into a pure, simple, imperceptible, volatile Salt, and a very subtil, pure, inactive, fixed Earth. 8. From this History, therefore, of Earth, it appears vastly more probable, that these Salts are thus generated from this Earth, and a saline Principle, than that Water, by being intimately united with the Earth, should be converted into an Alcali; for tho' all the contrivances within the compass of the chemical Art, are made use of to combine Earth and Water together, it never has appeared, that a fixed alcaline Salt has been thence produced, let the Fire be ever so intense. 9. This Earth, therefore, which is always, and every where the very same, is extracted from Plants in great quantities with the Water, Spirits, volatile and fixed Salts, and Oils, when they come under the management of the Chemist. And as for all the other Principles, the Water excepted, when they come once to be perfectly freed from their Earth, they are so attenuated, and become so active and volatile, that through this vast subtilty, they intirely escape all farther cognizance of our senses, and are scarcely afterwards to be confined in any Vessels, but return into their former aerial Chaos. The Water only, and solid Earth at last remain behind; all the rest quite disappear. The most ancient of the Chemists, therefore, were absolutely in the right, when they asserted, that the Spirits are held fast, that they may not fly off, by Oils, or Sulphur; that it is Earth alone that retains the Sulphur and Salts; and that, therefore, their fixity is to be attributed to the Earth. Thus, then, Gentlemen, from what has been said, we are come to a sufficient certainty about the nature of that Earth, which is found in the class of Vegetables;

tables; which, as it evidently appears to be perfectly the ſame in every kind of Vegetable, conſtitutes, perhaps, an immutable Element.

Earth in putrified Animals.

Let us now, therefore, proceed to examine this Earth in the Animal Kingdom. It has always been obſerved then, that all Animals, of what kind ſoever, whether they fly in the Air, ſwim in the Water, or live upon the Earth, or within it, if they are expoſed to a warm moiſt Air, preſently putrify after they are dead, in a Heat leſs than that of a Man in Health. And by this putrefaction, they are in a ſhort time ſo much altered, that their whole Bodies are reſolved into a moſt fetid putrid matter, which is ſo volatile, that it is diſſipated into the Air, there remaining only a ſmall portion of a firm ſolid ſubſtance behind. Whole Elephants left dead on the ground in hot Countries, and vaſt Whales thrown up upon the Shore, are ſoon conſumed, their bare Bones only being left behind, whilſt all the other parts are carried aloft. As for Camels too, Dromedaries, Horſes, and human Bodies left unburied, after the carnage of Battles, it's ſurprizing how ſoon there appears nothing of them at all but their Bones. Certainly, the Water, Spirits, Oil, and Salt, are diſperſed in ſuch a manner, that there is nothing but a little ſimple unactive terreſtrial Matter left behind: And then this Earth is exceedingly like that which we have juſt now been examining in Rain-water, and Vegetables. But why ſhould we inſiſt upon this any further, when we ſee it ſo evidently in the burying places of very populous Cities, where the Bodies that are buried are reſolved into ſo ſmall a quantity of Earth, that they hardly raiſe the ground at all? All the parts, therefore, both ſolid and fluid, of which Animals conſiſt, and into which they may be again reſolved by the action of the Air alone, are of ſo volatile a nature, that they intirely exhale, the Earth being the only part that remains fix'd, and is not diſſipated with the reſt. And this terreſtrial part, if we examine it more nearly, preſents to us only mere Bones, or a little Aſhes, which are diſperſed with a ſlight Wind and diſappear.

And in their humours diſtilled.

But the nature of our deſign leads us to examine this Earth in Animals ſtill more nicely. Let us firſt, therefore, take into conſideration any of the Humours of any kind of Animal whatever, after, by a due circulation, they have been quite changed from the crude diſpoſition they had when they were taken into the Body, and by the natural powers of the Animal, are aſſimilated to its peculiar Nature. Theſe then, under this Limitation, being put into a clean Retort accurately fitted, and luted to a Receiver, and expoſed to a Fire very gradually increaſed from a very gentle one to the greateſt, will in a Heat raiſed to 212 degrees yield, firſt, an incredible quantity of Water; ſuch a one as no-body could ever imagine ſhould enter into the compoſition of the animal Fluids. If you continue this degree of Heat for a conſiderable time, all the Water that is thus diſtill'd from theſe Humours, ſeems in moſt of its properties to be almoſt the ſame with that which is drawn from Vegetables, and was before conſidered; indeed, to ſuch a degree, that we find but little difference. There is, it's true, in this Water from Animals, ſomewhat of a ſubtil rancid Smell, and a diſagreeable Taſte; but theſe, as they don't diſcover the leaſt ſign of any Earth, have nothing to do with our preſent Enquiry. If you proceed then to urge the *reſiduum* with a ſtronger Fire, when all the aqueous part has been drawn off by the Heat of boiling Water, then this Maſs, which is always dry, and in ſome meaſure ſlightly burnt, will yield a light, yellow, Liquor,

quor, leſs volatile than the firſt Water, which has been called the Spirit of theſe animal Humours. This now is fetid, and of ſo ſaline a nature, that upon mixing with Acids, it will cauſe an Efferveſcence. If you collect then, this Spirit carefully by itſelf, and diſtill it in a clean Veſſel, it will produce ſome *fæces*, which being burnt, and depurated, as before, yield a ſmall quantity of Earth, perfectly of the ſame nature with the former; ſo that this Earth riſes with this Fluid, and may be procured from it. If the Maſs, then, of theſe Humours, thus deprived of their Spirit by its proper degree of Heat, is ſtill expoſed to a greater Heat, you will have from it diſtilled animal Oils in great abundance. But if you diſtill theſe again in a clean Veſſel, they likewiſe will leave at the bottom of the Retort a large quantity of fixed Earth, as we took notice in the diſtill'd Oils of Vegetables. And thus, likewiſe, will theſe Oils, by a reiterated diſtillation, be converted into Earth, till at laſt there will remain only an exceeding ſubtil Oil thus freed from its Earth, which is almoſt of a ſpirituous nature: So that the thickneſs, tenacity, and fixity of theſe Oils too, ought to be attributed, as before in Vegetables, to this very ſame Earth. And as for the volatile Salt of Animals, which partly is forced out of them by the Fire together with theſe Oils, and partly riſes afterwards, and is ſeparated by itſelf, this always in the beginning of its production has a large quantity of Oil united with it, which by its viſcidity, holds down, fixes, and retains it; for as ſoon as ever you have, by the chemical Art, perfectly freed this Salt from its Oil, it immediately becomes perfectly volatile, and in diſtillation leaves no *fæces* behind it. After the ſublimation, indeed, is made with a very moderate Fire, there remains at the bottom an unactive Water, which, let the Salt appear ever ſo dry, adheres to it ſo cloſely, that in a gentle Sublimation, it always diſcovers itſelf in this manner, nor can ſcarcely be perfectly ſeparated from by any contrivance whatſoever. All the fixity, therefore, of the native animal Salts, ſeems to be owing intirely to an Oil which is naturally in them, and ſerves to retain the ſaline parts; but this very Oil owes all its fixity and tenacity to the Earth with which it is united; and conſequently, the Earth is, in reality, the *Vinculum* by which the volatile Salt is ſecured, and held down, which would otherwiſe be of too volatile a nature: When the former Oils are thus drawn off, if you ſtill proceed to increaſe your Fire, you will then have a very black, thick, pitchy, tenacious Oil, which will often puff up, and fill the whole neck of the Retort, and thus in form of an inflated Pitch, paſs into the Receiver, being heavier than any of the Liquors that were drawn from the Vegetable in the former diſtillations. If you take now this laſt Oil, and diſtill it carefully, and according to Art, the greateſt part of it will remain an Earth at the bottom of the Retort, tho' you urge it with ever ſo ſtrong a Fire. And if you repeat this diſtillation again, and again, the Oil will every time become more and more limpid, and there will always a large quantity of Earth be left behind. By ſuch a tedious rectification of this, I reduc'd, formerly, ſome pounds of a thick Oil of Hartſhorn, into a very thin, pellucid, volatile Oil, and a large quantity of a black oily Earth, which being burnt in an open Fire, yielded the very ſame Earth, which we have already ſo often mentioned. By this means, then, I became certain, that when this laſt Oil, very tenaciouſly adhering to the Earth, was raiſed by the moſt violent action of the Fire, it carried likewiſe this Earth along with it; and conſequently,

consequently, that though we call this Substance Oil, yet, in reality, a great part of it is only mere Earth. Hence, then, we learn, that Fire, when it is applied to Oils united with Earth, is so far capable of rendering the Earth volatile: And again, that the properties peculiar to this Oil that rises only with this intense degree of Heat, almost all depend upon the Earth, and not upon the Oil itself. Hence, for instance, arises its very great degree of fixity, thickness, tenacity, and weight; all which it loses, as soon as ever it is perfectly separated from its large quantity of Earth. And hence, likewise, we discover farther, the intimate, and almost inseparable union of this Earth, with all the animal Oils, and the constant effect produced by this union, *viz.* the prevention of their being volatile; for as on the one hand, the Oils, by being united with the Earth, render it, in some measure, volatile in the Fire; so this, on the other, by this same union, prevents their being rendered too volatile, by a small degree of Heat. And as the very volatile Spirits are intangled, and held down by the Oils; so the Oils, which would otherwise rise too easily, are retained by the fixity of the Earth. But lastly, if the fixed, black *Fæces*, that remain at the bottom, after all the Oil is expelled by the former degree of Fire, applied for a good while, are urged with the greatest degree of Heat, and this is kept up for a long time, they will at length emit some blue, shining, dense Fumes, and throw out, at the same time, some sparkling Corpuscles, which, being received into pure cold Water, will be condensed, and by their weight sink to the bottom, where being collected in little Masses, they produce the Phosphorus, now called the Solid, as the former, whilst it floated about in the form of a Fume, may be called the Fluid. This Phosphorus, now, if it is exposed to the Air, takes fire, consumes in appearance of a little lucid Flame, and flies off with a fetid Smell; but even then it leaves behind it a very acid, thick Water, in which there is always something of terrestrial *Fæces*. Of this wonderful Substance, now, we may very reasonably inquire, whether it is, in reality, of the animal or vegetable kind? Or whether it is properly a Creature of the Fire? Or whether it don't owe its origin to all three together? This is certain, it burns perfectly, it will keep for years in Water without being dissolved, and at the bottom of Water it will by Heat be melted like Wax. It rather, therefore, seems to be of an oily nature, than a saline, or terrestrial one; and yet it is perfectly different from every thing that has hitherto been ranked among the Oils or oily Substances, and contains but a small quantity of Earth.

If we examine, now, the ultimate *Fæces* that remain after all the different parts above-mentioned are drawn off, we find them still to continue black; but if the Mass is taken out gently, and burnt in an open Fire, it becomes white, of an earthy nature, retaining its former figure.] This History, then, of Animals and Vegetables, given with a view particularly of coming at the true nature of Earth, lets us see, at the same time, that these two kinds of Bodies appear to be vastly near a-kin in all their properties, and in a great many of them to agree intirely. Hence, therefore, it is no wonder, that Animals, by means of their concoctive faculties, can subsist intirely upon Vegetables, with the simple addition of Water. And as this appears to be every where the case, the bodies of Animals seem almost, in many instances,

The likeness between Animals and Vegetables.

ſtances, to be nothing but tranſmuted Vegetables. The chief difference, indeed, between them ſeems to lie in their Salts; for theſe, when thoroughly concocted, and ſo become proper to particular Vegetables, are in many of them acid, or auſtere; whereas I have never been able to diſcover any acid ones, much leſs auſtere ones, in the native humours of Animals. Let me caution you, however, that this muſt not be underſtood of crude Juices, juſt taken into the Body, and ſtill retaining their own proper qualities; but of ſuch as by the natural vertue of the animal Body, have been truly aſſimilated to the animal Nature. But again, the Salts of moſt Vegetables, procured from them by burning, are found to be fixed; whereas there was never any fixed alcaline Salt diſcovered in Animals, when treated after the ſame manner; though, as I ſhall demonſtrate hereafter, there are Vegetables that have a volatile, alcaline Salt, like that of Animals, as appears in the Scurvy-graſs, Muſtard, and others. But the Earth itſelf, or the Oils, as they contain a large quantity of Earth in them, ſeem, by their admixture, to cauſe the chief difference that there is in the fixity of the animal and vegetable Salts: And hence it ſeems likewiſe to follow, that the Earth in Animals exiſts in leſs quantity, and is leſs intimately united with their Oils and Salts, than it is in Vegetables.

Let us, however, conſider, in the mean time, that the perfect putrefaction of Vegetables makes ſuch an alteration in their proper diſpoſition, that the Earth being, by this means, more diſengaged, recedes, both from their oily and ſaline parts, and thus effects, that Vegetables, which before putrefaction yielded, in burning, a large quantity of a fixed, alcaline Salt, being burnt afterwards, afford none at all, but then give out all their Salt, of a volatile nature, as Animals do. The union, therefore, of elementary Earth, with all the other Elements of Vegetables, is diſſolved by no action more eaſily than it is by means of putrefaction, which very powerfully divides and ſeparates their Elements from one another, and thus deſtroys their former particular form, by which means, thoſe both of Animals and Vegetables become nearly the ſame. And hence it comes to paſs, that this very putrefaction renders the Bodies of Animals and Vegetables exceeding fit to produce ſuch a matter in the Air, Water, and Earth, as ſhall be rightly diſpoſed to yield a kindly nouriſhment to new Vegetables, and ſo again, through their means, to Animals. On this account, therefore, all putrefied Subſtances are particularly ſerviceable in fructifying the Earth; and for this reaſon, all Animals whatever, are, by the grand Law of Nature, ſubject to putrefaction, ſooner or later, and thus afford freſh matter for impregnating their Mother Earth, and repleniſhing it with new fruitfulneſs.

The putrefaction of Vegetables ſeparates their Earth from them.

Fermentation does not ſeparate this arth.

Since, therefore, the putrefaction of Animals and Vegetables thus ſeparates the Earth from the other Elements, and by this means renders them ſo volatile; hence, perhaps, ſome perſons may be ready to infer, that fermentation, likewiſe, will do the ſame. But this happens quite otherwiſe: For though fermentation agitates Vegetables ſo powerfully, and for ſo long a time, yet it is never able thus to free the elementary Earth from its Salt and Oil. And for this reaſon it does not ſo aſſimilate Vegetables to Animals as purefaction does; nor prevents their yielding a fixed Salt in their Aſhes, if they are afterwards burnt; as evidently appears in Tartar. One ſort, indeed, of the vegetable Oils it converts into a volatile Alcali, but is not able to change all the oily parts

parts of it in the ſame manner. From ſuch a number of Experiments, then, we underſtand the nature of that elementary Earth which enters into the compoſition of Animals and Vegetables, as a true principle. And in both theſe, this Earth ſeems to be perfectly of the ſame nature, there being very little difference obſerved in it. This no where appears more evident than in the Cupels, which are made equally good from the Aſhes of Vegetables, or the pure Earth of Animals; and that, whether it is procured from Fiſhes, Birds, Beaſts, their Bones, Hoofs, Fleſh, or Juices, provided the Earth is but pure. See *Laz. Esker*, where he treats of this ſubject. This Earth, therefore, ſerves in the ſame capacity, both in Animals and Vegetables, gives a firm make to their Bodies, and affords a ſolid *Baſis* for the reſt of the Elements; for theſe muſt all be united with this Earth, that by this means they may be fixed, and held together, and thus reduced into the ſhape of any particular ſolid Body. This Earth alone gives to them all their proper form; and when this is ſeparated from them, they all ſink down into an irregular Maſs, or being reſolved, and ſet at liberty, become volatile, and are diſperſed from one another. This Earth, by its fixity and tenacity, proves a proper *Vinculum* to bind, aſſociate, and properly diſpoſe all the other parts with one another, and ſo hardens the Body that ariſes from this conjunction, that by this means it becomes capable of reſiſting the Air, Water, Sun, and ſome degree of Fire itſelf, without ſuffering any inconvenience. But then, likewiſe, on the other hand, pure, dry, elementary Earth ſtands in need of the aſſiſtance of Water, or Oil, as a kind of Cement, to hold together its ſeparate Elements, and thus to form them into one Maſs.

The Earth of Animals by combuſtion. If whole Animals are burnt in an open Fire, till they are intirely conſumed, there then remains nothing but white Aſhes, which being pounded, exhibit again an Earth exceedingly like the former, and free from all Oil or Salt. This can no ways be diſtinguiſhed from the Earth procured from Animals, by the former operations, and ſerves abſolutely for the very ſame purpoſe in every kind of Experiment.

Earth in Foſſils; firſt in Salts by ſolution. But it is time, now, that we take a view of the foſſil Kingdom, and ſee what Earth we are capable of diſcovering there. And here the native Salts, Nitre, *Sal-Gem*, Fountain Salt, and Sea Salt, firſt offer themſelves to our obſervation. Take theſe, then, as pure as they can poſſibly be procured, diſſolve them in very clean Water, and digeſt them for a long ſpace of time in Veſſels accurately cloſed, and they will yield an Earth at the bottom, precipitated from them, which will not be diſſolved in the Water. When the Liquor is thus depurated, and grown exceeding clear, let it exhale in a place free from Duſt, till you obſerve a Pellicle on its Surface; then remove it into a low, cool, quiet place, and it will ſhoot into little ſaline Glebes, of a particular figure, pellucid, and pure, which the Artiſts call Chryſtals, and theſe, if they are thus carefully prepared, produce a particular *Species* of Salt perfectly diſtinct from every other. If the Liquor then that remains after the Salts are thus formed, is gently poured from them, it may be again inſpiſſated to a pellicle, and by the ſame method as above it will generate freſh ſaline Chryſtals, but not ſo tranſparent, or pure, as the former. If you, then, as before, ſeparate the remaining Liquor, and proceed in the ſame manner, after the laſt chryſtallization, there will be left a fat ſaline Liquor, that will not be dried without a great deal of difficulty, but then will produce ſome Earth: And this Maſs, when you have rendered it dry by the Fire, will again ſpontaneouſly diſſolve in the Air, and be of an acrid auſtere nature. If you take then the Chryſtals thus procur'd, and diſſolve them, and proceed as before, you will every Operation have ſome more pure Earth, which being collected together, will produce a large quantity thus generated from the pure foſſil Salt. And at laſt, after this Chryſtallization and Solution has been repeated a great number of times, all the Salt will become volatile, be diſſipated into the Air, and eſcape any farther notice of our Senſes; and of the whole Maſs of Salt, which has thus paſſed under Examination, the Operator will have nothing left but mere Earth; for all the other parts, which in conjunction with this Earth, made up before the Body of the Salt, being by theſe Operations ſeparated from it, grow ſo ſubtil, as not to fall under our Obſervation, and ſo volatile, that they cannot remain at reſt, but fly away. Theſe Experiments concerning the nature of Earth in Foſſils, were known and deſcrib'd by the ancient Chemiſts, and have been ſince performed and confirmed by the Moderns. See *Du Hamel Hiſt. de l'Ac. Roy. des Sc.* 1701. p. 16, 17.

By Diſtillation. But again, if you take any one of the abovementioned Salts pure, and very dry, reduce it to Powder, and accurately mix it with three times its weight of very dry Clay, Bole, Brick-duſt, or pure Earth, and then urge it with the greateſt degree of Fire, it will by this means be reſolved into a liquid part, which will be volatile, acid, and corroſive, and a fixed one, which will remain at the bottom of the Veſſel in the Earth with which it was mixed. This fixed part, now, if, by boiling it in Water, and letting the Water ſettle, and afterwards filtering it, you perfectly depurate it, and then reduce it to Chryſtals, will yield a Salt pretty much reſembling that which was made uſe of in the diſtillation, except, that that from the Nitre will be in ſome meaſure alcaleſcent. And if the Salt thus generated, is again diſſolved, inſpiſſated, and chryſtalliz'd according to Art, it will likewiſe produce a great deal of Earth of the ſame nature with that which was procured from the original Salt. The acid Liquor, too, thus drawn from the Salt by diſtillation, being again diſtilled in a clean Veſſel, will leave ſome yellow *fæces* at the bottom, which when they are dried, are found likewiſe to contain ſomething of Earth. And theſe acid Salts, now, thus prepared, are ſo volatile, when they are accurately freed from all their Earth, that being impatient of reſt, they are continually diſperſed into volatile Fumes, which can ſcarcely be contained within their Veſſels, and fly off as ſoon as ever they come to have a free communication with the Air; as appears evidently in the diſtillation of *Aqua Fortis*, Spirit of Nitre, *Glauber*'s Spirit of Salt, and Spirit of Sea-Salt; for in theſe the pure Volatile acid Salt ſpontaneouſly reſolves itſelf into white or red Fumes, and without the aſſiſtance of any external cauſe, immediately flies off into the Air. If you thoroughly now conſider theſe *Phænomena*, perhaps you will think it not very abſurd to ſuppoſe, that all theſe acid Salts hitherto deſcribed, would not of themſelves be at reſt in our Air, but that they owe this reſt, or as the Artiſts call it, fixity, principally to the latent elementary Earth, which ſecretly uniting with them, fixes their volatility, and thus holds them down: And on the other hand, that whenever they are diſengaged from their confinement, and get free, they then ſpontaneouſly regain their former and proper volatility. Suppoſing, therefore,

this

this to be the caſe, then both the ſimple Acid, and alcaline Salts, would, as has appeared by the former Experiments, from the purity of their ſimplicity, be always volatile, and then only become fixed when they were intimately united with Earth. In this Doctrine, however, there are two things that ought to be taken notice of; firſt, that the Acid of Vitriol, and burnt Sulphur, remains fixed in a Fire of 560 degrees, tho' it is purified by repeated diſtillation, and has depoſited its *fæces* at the bottom of the Veſſel. This, I confeſs, indeed, may poſſibly be owing to ſome non-acid that is intimately mix'd with it, whether you ſuppoſe it of a metalline or terreſtrial Nature, that cannot eaſily be ſeparated from it; for during the diſtillation, the Receiver is filled with very volatile Fumes, which, if there unfortunately happens to be any crack through which they can make their way, burſt out in a deadly Vapour: Secondly, that the moſt volatile acid Salts, by being united with a very volatile alcaline one, are converted, without the aſſiſtance of any Earth to fix them, into a compound *Sal-Ammoniac*, which is ſemi-fixed. But to proceed, if Foſſil Alum is diſſolved, chryſtallized, and treated in the ſame manner as the Salts abovementioned, from this likewiſe may be procured a great quantity of Earth, which being perfectly ſeparated, this Salt too becomes volatile. This likewiſe in diſtillation ſends forth a very volatile and pernicious Vapour, and leaves a great deal of a kind of Lime-Earth at the bottom of the Retort. But proſecuting theſe inquiries ſtill farther, I diſſolved ſome Vitriol in Water, and digeſted it, and by this means procured from it a large quantity of Earth, called Ochre: And whilſt I patiently repeated the former work of ſolution, and chryſtallization, and in the ſame manner removed the *fæces*, all the Vitriol was converted into a yellowiſh *Calx*, which was the greateſt part of it, a volatile part that was diſſipated into the Air, and a thick Liquid, which was pinguious, and very auſtere. Theſe *Fæces*, now, I am very well apprized, indeed, cannot properly be referred to elementary Earth, but are rather the *Calx* of the corroded Iron: In the other particulars, however, this *Analyſis* of Vitriol reſembles the former Operations. The *Calx* now thus procured, may, by a very ſtrong Fire, be converted either into Copper or Iron, according to the different ſort of Vitriol you make uſe of; and hence we evidently ſee what judgment we ought to make of that opinion, which ſome Perſons have fallen into, who upon ſeeing the ſeparation of ſuch a *Calx* from a metalline Vitriol, have hence inferred, that Earth itſelf enters into the compoſition of Metals. For my own part, I confeſs, I don't remember, that by any one Experiment I have ever diſcovered a true Earth in Metals: As for that which is offered for it, it is capable of being melted into Glaſs, and by this very property ſhews, that it is not of a terreſtrial nature, and gives ſtrong ſuſpicion that it is of a metalline one.

And in ſulphureous Liquids.

If we examine farther, the foſſil liquid Sulphurs, and the ſubſtances produced from them, as the *Aſphaltus*, Bitumens, *Naptha*, *Petroleum*, and *Oleum Terræ*, theſe, if they are expoſed to an open Fire, burn in Flames, produce Soot, emit black acid Fumes, and when they are quite conſumed, have ſomething of Earth at the bottom; and from this, if by farther burning you reduce it to a *Calx*, you will always be able to obtain a pure Earth, exceedingly like that from Animals, Vegetables, and Foſſil-Salts.

And Solids. And as for true Sulphur, if you ſublime it into flowers in a cloſe Veſſel, it will always the firſt time leave ſome Earth at the bottom; tho' the Flowers, indeed, thus produc'd, in a ſecond ſublimation ſcarcely yield any. But if with the pureſt Sulphur, you intimately mix over the Fire an equal quantity of a very pure alcaline fixed Salt; then the compound that ariſes hence, being put into a clean glaſs Baſon, and expoſed to the Air in a place free from Duſt, will very ſoon diſſolve into a Liquor, to the bottom of which will ſubſide a great deal of Earth. This Earth you may poſſibly attribute to the Alcali; nor do I deny but this may be concerned in it. Give me leave, however, to aſſure you, upon undoubted evidence, that the Oil, which, in conjunction with the foſſil Acid, produces Sulphur, contains likewiſe, and will yield a good deal of Earth. Hence, therefore, you will be apt to be of opinion with me, that this Earth may in this caſe be regenerated in the reſolution of the Sulphur, and thus diſcover itſelf to the Operator.

Is there any likewiſe in Metals? The moſt ancient of the Chemiſts who got a knowledge of the Laws of Nature purely by the aſſiſtance of Experiments, were of opinion, that all Metals conſiſt of Mercury exceedingly homogeneous, and another principle, which gives it fixity and ductility under the Hammer: That theſe two Principles alone enter into the compoſition of Gold and Silver; but that in the other Metals, beſides theſe two, there is likewiſe another matter that won't bear the Fire, is ſubpinguious, and in ſome meaſure inflammable, which being intimately mixed with them in their original formation, becomes very firmly concreted with them: As for any other Principles, they ſcarcely make mention of them in their natural Hiſtory of Metals. The Moderns, however, relying upon the evidence of their Experiments, every where in the *Analyſis*, and compoſition of Metals, tell us of an Earth, and that too, one that will vitrify, which enters into their compoſition, and is the firm *Baſis* of them all: But this Earth, which they thus tell us may be procured from Metals, does not, in reality, anſwer to the character of Earth, and therefore in a ſtrict ſenſe does not deſerve the name of it. For my part, I have taken a great deal of pains in that affair, but have never yet, I confeſs, been able to diſcover in them any true Earth.

Scarcely in Mercury. Mercury, when it is freſh brought out of the Mines, if it is ſtrongly preſſed through a thick Leather, ſeems to leave a little Earth behind it, whilſt it thus paſſes through its Pores. If you then, after it is depurated in this manner, diſtill it in a clean glaſs Veſſel, it will leave a ſmall quantity of *Fæces*, of no weight hardly, or ſcarce worth taking notice of. Nor can I, indeed, venture to call this, Earth, which is thus ſeparated from the Mercury by diſtillation, ſince the diſtinguiſhing marks, by which we before defined Earth, are not found to belong to theſe *Fæces*. Take then this Mercury, now rendered exceeding pure by diſtillation, and put it into a ſtrong glaſs Bottle, made of deep green Glaſs, and ſo thick, that it may bear the concuſſion of the Mercury without any danger of being broke: Then ſtop the mouth of the Bottle exceeding cloſe with a Cork covered with a Hog's-bladder, which drive in tight, and then ſecure it all round with Pitch, that let the agitation be ever ſo great, none of the Mercury may be able to eſcape out of the Bottle. This being done, let the Bottle with the included Mercury be mov'd very ſtrongly about, and for a great while together; which will be beſt effected by faſtening

tening it to the Sails of a Wind-mill, or fixing it in ſome ſwift carriage that is every day driving about: And by this means, the Mercury being thus continually agitated within this narrow compaſs, the greateſt part of it, without the addition of any thing elſe, will be converted into a dry, black, heavy, fine Powder, which is exceedingly efficacious in curing ſtubborn Ulcers, and as it is imagined, is ſcarce diſſoluble in any *Menſtruum.* This very extraordinary Experiment, which has been tried by the egregious *Homberg*, and which few people are acquainted with, has given occaſion to its being aſſerted, that true Earth may be produced from the very Body of the Mercury by this ſimple mechanic motion; whilſt on the other hand, others have rather been of opinion, that the pure Mercury, by being agitated by this continued concuſſion, diſengages itſelf from the terreſtrial part, which nature had united with it in its formation; and that, therefore, that part of the Mercury, which remains after this ſeparation, being purified, and freed from its unactive Earth, become agile and pure, and by this means grows fit for the profound Operations of Alchemy, and is, in reality, the ſo much wiſh'd for *Mercurius Sophorum.* Perhaps you may deſire to know what is my Opinion of this Affair: In ſhort then, I take the liberty to aſſert, that the Powder thus deſcribed is not elementary Earth, much leſs an Earth, that as a conſtituent Principle, enters into the compoſition of native Mercury. And if any Perſon will but take the pains to examine this Earth by calcination, and nicely obſerve the various and wonderful Colours that ſucceſſively appear in it, and will in particular, at the ſame time conſider its wonderful vertues in curing carcinomatous Ulcers, I am perſuaded he will hardly be of opinion, that this is the mere ſimple Earth of Mercury. Nay, but ſhould I aſſert farther, that this Powder may be diſſolved in various *Menſtruums*; and that afterwards it may be reduced again into pure Mercury, it would not be without foundation. Believe me, Gentlemen, who have had long experience in theſe things, minds that are always ready to run into haſty concluſions, are not properly ſuited to the proſecution of the chemical Art, which diſcloſes its ſecrets to thoſe only who are patient of labour, and carefully compare together the events of various Experiments, whom it rewards with proper diſcoveries. As it is exceeding difficult, therefore, truly to demonſtrate any Earth in Mercury, ſo on the other hand it is eaſy enough to come at the knowledge of many various forms of this changeable Body, which from its own nature is capable of being converted into a thouſand odd and different appearances, and thus impoſes upon the unwary, tho' at the ſame time it remains always one and the ſame at the bottom.

And let a Man, now, examine the reſt of the Metals ever ſo accurately, where will he be able to diſcover any Earth in them? In the *Calx* of them? Theſe certainly all continue true Metals: For altho' the *Calx* be inſipid, inodorous, fine, and ſometimes too pulverizable, yet, by the addition of ſome reducing Powders, as they call them, and other contrivances, they may be brought back again to their original form. Whoever, therefore, looks upon theſe *Calx's* as true elementary Earth, may ſuppoſe with equal reaſon, that by theſe ſlight methods, too, he is able to tranſmute Earth into Metals whenever he pleaſes. But beſides, the Metals calcined in this manner, may, by the efficacy of the Fire alone, or by admixture of ſome other ſubſtances with them, be converted into true Glaſs, which every one, who is acquainted with theſe things,

Nor from other Metals.

knows

knows very well, can ſcarcely be affirmed of pure ſimple Earth. In the mean time, however, I muſt caution you, that the baſer Metals, Iron in particular, when they are analyz'd according to Art, do yield ſomething that comes very near to the nature of Earth; tho' this, indeed, is but in ſmall quantity, and even here does not appear to be perfect Earth. But whilſt we are upon this head, give me leave to lay before you, what I myſelf, after a great deal of pains in examination of Metals, have been able, with certainty, to diſcover. If Gold, Silver, Copper, Tin, and Lead, are firſt prepared in a certain ſimple manner, and then accurately mixed with the pureſt Mercury, and by this means intimately diſſolved, and are afterwards digeſted for a long ſpace of time, and then either very patiently rubb'd or ſhook about, there will at laſt be produced from this Mixture, a great deal of inſipid, inodorous, fine black Powder, which in all of them, will be of the ſame kind, and which being perfectly ſeparated by Water and Motion, will leave a pure metallic Maſs. This being agitated by farther ſhaking, or rubbing, will generate as before a large quantity of the like Powder; and this will be always the event, tho' this Operation ſhould tediouſly be continued for years together, as I myſelf have often experienced. If thoſe Gentlemen, therefore, who in their Writings ſuppoſe Earth to enter into the compoſition of Metals, had proſecuted theſe inquiries in the ſame manner, they would not certainly, in order to confirm their opinion, have too haſtily referr'd us to this Powder. For my part, who have hitherto laboured in vain to bring theſe Experiments to the deſired iſſue, I am obliged ingenuouſly to confeſs, that the Powder procured by this Art, is by no means Earth, but a wonderful metalline Production, whoſe properties I have found to be very ſurprizing. Upon this head, therefore, I may be excuſed at preſent ſaying any thing farther, as I think, to the wiſe, what I have offered is ſufficient. If any Perſon goes about to ſeek for a true Earth in this metalline Powder, he will hardly accompliſh his end; tho', at the ſame time, he will diſcover a great many things that he never dreamt of. And, indeed, upon the evidence of what I have ſeen, whilſt I have been cloſely engag'd in theſe purſuits, I may almoſt venture to affirm, that neither Gold, Silver, or Mercury, contain any thing of Earth in their natural Compoſition; but that they are formed of ſuch a nature, that tho' they are divided into their leaſt poſſible parts, yet they will ſtill retain ſuch a diſpoſition, as will render them fuſible in the Fire, or ductile under the Hammer. Concerning Gold, I can teſtify myſelf, that I have reduced it into a Liquor by the aſſiſtance of foſſil Acids, I have formed it into ſoft Paſtes, and procured *Calx's* from it in different manners; it may eaſily, likewiſe, be converted in a volatile ſcarlet Oil; it may be chang'd into a Subſtance like Butter; it may be turned into Glaſs; and it will ſometimes moſt exactly reſemble Earth: But ſtill, notwithſtanding its appearing under all theſe different forms, it may always be again reduced to Gold, perfectly the ſame in all reſpects, its weight not in the leaſt, either increaſed or diminiſhed. And after an incredible number of diſtillations of it with Mercury, I have always at laſt procured my Gold again. With Silver too, I have performed the ſame tedious Operations, and the event has been conſtantly the ſame. Upon the evidence, therefore, of theſe Obſervations, I could not help again admiring the ancient Alchemiſts, who have openly told us, that Gold and Silver are generated from pure Mercury alone,

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fixed by a condensing Sulphur; and that the rest of the Metals too, owe their origin to the various combinations of a Mercury less pure, and a Sulphur less defæcated.

From the Doctrine, now, that we have thus delivered, we may deduce the following Corollaries. Hence then it appears in the first place, that the very same simple elementary Earth, concurs, as a constituent Principle in the formation of the particular corporeal fabrick of Animals, Vegetables, and some Fossils, that are less durable, and less simple: That in all these it serves as a firm *Basis* to give them their proper form, and unites all the other Principles, both with itself, and with one another, into one single particular Body: That by this means, it fixes, retains, and keeps from dissipation the other parts, that are of themselves too volatile, and thus disposes and qualifies every Body to continue what it is for some time, and that, both with regard to the whole Body, and every part of it: That this is the principal natural cause, that the whole frame is not too easily, or too quickly dissolved, either by the Air, Water, its own proper juices, or even Fire itself: And that to the efficacious concurrence of the Earth, therefore, in giving to every single Body its proper and peculiar structure, must be ascribed in an especial manner, the power of assimilating foreign substances into the nature of the Body that is nourished, and consequently, in some measure, the seminal vertue that Bodies have of generating their like; for this always perishes in every particular Body, as soon as ever its structure, which depends principally upon the Earth, is destroy'd. 2. These Bodies, therefore, that owe their origin to the very same Earth, must in this respect, wonderfully agree with one another. Nor, indeed, do they resemble one another only in respect of their Earth, but generally likewise, in the very great affinity there is between their other concurring Principles. If you consider all the different kinds of Animals, in what a vast number of circumstances are they like one another? As Vegetables, we see all agree in many surprizing Properties. The Elements of Animals, we observe, are continually changing into the Matter of Vegetables; whilst on the other hand, the Bodies of Animals are perpetually supported and nourished by the Vegetables which they take in, and assimilate to their nature, and which afterwards actually enter their very make. The same thing likewise holds true in most kind of Salts, which are partly composed too of this Earth. Who will pretend to assert, that Salt of Nitre, or Sea-Salt, are so very remote from the disposition of the animal Body? But in these we discover the same Earth. And hence, by the way, it comes to pass, that alcalious fixed Salts, when they are taken in a moderate dose, are so easily assimilated to the animal Nature: For if a strong healthy Man takes small quantities of these, at suitable distances of time, they will lose their proper qualities in his Body, nor will there any fixed Salt appear in his Urine. 3. Bodies, therefore, that owe their origin to the same Earth, are easily transmuted into one another. 4. Iron, which of all the Metals seems to come nearest to the Earth of Animals and Vegetables, must be allowed likewise to come nearest to Animals and Vegetables in nature, and seems as if it might in some measure be dissolved in them: And hence it yields a noble, and very safe remedy for Diseases of the human Body, whilst the rest of the Metals act with more violence. 5. For these, as they do not acknowledge Earth, but Mercury for their *Basis*, seem to remain immutable

immutable in all Bodies, nor appear to be capable of being digested by our concoctive faculties. For this reason, therefore, they always continue foreign to our nature, and contrary to it; and tho' sometimes in certain exceeding stubborn diseases they are of service, yet if you regard them in another view, they seem intirely superiour to the animal powers. 6. If there was no such thing, therefore, as Earth or Mercury, would all the Bodies that we are acquainted with be active, volatile, and so subtil as not to fall under the cognizance of our senses, and consequently be floating Atoms? Even the Sulphur of Metals itself, before it fixes, and is fixed by Mercury, the Alchemists tell us, is of all Bodies the most subtil and volatile. Concerning the rest, the doctrine we have above delivered leaves us no room to doubt. 7. Earth, therefore, principally furnishes the Chemists with their Instruments and Vessels. All kind of Glass has a great quantity of terrestrial matter united with its fixed alcaline Salt; and therefore, in this respect, owes its origin to Earth. As for the Potter's Vessels, these consist chiefly of pure Earth, compacted into a solid Mass, by the intervention of Water. China-vessels too must be referred hither, tho' they are of a particular kind. And Chalk, on account of its great likeness, may be reduced hither also. 8. But again, pure Earth being mixed in a proper quantity with pure fixed Salt, prevents their running into a Mass, if they are exposed to a strong Fire, which would certainly have been the case, had the Earth been away. And as by this simple intermixture it thus hinders their fluxing, so likewise, at the same time, it renders them volatile, tho' they were ever so fixed. Salt of Tartar may serve as an instance of this, which, if it is very good, and has nothing else mixed with it, will melt in a strong Heat, and if it don't insinuate itself through the Pores of the Vessel, will continue fixed there a great while; and yet, if you accurately mix it with three times as much pure Earth, calcin'd Bones, for instance, and then expose it to the same Fire, it will in a short time almost totally fly off, nor will it run as before. In the same manner, Nitre and Sea Salt, more particularly, if they are alone, and urged with a strong Fire, will flux, and remain fixed; if you mix Earth with them, they will not melt, but will be converted into Acids, and become volatile. Pure Earth is, likewise, of excellent service to the Chemists, when they want to purify animal or vegetable Salts from the Oil which tenaciously adheres to them, and renders them very impure; for when these are exceeding foul from the empyreumatical Oil that is united with them, by the mixture of very pure Earth, they will be disposed to rise in a proper Heat of an exceeding white colour, depositing all their Oil in the bibulous Earth, and being by this means intirely freed from it, which, without the addition of such Earth, would be very difficult to accomplish. And here the purer and dryer your Earth is, and the greater quantity you make use of for this purpose, the finer and more perfect will you obtain your Salt, especially, if you make use of a tall Vessel, and expose it but to a gentle Heat: With these circumstances the operation is always performed most to advantage, which was formerly very cautiously concealed among the *Arcana*. 10. This same Earth, again, by being mixed with a great many Substances disposes them to discharge a flatulent Vapour, which otherwise, upon the application of Fire to them, would make them puff up to such a degree, that not being able to bear the Heat necessary for the distillation, they would swell

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and riſe in the Retort in ſuch a manner as to run over into the Receiver, and thus confound every thing together, and prevent the hop'd for effects of the operation. If a perſon has a mind to diſtill Honey, for inſtance, or Wax, for any valuable purpoſes, he will loſe his labour, if he makes uſe of theſe for this operation by themſelves: For by a gentle Heat you won't be able to bring about the ſeparation of theſe tenacious particles; and if you apply a ſtrong one, theſe Subſtances will ſwell and puff up, like a ſponge, and by this means, in a liquid form will riſe through the neck of the Retort, altered, indeed, but not ſeparated, according to art: But when by practice the Operator has learn'd to mix a proper proportion of Earth with them, then the effect of the tenacity of the Particles being prevented by the interpoſition of the Earth, they will bear a conſiderable Fire, without any danger of this inconvenience, and the flatulent expanſion being thus reſtrained, the ſeparation of the parts by the action of the Fire will be equable and regular. Nor is this obſerved to be the caſe only in ſuch kind of viſcid Bodies, but it is found to hold true, likewiſe, in others. Take, for inſtance, Blood, Eggs, or Urine, and by very patiently and cautiouſly diſtilling them, proceed till you have drawn off all the volatile parts, and there remains a fixed Subſtance at the bottom of the Retort: If then you increaſe your Fire to the laſt degree, the whole Maſs being now grown tenacious, like pitch, will be wonderfully expanded, will cohere together, and in this manner will riſe into the narrow part of the neck of the Retort, will fill and ſtop it up, and thus incloſing the Matter, which is under it, and which too is equally expanded, has been often the occaſion of the Veſſel's being burſt in ten thouſand pieces, in a very dangerous, and ſometimes fatal manner. All this violent effect, now, may be prevented, by throwing only a terreſtrial Powder upon the Matter that you are about to urge in this manner; and hence the addition of Earth is of vaſt ſervice in the production of Phoſphorus from inſpiſſated Urine, by the extreme force of the Fire. 11. All that I have hitherto laid down concerning the nature of elementary Earth, muſt by no means be applied to our common Sand, which many perſons very wrongly imagine to be true Earth: For this, if it is very pure, upon examination with a microſcope, diſcovers itſelf to be nothing but a heap of ſmall, pellucid, multangular chryſtals, every one of which is of a different ſize and figure: Theſe, in conjunction with a fix'd Alcali, will eaſily run into Glaſs, as has long ago been diſcovered: Theſe the wiſe Author of Nature has diſpoſed about the World, that the fructifying Water might be always able to inſinuate itſelf through the pores of the Earth, which would otherwiſe very eaſily unite and coaleſce into one Maſs, and by this means in a ſhort time acquire a perfect ſtony hardneſs, to the infinite detriment of Mankind. Nor muſt we refer the Boles, or medicated Earths, commonly called the ſcal'd Earths, to this natural claſs of elementary Earth: For who don't know, that theſe are compound Bodies? That ſomewhat pinguious predominates in them, the Writers of Natural Hiſtory have long ago taken notice; and hence they have called ſome of them, the *Axungia* of the Earth: In others of them there is ſomewhat of a ſaline aſtringency, ſometimes of the aluminous, or vitriolick kind, to which their particular virtues are owing; not to mention any more of them. When Water, however, and Fire have exerted their utmoſt force upon theſe Boles, then, I confeſs, fefs, they come nearer to true Earth, but then too they lofe at the fame time their medicinal vertues. But leaft of all, muft we, in a chemical fenfe, look upon the earth, as it is commonly called, which we tread upon, and which furnifhes us with fupplies both of health and life, as fuch an Earth as we have been defcribing. For this our Earth evidently contains fat Clays, medicated Boles, fterile Sands, little Stones, Water, Air, Oils, Salts, all the Elements of Animals refolved into their Principles, and all the Principles of diffolved Vegetables, blended, and confounded together. This, therefore, appears to be fo far from a pure Element, that if we would confider it in a proper view, we muft regard it as a Chaos of all the natural Elements, and the Bodies compounded of them. Many things more, Gentlemen, I could offer upon this Head, but by the length of my difcourfe, I am fenfible I have already grown tedious. What things I have delivered, however, I think I could not length omit, as they are every where of fervice, nay, indeed, and neceffary to be rightly underftood. You'll be fo good, therefore, to excufe my entering fo minutely into thefe inquiries, if it was for no other reafon than this, that you have by this means had a faithful account, at leaft, if not a compleat one, of thofe four Elements, by the concurrence of which the moft ancient of the Philofophers fuppofed every kind of Bodies to be formed. The particular opinion too of the Alchemifts, upon thefe fubjects, you have here had likewife laid before you. And laftly, I may almoft venture to doubt, whether you have not here met with fome things which were never publifhed before. You have feen, that what are generally looked upon as Elements, are, in reality, mixed with an incredible quantity of various Bodies, and by this means are of an exceeding compound nature: That thefe, however, when they are artfully feparated from every thing elfe, and thus obtained perfectly pure, and by themfelves, far excel all other Bodies in their individual fimplicity. What is there in Nature more fimple than pure Fire, Air, Water and Earth? And again, in another fenfe, what is there that is more compounded? I have endeavoured to offer nothing concerning thefe Elements that is not found, and will bear the teft; and therefore always caution'd you where I was at a lofs myfelf, nor have ever been too hafty to come to conclufions, where the thing was doubtful. What I have interfperfed concerning Metals, I formerly did not think to have added; but the diligent attendance with which you have honoured me has drawn it from me.

Of CHEMICAL MENSTRUUMS.

Having thus, Gentlemen, difpatched thofe four Inftruments both of Nature and Art, Fire, Air, Water, and Earth, let us now pafs on to a fifth kind, which is look'd upon as almoft proper to Chemiftry, and to which the Mafters of this Art affign the principal place, valuing themfelves particularly upon it, and chiefly afcribing to it the furprizing effects of their Art; and this they have called a *Menftruum*.

Definition of a *Menftruum*.

By this barbarous term, now, they defigned to exprefs a Body, which being applied to another, according to the rules of art, would fo minutely divide it, that the Particles of the Solvent fhould be perfectly intermixed with thofe of the Solvend, or Body to be diffolved. This definition I chufe particularly for this reafon, becaufe it accurately diftinguifhes the action of a *Menftruum*

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ſtruum from the other ſolutions of Bodies, which are performed chiefly by the mechanical powers: For in theſe caſes, the Solvent recedes from the Solvend, nor is reciprocally diſſolved by it, but as ſoon as ever the ſolution is over, they ſeparate from one another, according to the diſpoſition of their ſpecific gravities.

The reaſon of a Solvent's obtaining this name, was this; as the application of the *Menſtruum* to its Solvend was promoted particularly by the help of a moderate Fire, which was conſtantly kept up for forty days, or a philoſophical month, hence the Solvent came to be called the Solvent *Menſtruum*, and at laſt by the ſimple name *Menſtruum*. The reaſon of the term.

From the nature of a *Menſtruum*, then, it will follow, that this itſelf muſt be equally diſſolved by the Solvend, as the Solvend is divided into its parts by the *Menſtruum*. And this circumſtance obtains in every kind of ſolution whatſoever, that is effected by the help of a *Menſtruum*, though, at the ſame time, it is true, it may happen, that when the Solution is perfectly compleated, the Solvent and Solvend may be ſeparated from one another. And, indeed, in the Solutions that are performed by the Liquor, Alcaheſt, *Van Helmont* tells us, the Solvent and Solvend are diſtinguiſhed into two different *Strata*, lying upon one another; but ſetting aſide this, this ſeparation is rarely obſerved in theſe ſolutions. The proper faculty, therefore, of the Solvent conſiſts in this, that it on every ſide applies its own particles to thoſe of the Body to be diſſolved. The divided Particles, therefore, of the Solvent muſt inſinuate themſelves between thoſe of the Solvend, and ſo interpoſe themſelves between their Surfaces, and thus divide the Body to be diſſolved. And at the ſame time that this happens, you ſee, likewiſe, that the *Menſtruum* muſt be ſeparated into its minuteſt parts by the divided Particles of the Solvend, as well as that is ſeparated into its Particles by the *Menſtruum*. And hence, likewiſe, appears the truth of our former aſſertion, that this action of a *Menſtruum* is abſolutely different from any common mechanical ſeparation; for in this caſe, the dividing Body remains whole and intire, both whilſt the diviſion is effecting, and when it is compleated. This you ſee evidently in the action of a Knife, Wedge, Sword, Ax, Hatchet, Saw, Dagger, Augre, and Hanger; for theſe all, whilſt they divide, are not divided, but remain nearly the ſame they were before. In the mean time, however, if we examine into this Affair more nicely, there will be room to doubt, whether every ſingle Particle of the *Menſtruum*, ſeparately conſidered, does not, whilſt it is diſſolving, act in reality, in the ſame manner as the Inſtruments juſt mentioned. Certainly, one ſuch diſſolving Element will have its proper ſize, figure, hardneſs, and weight, and will act by theſe Powers, which ſo far may be called mechanical. At the ſame time too it is conſtantly true, that every *Menſtruum*, whilſt it is diſſolving, and even in this reſpect, that it does diſſolve, as it is then divided into Particles that, on account of their ſubtility, become inſenſible, muſt for this very reaſon be a Fluid, and in the very point of time that the Solution is perfected, the Solvend too itſelf, as ſuch, muſt likewiſe be diſſolved into a fluid Body. Hence therefore, at laſt, it follows, that at the time of ſolution, the Solvent with its Solvend will be converted into one Fluid. Property of a *Menſtruum*.

But here it is neceſſary we take notice, that many *Menſtruums*, before they perform their office of diſſolving Bodies, are themſelves ſolid, hard and denſe; Diviſion of *Menſtruums*.

though indeed ſo long as they continue in this ſolid form, they by no means act as ſuch. By uſe, however, it has obtained, that theſe ſhould be called *Menſtruums*. And hence the Chemiſts have always laid down, that ſome *Menſtruums* are hard or ſolid; others fluid. And this diviſion may be allowed of, if the diſtinction juſt mentioned is firſt properly underſtood.

1. Into thoſe that are dry before the ſolution.

To the hard, dry, and ſolid *Menſtruums* then may be referr'd the following Bodies, which we have reduced into their proper claſſes. 1. The ſix ſolid Metals, Gold, Lead, Silver, Copper, Iron, Tin. Theſe, now, when they are cold, hard, and ſolid, have no effect at all upon one another, but when they are put in fuſion, may be ſo intimately mixed together, that to the ſenſes the Maſs will appear homogeneous, nay, and will have this ſurprizing property, that in every ſingle Particle of the compound, there will be found the very ſame proportion of the different Metals, as there is in the whole Maſs. For if in a ſtrong Fire you melt ten ounces of Silver with one ounce of Gold, and thus form a Body of eleven ounces; then if you give but one grain of this mixture to a perſon well ſkill'd in the docimaſtic art, he will return you $\frac{1}{11}$ of a grain of Gold, and $\frac{10}{11}$ of Silver. But another thing here ſtill more remarkable is this, that it is poſſible to divide Gold in this manner as long as ever you pleaſe, without any limitation hitherto obſerved; for if with a hundred thouſand parts of Silver I thus mix one part of Gold in the Fire, and then examine but one ſmall Particle of this whole Maſs, according to the rules of the metallurgic art, the event will be exactly the ſame as the former. This ſurprizing *Phænomenon* then evidently demonſtrates the very extraordinary power that Metals have of dividing one another by the ſole help of fuſion. Conſider, I beſeech you, to what an expanſion this ſmall Particle of Gold muſt be diſtended in ſo great a Maſs, to effect, that there ſhall not be the leaſt Particle of Silver aſſignable in the whole, in which there will not be always a proportionable part of Gold; which nevertheleſs continues ſtill immutable among other immutable Particles, exceeding denſe among other denſe ones, and perfectly ſimple among other ſimple ones. Think of theſe things, Gentlemen, attentively, for it is well worth your while, and learn hence how wonderfully the Great Creator has formed theſe Metals: Certainly you will diſcover here ſomewhat infinitely myſterious, and that ſurpaſſes all human comprehenſion. Upon the contemplation, poſſibly, of this property, the Chemiſts have ſo often aſſerted, that Metals are opened by Metals alone; that nothing is intimately admitted, or enters into Metals, but Metals themſelves; and that the Mercury of Metals is of infinite ſubtilty, and continues always the ſame. 2. Solid ſemi-metals, to which may be referr'd Antimony, Cinnabar, Biſmuth, Merchaſite, Zincq. Theſe too, like Metals, when they are melted in the Fire, may be mixed together, and will divide one another no body can tell how far; and theſe, likewiſe, may be mixed and blended with Metals with the ſame ſucceſs: Cinnabar, indeed, with more difficulty; the reſt eaſy enough. But with this admixture with Metals, they conſtantly deſtroy their malleability, and render them ſo brittle, that they will ſuffer themſelves to be reduced to powder, though before they were ever ſo tough: And this again holds true in every the leaſt Particle of the Metal. Here, therefore, likewiſe you have a wonderful *Phænomenon* that deſerves your conſideration. 3. To dry *Menſtruums* again muſt be referred all perfectly dry Salts, Alum, Borax, Nitre, *Sal-Ammoniac*, Fountain Salt, *Sal-Gem*, Sea Salt, Vitriols,

Vitriols, dry, fixed alcalious Salts, and corrosive Sublimate of Mercury. All these, now, when they are acted upon by the Fire, or melted, bring about by their dissolving powers, very extraordinary effects, scarcely imitable in any other manner; and they suffer themselves, likewise, to be very minutely divided by the Fire, and by this means may be intimately mixed, not only with one another, but also with Metals, Semi-metals, and other Bodies. 4. Among these must be reckoned all hard, fossil Sulphurs, quick Sulphur itself, common Sulphur, Arsenic, Orpiment, and Cobalt. In these, likewise, when they are assisted by the Fire, or melted, and so mixed with one another, or other Bodies, there is a wonderful dissolving power, by which they produce such effects, as we can scarcely accomplish by any other causes. 5. And lastly, under this head I reduce all those kinds of Fossils, which the Metallurgists commonly call Cements; for these consist of Salts, Sulphurs, and Bricks, reduced to a dry powder, which is then disposed between plates of Metals, either to heighten their colour, or to separate them from one another.

But among the various *Menstruums*, we find some, likewise, that, after they have performed their solution, and are left to themselves, coalesce into one hard Mass, which to our senses appears simple, and every where of one uniform nature. And the apparent simplicity is here often so great, that though the Mass is compounded in this manner of different Substances, yet still it appears simple. To Lead, whilst it is in fusion in the Fire, pour melted Tin, and they will run and mix together, like Water with Water, or Mercury with Mercury; and this will always be the case, let the proportion of one to the other be what it will. Look at these Metals thus melted in the Test, and you won't discover the least sign of any different Substance; and if you suffer them to grow cold together, they will form one solid homogeneous Mass, that appears simple to the sight, and will afterwards continue so. The same holds true in all Metals, and in some Semi-metals beforementioned. If to a pound of melted Tin, in the Fire, you add a scruple of *Regulus* of Antimony, when the Mass is cold, it will appear homogeneous, and be so britle through the whole, that take ever so small a particle of it you will not find the malleability in it that is natural to Tin; but on the contrary, you will always find a proportionable part of the Antimony mixed with it. Does not a fixed Alcali run, likewise, with Sand or Flints into one simple Mass? But there are an infinite number of like instances, as you yourselves very well know, and therefore these we have mentioned are sufficient. In all these cases, now, the Particles both of the Solvent and Solvend are so minutely divided, intermixed, and concreted together, that they form a new Body, in which it is not possible for any person that don't know the composition to discover the concurring Substances, except by some other contrivance he again resolves the Body into its component parts. Sulphur too and Mercury are by rubbing converted into a black, dry powder, and this being sublimed with a strong Fire, produces a Cinnabar, of a beautiful red colour, and to all appearance, exceeding simple. But in the second place, it is likewise observed, that a great many solvent Fluids perfectly dissolve solid Bodies into their ultimate parts, but when the solution is completed, unite again in one hard, and often dry Mass. Not to mention again Sulphur and Mercury; if we examine almost all the *Menstruums* of Metals, don't we find, that these

2. Into dry ones after solution.

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unite with their Metals into Vitriolick Maſſes that are conſiderably firm, and durable? The very ſtrong Acid of Wine, Vinegar, after it has corroded Oyſter-ſhells, Stones, or Chalk, ſeparates from its aqueous part, and with theſe diſſolved Subſtances hardens into a dry Maſs.

3. Fluids before ſolution. But a geat many, and perhaps the greateſt number of *Menſtruums*, do really exiſt in a liquid form, before they perform the office of ſolution; of which ſort, indeed, are almoſt all what the Chemiſts uſually call *Menſtruums*. Vinegars, Water, fermented Spirits, ſaline, acid Spirits, alcaline and compound, alcalious Oils, as they are called, *per Deliquium*, and many other Liquids, are referred hither: And as all theſe appear in a fluid form, the action of them is much more evident, and eaſy to be underſtood; and that the more ſo, becauſe they are continually in uſe in the Elaboratories of the Chemiſts.

4. Fluids after ſolution. And laſt of all, there are ſome *Menſtruums*, or Solvents, which before ſolution are liquid, and when that is completed, ſtiſt continue together with their diſſolved Body, in the ſame form. This no where appears more evident, than in the Solution of the five Metals by ſimple Mercury; for when theſe are throughly mix'd together, according to art, there ariſes hence a ſoft Paſte, which, by the affuſion of more Mercury, you may dilute at pleaſure, without any limitation: But ſcarcely any body has ever been able to render this Subſtance hard by the chemical contrivances that are vulgarly known. Whoever can make himſelf Maſter of this ſecret, will be a good, and perhaps a rich Operator; but whoever attempts it, will find in it plague enough. But again, any acid Liquids, when they have diſſolved their proper Metals, if they are mixed with them in a large quantity, will, together with their Solvends, continue moiſt, nor will afterwards be dried very eaſily. Hence a great many perſons have looked upon theſe diſſolved Bodies, with their Solvents, as fixed, metalline Oils, and idly expected from them wonderful ſecrets; whereas in reality theſe are nothing more than a large quantity of acid Salts, collected about Metals. There are beſides vaſt numbers of other *Menſtruums*, which with the Bodies diſſolved ſtill continue in a liquid form, ſo that we need not detain you any longer upon this head.

The action of *Menſtruums*. From the conſideration, now, of the ſeveral kinds of *Menſtruums* juſt mentioned, we eaſily perceive, that many of them unite Bodies together, as well as ſeparate them into their minuteſt parts. For it is a common obſervation, that when the Particles of ſome *Menſtruums* have by their proper action diſſolved their Solvends, they then ſo unite themſelves to the Particles of the Body diſſolved, that by this concretion they become together formed into a new compound Body, oftentimes very different in nature from the ſimple, diſſolved one. And here it is likewiſe certainly true, that the Particles of the Solvent do not any longer continue in mutual contact, but are ſeparated from one another, by means of the Particles of the diſſolved Body that are now interpoſed between them: And again, that the Particles which before, by their union, compoſed the Solvend, are now kept too at a diſtance from each other, by the interpoſition of the Particles of the Solvent. From this diviſion, ſeparation, and concretion, therefore, of heterogeneous Particles thus brought about by the help of *Menſtruums*, there ariſes a vaſt variety of new Bodies. But this now becomes particularly remarkable, when only ſome of the Particles of the Solvent and Solvend are united together into one Maſs, whilſt, at the ſame time, others are not admitted to this new concretion, but appear in a different form.

Hence, therefore, it evidently follows, that the Particles of the *Menſtruum* apply themſelves to thoſe of the Body to be diſſolved, and become chiefly united with them, at the very inſtant of time that the ſolution is effecting. Here, therefore, ſome certain cauſe is neceſſary to occaſion the Particles of the *Menſtruum*'s receding from one another, and applying themſelves rather to thoſe of the Solvend, than remaining in the ſituation they were in before. And when the Particles of the Body diſſolved are by the power of the *Menſtruum* ſeparated from one another, is there not a ſimilar cauſe requiſite, that theſe Particles ſhould continue united with thoſe of the *Menſtruum*, and not rather, that after the ſolution is compleated, the Particles of both of them ſhould, by an affinity of nature, collect themſelves into homogeneous Bodies? This, Gentlemen, I would deſire you to take particular notice of; for it highly deſerves your obſervation. Conſidered more nicely.

But again, pleaſe to conſider, that this cauſe, be it what it will, muſt for the very ſame reaſon be ſought for in the Solvent, as in the Solvend: And hence it will be common and reciprocal in both. For when Gold is diſſolved in three times its weight of *Aqua Regia* into a yellow Liquor, the Particles of Gold remain ſo united with thoſe of the *Aqua Regia*, that, though thoſe of the former are eighteen times heavier than the latter, yet they keep ſuſpended in this Fluid, nor ſink to the bottom. Is it not plain, therefore, that between every Particle of the Gold and *Aqua Regia* there is ſome reciprocal vertue, by which they attract, and come into a cloſe union with one another? If this was not the caſe, the Particles of the diſſolved Gold would certainly ſubſide to the bottom; the ſaline parts in a different *Stratum* would lie next above them; whilſt the Water would ſwim ſeparately and diſtinctly at top; whereas, on the contrary, we ſee that all theſe three, though ſo very different in their natures, appear in the form of one ſimple, uniform Liquor. Both in the Solvent and Solvend.

If we may be allowed, therefore, to reaſon from analogy, the action of diſſolving, ſo far as we are hitherto acquainted with it, ſeems rather to be performed by a certain power, by which the Particles of the *Menſtruum* endeavour to aſſociate to themſelves thoſe of the Body to be diſſolved, than by one which makes them fly from, or repel one another. Here, therefore, we are not to conceive of any mechanical actions, violent propulſions, or natural diſagreement, but there ſeems, on the contrary, to be a ſociable attraction and tendency towards an intimate union. This I confeſs, indeed, appears a paradox: But conſider, if you pleaſe, what you yourſelves have obſerved in any violent ſolution; certainly, the agitation, noiſe, and confuſion continue no longer than till all the Particles of the Solvent have united themſelves with all thoſe of the Solvend, and the very moment that this is compleated, there appears among them but an intire and perfect reſt. As an inſtance of this, pleaſe to take notice of this Veſſel, which contains ſome diluted Spirit of Nitre. The Liquor, you perceive, at preſent does not diſcover the leaſt ſign of motion. In this now I immerge this piece of Iron, and what a multitude of Bubbles are by this means produced ſpreading themſelves even to the brims of this large Veſſel? What a violent agitation, ebullition, noiſe, and almoſt fiery Smoak! But how long do all theſe laſt? Certainly no longer than whilſt there are ſtill left ſome ſaline Particles of the Nitre, which are not come into contact with thoſe of the Iron, for as ſoon as ever this adunation is to- More from attraction than repulſion.

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tally and perfectly completed, then the whole mixture is immediately quiet, and all the Acid becomes so closely united with the Iron, that it can scarcely afterwards be separated from it.

Is performed always successively.

Nor must we here neglect to take notice, that the whole Solvent never acts at once upon the whole Body of the Solvend; for this, as I know of, has been never known to happen: But on the contrary, the Particles of the Solvent act only upon those of the Solvend, which they first come into contact with, and having dissolved these, and separated them from the whole Mass, then other fresh Particles of the *Menstruum* apply themselves to those of the Solvend that still cohere together, and so proceed, till the solution is quite completed.

Exciting itself.

Part of the *Menstruum*, therefore, acts upon that part of the Body which it actually dissolves and separates from it. But whilst this separation happens among these parts, from the conflict that arises between them, there necessarily follows an agitation through the whole, by which means the other Particles of the *Menstruum* which were at a distance are put in motion, and thus in their turn are brought more easily to the remaining part of the Body that is not dissolved.

And increased by Fire.

But as the agitation thus excited proves an efficacious cause in these solutions, so there is another that promotes them likewise, and that is Fire. What the consequence would be, should this be totally absent, it is not possible for any mortal to determine, as it has formerly appeared, that it is impossible intirely to exclude it from any part of space. This, however, in the mean time, we are absolutely certain of, that if Fire is applied to a *Menstruum*, it excites, supports, and increases the vigour of its action. And on the other hand, when the Fire that is every where distributed, in extreme Cold becomes less efficacious, we find that these solutions will not be effected, or at least will proceed more slowly, though they will immediately be promoted again if this is augmented.

Various in various Bodies.

But here again some *Menstruums* stand in need of a great degree of Heat, to make them capable of dissolving Bodies, as appears evidently in the solution of Metals by *Mercury*; whilst others require a very gentle one, as we see *Sal-Ammoniac*, *Sal-Gem*, and Salt of Tartar, dissolve in Water very quickly. Some again dissolve by the assistance of a moderate Heat, whereas if it is much increased, they lose this vertue, nay, and acquire a contrary power of coagulation; witness Water, which, when it is warm, will dissolve the White of an Egg, but when it boils, will coagulate it after it is dissolved.

How does Fire assist *Menstruums*?

But if we examine more nicely into the manner in which Fire thus assists *Menstruums*, we easily conceive, that it must do this, in the first place, as it puts in motion, impells, and agitates their ultimate Particles. Some farther efficacy, likewise, in this case, must be ascrib'd to its dilating the dimensions of all kind of Bodies. And lastly, as it often divides and carries off the Particles of Bodies, and thus dissolves many itself, it by this means unites its power with that of the *Menstruum*, and so operates jointly with it. In all these respects, therefore, Heat promotes the proper action of *Menstruums*, and makes them proceed more successfully, and hence, as a concurring cause, becomes necessary to them. And, indeed, in most cases, in the very act of solution, though, at first, perhaps, it is slow, the Heat successively increases, whilst the solution is effecting, which then always goes on more efficaciously, and

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hence is commonly pretty evidently obſerved to have its activity more and more augmented, as the Body is diſſolving. Nay, and the action of thoſe *Menſtruums* too is likewiſe increaſed by Heat, which whilſt they are diſſolving, produce an intenſe degree of Cold: This you have taken notice of in the ſolution of *Sal-Ammoniac* in Water, which, if the Water is warmed, will be diſſolved ſooner in it than if it is cold.

The changes, therefore, that are obſerved to be produced in Bodies by the diſſolving action of *Menſtruums*, ſeem chiefly to depend upon the very cloſe union that ariſes between the ultimate Particles of the *Menſtruum*, and thoſe of the Body diſſolved, and not to any real alteration induced by the *Menſtruum* upon theſe ſeparated Particles themſelves. I am ſenſible, ſome Authors of the firſt rank in the Chemical Art are of a different opinion; but the thing itſelf, I think, favours this doctrine. For if we conſider the moſt perfect Metals, Gold, Silver, and Mercury, when they are thoroughly corroded by their ſolvent Acids into a pure Liquor, how mightily altered do they appear in all their parts? and yet if they are again accurately ſeparated from their Solvents, which may be eaſily effected, you may procure from them again the very ſame metallic Particles they were combined with, which being melted together, will give you the true Metal, without the leaſt alteration. Hence, then, it evidently appears, that the *Menſtruum* did no ways affect the intimate nature of the Particles of the Metal, but only ſeparated them aſunder, and then adhered to their external Surfaces. * This, likewiſe, when it is diſſolved by Vinegar, or other Salts, may be again regenerated from them, without any alteration. But again, if you mix Metals with one another ever ſo intimately, in the Fire, and in whatever proportion you will, they will return again in the Cupel, perfectly pure and ſimple. I formerly diſtilled Gold and Silver with Mercury above fifty times, and yet when the Mercury was again ſeparated from them, there conſtantly remained the very ſame Gold or Silver that there was in the Amalgama. Diſſolve Salts, in what quantity you pleaſe, in Water, and by a proper inſpiſſation you may procure them again, without any alteration. If by melting Salts together, you mix them ever ſo intimately over the Fire, by diluting them afterwards in Water, and inſpiſſating them according to art, they will be found again perfectly the ſame as before. And farther, if you diſſolve Salts in Oil, when they are recovered again they will be very nearly the ſame. Nay, even fixed Alcali's, when, with Earth that will vitrify, they are converted into Glaſs, may, even in this circumſtance, by a chemical management, be reſolved into their former Principals. Sulphurs diſſolved with Salts, or united with Metals, confirm the ſame thing; as well as Alcohol mixed with Oils, Reſins, and other Subſtances. Theſe inſtances, then, are ſufficient to evince, that the action of *Menſtruums* is really the ſame as we have aſcribed to them. *The action of Menſtruums.*

To this you will in all probability reply, that by means of theſe ſolutions, performed by *Menſtruums* alone, there are very often produced new Bodies, which were never obſerved before. This, you'll ſay, is the caſe of Sugar of Lead, made by boiling a *Calx* of Lead with the ſtrongeſt diſtilled Vinegar; for this will conſiſt of the Acid of the Vinegar attracted into the Elements of the Lead, and yet if you diſtill this Salt of Lead in a very ſtrong Fire, it will not yield back again a Spirit of Vinegar, but a particular Liquor that is inflammable. To this I anſwer: This obſervation is really juſt, and there may *Very ſeldom alters the Elements.*

* This I don't underſtand, and forgot to mention to our Author. Shou'dn't it be, Lead likewiſe, &c.

may be brought many instances of the like nature; but then, at the same time, we must carefully consider, that the Particles of the *Menstruum*, when they once strongly adhere to the Surfaces of the dissolved Corpuscles, are not always again very easily separated from them, but are often so closely united, that they are capable of being moved about with them, and continue a long while in this union. And hence it comes to pass, that the Operator frequently imagines, that the nature of the Body is destroyed, when, in reality, the new appearance arises only from this simple conjunction of their Particles, which continue still perfectly the same. This is easily conceived of by an example. If one has a very sharp Lancet, by itself, its power of dividing appears evident to every body. If this is afterwards put into a Case, it perfectly loses, so long as it remains there, its power of hurting, though it still continues in all respects the same as it was before. Examine this Lancet again bare, and it immediately discovers its former nature. Hence, therefore, you see, the more easily the sheath comes off, the sooner will the Lancet recover its first appearance; and if it was almost inseparably fasten'd to it, every body would be ready to assert, that the Lancet was alter'd. But let us consider again a little Cylinder of choice Silver, gilt over thick with Gold, and immersed in pure *Aqua Fortis:* In this case all the Silver will be intirely dissolved by this *Menstruum*, and there will remain in the *Aqua Fortis* a hollow Case of Gold, of a disagreeable, black colour, and perfectly intire. In the instance mentioned, therefore, it may happen, that the acid Particles of the Vinegar may be united with the Particles of the Lead, in such a manner, that they will not be separated by distillation, but will rather rise along with them. And hence any person would be deceived, who should imagine, that the Acid, by its union with the Lead, was converted into a new kind of inflammable Liquor. And, indeed, it seems exceeding probable, that this alteration that is here observed arises much more frequently from such an adunation, than from any change in the real Substance. And in separation, the same thing must be supposed to hold good; for it very often happens, that the Body to be dissolved consists of very different parts, some of which will be intirely dissolved by the *Menstruum* made use of, whilst others will not be affected by it, but will be divided from the former, and appear separately by themselves. If afterwards therefore the *Menstruum* is drawn from that part which it had dissolved, the matter that remains will be very different from what was made use of for the solution: And hence an unwary person would be ready to infer, that this Body, which he would look upon as a new one, was produced by the transmuting vertue of the *Menstruum*; whereas it had in reality effected nothing more than a mere separation of its parts.

Act solely by motion.

From all now that has been hitherto delivered upon this head, it evidently follows, that all known *Menstruums*, whilst they perform their office, act solely by motion, notwithstanding, the Chemists have supposed their action to be so abstruse and mysterious; for if a *Menstruum* did not put in motion the parts upon which it acted, then those parts would remain the very same they were before; which is contrary to the supposition.

But one that arises from a particular cause.

In the mean time, however, though this is undeniably true, yet it is not so easy to comprehend the physical cause, by which this motion is excited in the *Menstruum*. For so long as the *Menstruum* is alone, it remains perfectly at rest; nor

nor is the Solvend in motion till it begins to be moved by the *Menstruum*; and yet as soon as ever they are brought to one another, within a certain distance, and in a determin'd degree of Heat, there arises a new, and frequently a very great motion, which was in neither of them before, but is now in both of them. Upon a careful consideration, now, of this matter, we cannot safely attribute this effect to any of the common origins of motion. In Propulsion, Gravitation, Elasticity, Magnetism, or any other general cause, if there is any other, we shall in vain seek for the Principal of this Agitation; for this is peculiar to the Solvent and Solvend, and not common to Bodies in general. Each of these, however, deserve a particular and accurate Examination; as a person who is thoroughly acquainted with the powers of *Menstruums*, will understand the principal part of the Chemical Art, and be capable of performing its most beautiful Operations. And, indeed, whilst we are upon this head, this task is absolutely necessary, on account of the authority of some very great Men, who are of opinion, that the actions of all Bodies whatsoever may, and ought to be explain'd solely by mechanical Laws. Let us therefore examine the matter fairly, and see what will be the issue.

Not mechanically, except rarely. Such a Solution more nicely examined.

First, then, I say, that whenever any solvent *Menstruum* dissolves its Solvend by what the Mathematicians call a pure mechanical motion, then the Particles of that Solvent must be agitated by some cause, which, though they were at rest before, will put them in motion; and this cause, for the most part, is Fire. The Particles, then, of the *Menstruum*, being thus moved by this cause, must strike upon the Corpuscles of the Solvend, which as yet cohere together, must impress their motion upon them, and by this means abrade and separate them from the solid Body, and that, either by exerting this effect upon the external Surface of the whole Body, or by insinuating themselves within its pores, and acting there, likewise, in the same manner. This, now, I am of opinion, every body will agree can be in this case the only mechanical manner of acting; which, as I will allow to have some effect, so, at the same time, I think it necessary to caution you, that it is a great deal less than persons generally imagine. Fluid Bodies, indeed, surround, press, and penetrate the Substances that are immersed in them; but then they afterwards make very little alteration in them, by their bulk, hardness, figure, and weight. I confess, indeed, that, by a motion communicated to them by the grand mover Fire, they are carried against the extreme Surfaces of the Solvends; but how little efficacious must this power be, which acts equally both upon the Fluid, and upon the hard Body, and therefore cannot exert an applying and impressing force upon it: These, certainly, must be sought for somewhere else. Can you imagine, that a mechanical Instrument, a Wedge, for instance, suppose it ever so perfect, could ever divide a piece of Wood, only by being placed close to it, or by swimming gently about it? Certainly, there is here something more necessary: It must first be fixed fast into the Body to be divided, and then, by an external force, it must be struck and driven forwards, and that without its being able to slip out whilst it is thus in motion. Try, now, if you can find all these requisites in particles quietly disposed, and freely swimming about in a soft Fluid, and wanting intirely a propelling power. But we'll suppose, for once, both the parts of the Solvent, and those of the Solvend, to be divided by a mere mechanical force, and that they are now just swimming among one another; then, certainly, if there was not at the ſame time ſome other power likewiſe, the very moment they are thus ſeparated, and become fluid, they would diſpoſe themſelves according to their ſpecific Gravities, that is to ſay, the heavieſt would ſink to the bottom, and ſo the reſt, in order, wou'd ſettle in diſtinct *ſtrata*, nor would the heavy continue mixed with the light, nor the Solvent with the Body diſſolved. When Metals, Stones, or other hard Bodies are worn away by the fall of Water from on high, or by the force of a rapid ſtream, you know very well, that the Water then acts only by a mechanical power, and is able indeed in this manner to divide the very hardeſt Bodies into their ſmalleſt Particles; but then the impalpable Powder thus produced does not mix with the Water, or is united with it, but ſinks, and is collected at the bottom; and though it is agitated very frequently, yet as ſoon as ever it comes to be at reſt again, it preſently ſubſides. And the ſame thing you have obſerved, likewiſe, in the ſolution of Bodies conſiſting of terreſtrial and oily parts, in boiling Water; for as ſoon as ever the heat of the Water has melted the Oil, it preſently aſcends and ſwims at top, whilſt the earthy part falls to the bottom. Theſe ſolutions, therefore, may ſo far be looked upon as mechanical. In this manner act, likewiſe, the Currents of Rivers, rapid Winds, the Sounds of great Cannon, and Thunder; and here always, as ſoon as ever the ſeparation is made, and the concuſſion is over, the Solvent and Solvend recede from one another, as their gravities variouſly determine them. And thus in the fuſing of Semi-metalline Glebes, Antimony, for inſtance, with Salts and Metals, the whole Maſs, whilſt you urge it with a violent Fire, appears in the Crucible to be intimately mixed together; and yet when you remove it from the action of the Fire, pour it into a melting Cone, and ſuffer it to ſtand quiet, the *Scoriæ* ſoon riſe to the top, and form themſelves into a Cruſt, whilſt the pure metalline part by its weight ſubſides to the bottom. But a repulſive force alſo is ſometimes a cauſe, that Bodies, which are mixed together, ſeparate again from one another. This we ſee evidently in a very ſtrong, alcalious *Lixivium* and Alcohol, and in Oil and Water; where not only their gravity, but this repulſion, likewiſe, makes thoſe parts, that are of the ſame nature, collect themſelves together. Metals too ſometimes do the ſame, when they are in fuſion; as appears very remarkably in Mr. *Homberg*'s method of purifying Silver. We are perſuaded, therefore, that thoſe *Menſtruums* alone act purely by a mechanical power, which after they have by a mechanical motion ariſing from their ſize, hardneſs, figure, weight, and impulſe, divided Bodies into their ſmall Particles, recede from theſe Particles, either upwards or downwards, according to the determination of their ſpecific gravities, nor afterwards produce any conſiderable alteration by ſuch diviſion. By this mark, then, I think, one may be able to determine whether the action of any given *Menſtruum* is properly mechanical; and ſuch a Solution, if any ſuch is obſerved, may by this means be eaſily diſtinguiſh'd from all others.

What Solution is not mechanical.

Whenever, therefore, we ſee any ſolution performed by means of a *Menſtruum*, where the Particles of the Solvend, after they are ſeparated from one another, cohere with thoſe of the *Menſtruum*, and remain equably intermixed with them, though there is a conſiderable difference in their comparative gravities, we then ought to conclude, that this Solution was effected partly by a univerſal, mechanical power, which almoſt always concurs, but chiefly by ſome other cauſe

ariſing

arising from the particular relative disposition of the Solvent and Solvend to one another, by which power we suppose the Elements of one attract those of the other from their former concrete, and being combined together after the Solution is compleat, compose numberless new *Species* of Bodies.

Give me leave to explain this whole affair by one Example. If a Ball of soft Clay is thrown into Water, and this is set over the Fire, and made to boil; then the Particles of Water, being put in motion by the action of the Fire, will divide the Ball of Clay into its least Corpuscles, which will be intermixed through the whole Water so long as it is kept boiling; but as soon as ever the impelling force of the Fire ceases to act, and the Water is suffered to be at rest, and cool, then all the Clay soon subsides to the bottom. This, then, I should chuse to call a mere mechanical Solution, because the Particles of Water impell those of the Clay, by the motion they receive from the Fire, and when they are deprived of this, they continue to act no longer.

An instance of a mechanical Solution.

On the other hand, if a Ball of *Sal-Gem*, whose specific gravity is greater than that of Water, is put into 4 times its weight of boiling Water, the heat of the Water will presently dissolve it; but then, too, when the Solution is compleated, and the Water suffered to stand quiet and grow cold, all the Salt, though it is heavier, will still continue distributed through the whole bulk of Water. Hence therefore it evidently appears, that there is some quality in the Water, by which it unites itself with the Elements of the Salt in such a manner, that they are not capable of disengaging themselves by their weight, but are forced to remain suspended. Here, then, you will no doubt begin to suspect, that there are fewer *Menstruums* that perform their office, by a pure mechanical power, than persons generally imagine. In this manner, indeed, Water dissolves Ice, Water Water, Alcohol Alcohol, and other such Liquids one another. But there is observed, likewise, a great deal of difference in the cohesion of different *Menstruums* with the Elements of the Body dissolved; some of them cohering much more firmly than others: And hence the Corpuscles that are produced by *Menstruums* become very various; for among these, some are found to be so immutable, that they refuse to be resolved again into the simples from which they were compounded; whilst others very easily part again, and become what they were before the Solution. But of these there is no End.

An example of a Solution not purely mechanical.

According to the distinctions, therefore, thus laid down, I could venture almost to distribute all the *Menstruums* I am acquainted with into four distinct Classes. To the first of these I wou'd reduce all those which act only by a simple mechanical power; which, therefore, may be explained, and understood by those mechanical principles which consider the powers that are common to all known Bodies in general. Of these, now, there are but few, and those generally very simple. The second Class should contain those *Menstruums*, which, though they do in some measure act by a mechanical impulse, yet, at the same time, perform their office chiefly by a power of repulsion. To the third should be referred those which act principally by a mutual attraction between the Particles of the Solvent and the Solvend; which very frequently occur, and are vastly numerous. Whilst the fourth and last should comprehend all those which operate by the concurrence of all the former together: And this will be much the greatest of all; as in almost all the actions of *Menstruums* a mechanical, repulsive,

Division of *Menstruums* from their manner of dissolving.

pulſive, and attractive power are united together. If it was poſſible, now, to accompliſh, that *Menſtruums* ſhould be reduced into order, according to the difference of their manner of acting, and then be diſtributed into inferiour claſſes, then the doctrine of Chemiſtry might be brought to the certainty of a Science; and conſequently, it might always be foretold, what would happen in a particular Operation; and thus chemical experiments might be made vaſty uſeful to the other branches of Natural Philoſophy.

An example of a purely mechanical *Menſtruum*.

Of each of theſe ſolutions, now, I'll give you an ocular proof, that you may be the better prepared to underſtand what follows. For an Example, then, of a mere mehanical one, beſides thoſe mentioned above, let us take the ſeparation of melted Silver into little Particles, when it is poured into cold Water. This the Metallurgiſts call Granulation, and it is performed in the following manner. I take an ounce of the beſt Silver, and put it into a ſtrong, clean Crucible, and cover it ſo cloſe with a clean Tile, that nothing from without can fall into it. I then heat the Crucible gradually, till it is almoſt red hot, and then put it into a ſtrong Fire, which is kept blowing till the Silver is melted and runs like Water. The Silver then being thus thoroughly fus'd, holding it up pretty high, I pour it, as you ſee, a little at a time, into the cold Water, that is at leaſt a foot deep in this Veſſel; and at the ſame time you hear the Particles of the melted Silver paſſing through the Water, with a gentle, hiſſing noiſe, and perceive, that as ſoon as ever it comes to the Water, it flies aſunder into little Grains, and in this form ſinks to the bottom, both the Water and the Silver continuing exactly the ſame they were before. In this example, then, you ſee, that the Silver, when it comes melted from the Fire, and is thrown into cold Water, both divides the Water, and is divided by it, and that when the diviſion is over, they recede unaltered from one another, and diſpoſe themſelves according to their reſpective gravities. If you have a mind to perform this operation yourſelves, all the circumſtances that I have mentioned muſt be carefully attended to, otherwiſe the Experiment will not ſucceed, as you have here obſerved it. The ſame may be performed with Gold.

An example of a repelling one.

If Copper, now, had been melted in the ſame manner, and then dropped into cold Water, as ſoon as ever it came to the Surface of the Water, it would have been repelled with an incredible *impetus*, and the whole ſubſtance of the Copper would have been ſo minutely divided, that ſcarce two Particles of the Metal would have remained united together. By this inſtance, then, it appears, that there are *Menſtruums*, as in this caſe Water, which, by means of a repelling force, very ſurprizingly diſſolve other Bodies, as we ſee here in melted Copper. And the event had been the ſame, if Gold or Silver had been mixed with the Copper, for if the mixture had been thus melted and thrown into Water, it would have flown about in the ſame manner. But here let me caution you not to venture too raſhly to make this Experiment, which can't eaſily be performed without great danger to the Operator.

An example of an attracting one.

In the third place, now, I'll give you an example, where different Subſtances being brought into contact, divide one another, and then unite pretty ſtrongly together. Into this earthen pan, then, which is not glaz'd, I have put four ounces of Flowers of Sulphur, and covered it carefully with a Tile, that when the Sulphur is melted, it may not take Fire. This, now, I ſet upon ſuch a Fire, as is juſt ſufficient to melt it, and to keep it in that condition, and no

 more.

more. In this Bag, which is made of very thick Cloth, and is very clean, I have put ſix ounces of the pureſt Mercury, and tied the back very faſt at top; and the Mercury, you perceive, does not paſs through the Bag, except it is compreſs'd. I now take off the Tile, and ſqueeze the Mercury very gently into the melted Sulphur, ſo that it falls into it gradually, in very ſmall drops, and a very little at a time, and all the while this is doing, the Sulphur is kept conſtantly ſtirring with a warm *ſpatula*, which is continu'd till all the Mercury is perfectly mixed with the Sulphur. You perceive, now, there remains but one Maſs, which is black, drawn out as it were into ſtrings, and very brittle, and which, if it is examined with a microſcope, glitters, and diſcovers ſome appearance of Mercury. Here, then, you have an inſtance of a fluid *Menſtruum*, indeed, but a dry one, and a hard, dry, ſolvend Body, which, when they come to have their ſmalleſt Particles in contact with one another, attract and retain one another ſo ſtrongly, that upon the application of Fire to them afterwards, they do not quit their hold, but riſe united together, and are converted into a Cinnabar. The principles, now, that are here conjoined, how different were they, as to their origin, weight, kind, and volatility, and how diſtant from a combination with one another? And yet when they are brought thus cloſe together, how tenaciouſly do they cohere together? What now were the cauſes that brought about this adunation? Why, firſt, the Fire, which melted the Sulphur into its diſtinct elements. Secondly, the diviſion of the Mercury whilſt it was made to paſs through the Bag, as through a very fine ſieve, by a very ſmall quantity at a time. Thirdly, the continual agitation of the melted Sulphur, and the Mercury that fell into it, by which means they were accurately mixed together. But all theſe, now, did nothing more than barely apply the Sulphur to the Mercury; and therefore, fourthly, there is ſome other power in the Sulphur and Mercury, by which, when they thus touch one another in ſuch a vaſt number of Surfaces, they attract each other into ſo ſtrong a coheſion, that they require ſome great force, or ſome other power attracting one of them more ſtrongly, to ſeparate them from one another. And this reciprocal attraction acts here as the principal cauſe. And hence, fifthly, ariſes this conſtant combination, as the ultimate effect, which is ſo great, that if you ſublime this compoſition in a cloſe Veſſel, it will not be divided into Mercury and Sulphur, but they will both aſcend at once in very ſmall particles of Cinnabar, in every one of which they are both always found to be united together. Nay, though after you have once performed this operation, you repeat it again in the ſame manner, you will not, even then, be able to ſeparate them aſunder, but on the contrary, will force them by this means into a more intimate union. It's true, indeed, that the Cinnabar, after it is once made, will not riſe ſo eaſily as it did the firſt time, but will, upon every freſh attempt, grow ſtill more and more fixed in the Fire, 'till it at laſt becomes of an exceeding fixed nature; but even in that caſe, the volatile, mercurial part will not divide from it, but will remain ſo entangled in the Sulphur, that it will not be able to diſengage itſelf, though it is at laſt expoſed to an exceeding ſtrong Fire. It is no wonder, therefore, that ſome novices in the art ſhould, upon the ſight of this Experiment, be led to imagine, that they could in this manner produce even Metals themſelves, by the adunation of theſe two Principles, Sulphur and

Mercury

Mercury, thus effected by the Fire, of which the Adepts unanimously agree, that Metals are compounded. They found, however, upon better examination, that they had only laboured in vain, the Sulphur in every operation still remaining Sulphur, and the Mercury under a proper management, still returning true Mercury; but as he says in *Sendivogius*, never wiser. The truth of this appears evident, by making use only of a very dry *Menstruum*, that will attract the Sulphur more strongly than the Mercury does. Take, for instance, 12 ounces of Cinnabar that by Sublimation is rendered exceeding fixed, reduce it into Powder in an iron Mortar, and then add to it the same quantity of Filings of soft native Iron, not Steel, which too must be fresh filed, not rusty; rub these then accurately together for a considerable time, and then, as before, sublime them in a Cucurbit with a strong Fire: And what then will be the consequence? Why the Mercury, to the quantity of six ounces, will rise pure, and fall in its original form, into the Water in the Receiver, and at the bottom of the Retort, there will remain a fixed Mass composed of Sulphur and Iron; for Iron being thus exposed to the Fire, most greedily unites itself with the Sulphur as its *Menstruum*, and repells the Mercury from its cohesion with it, which then flies off separately, and laughs at the too credulous Alchemist. The same thing may be effected by using a fixed alcaline Salt, instead of Iron; for as soon as ever the Salt comes to be melted by the Fire, it dissolves the Sulphur, unites itself intimately with it, and by this means dislodges the Mercury. Quick Lime too, will do the same. Another instance of a merely attracting *Menstruum*, we have in the following Experiment. Take 2 drachms of Flowers of Sulphur, add to them in a glass Mortar 3 drachms of Mercury, and with a glass Pestil rub them together, the longer the better; and by this means, the Mercury will gradually disappear, and become united with the Sulphur, and when they are intimately mixed together, they will produce a very black Powder, which was continually changing its appearance during the rubbing: And the blackness of this Powder will be so much the greater, as they are longer rubbed, and more closely united together. Hence, if you continue rubbing it a good while, it will at last become exceeding black and very fine, and if it is left to itself, in a short time it naturally hardens into a black Mass. This Substance, now, very intimately contains a latent Mercury, and fixes and retains it, in such a manner, that if it is taken by Animals in great quantities, it does not act with the efficacy of Mercury, which cannot be recovered from it again, except by the contrivances abovementioned: This may be sublimed too into a very red Cinnabar. This some of the avaritious Alchemists observed likewise, and rejoiced over their black Powder. They imagined it to be the head of the Crow, which the Adepts had told them appears in the beginning of the grand Operation, when the Principles, Sulphur, and Mercury, are properly united together. Thus again, you have an instance of a dry fluid *Menstruum*, and a solvent Body, divided only by a simple mechanical Attrition, and then by the power of Attraction remaining closely conjoined with one another.

An instance of an attracting and repelling *Menstruum*.

I have here now some very good common Antimony reduced to Powder. This I put into this clean Crucible, which I cover close with a Tile, and when it is gradually heated, set it upon this Fire that on every side surrounds it. You see now, the Antimony begins to fume a little, and whilst I keep it on the

Fire 'till it melts, and runs like Water, it emits a great quantity of a whitiſh Smoke. The Crucible I then take off of the Fire, and let it ſtand quiet 'till it is perfectly cold. If you examine, now, the ſurface of the Antimony, which is now condenſed by the Cold, it looks rough, unequal, and full of holes. I'll now break the Crucible; and you ſee the Maſs of Antimony towards the lower part is ſolid, and ſhines with a metalline caſt, whilſt at top it is ſpongy, whitiſh, and yellowiſh, intermix'd with a lead Colour. Here, therefore, you ſee that the Fire, by melting the Antimony, has reſolved it into its metalline, and ſulphureous parts: That hence, theſe being ſet at liberty, have aſſociated themſelves together, the metalline with the metalline, and the ſulphureous with the ſulphureous, whilſt the metalline parts have driven from them the ſulphureous ones, and theſe have done the ſame by the metalline. And here, whilſt this Solution was brought about by the Fire, Fuſion, Attraction, Repulſion, and Gravity, all joined their concurring efficacy to produce this effect. If you imagine that this Experiment don't ſo properly belong to the nature of *Menſtruums*, this at leaſt you will allow me, that, by the help of it, we come to the knowledge of many things which actually happen in their operation.

But that I may ſtill exhibit to you ſome farther inſtances of the action of *Menſtruums*, and thus lead you to a proper conception of thoſe which act by the concurrence of different cauſes, I here again take an ounce of Salt of Tartar, and half an ounce of Flowers of Sulphur, rubb'd very briſkly in hot mortars, in a hot dry Air, and ſtill continuing very hot, and put them into a Crucible upon the Fire, and cover them. You perceive, now, how ſoon they are both melted together, tho' the fix'd Salt melts with ſo much difficulty when it is by itſelf. This diſſolved Matter, now, I pour out of the Crucible upon a clean Stone, and you ſee we have a homogeneous Maſs, than which nothing melts more eaſily in the Air, eſpecially, if it is reduced to Powder; for as you perceive, it immediately runs into a very red Oil. Hence then you learn, what a very ſtrong adunation there is brought about between this dry *Menſtruum*, and the dry Body of the Sulphur, which is ſo incapable of ever being diſſolv'd by Water, and yet now by the efficacy of the *Menſtruum*, melts ſooner than any thing with the Water of the Air, which it ſeems to attract into it with a vaſt deal of greedineſs. But pleaſe to take notice of the following Experiment, which is more extraordinary, and what one would leſs expect. I have here four ounces of the choiceſt Antimony levigated to a very fine Powder, and rubb'd with 2 ounces of hot dry Salt of Tartar, in a hot dry Air, and with a hot Peſtil and Mortar. This Mixture, now, I put into a Crucible, and melt with a very ſtrong Fire 'till it is perfectly fluid, and then pour it into a melting Cone. And now it is cold, I ſtrike it out, and you ſee it is become one homogeneous Maſs, very equably diſſolved through the whole Body, which flowed in the Fire juſt like Water. It is farther, as you obſerve, of an aſh Colour, and it in ſome meaſure reſembles Glaſs, is of a cauſtic taſte, diſſolves in the Air, and then changes its Colour to a bright red: Here then the fixed Alcali, the Sulphur of the Antimony, and its metalline part, are very minutely divided by the action of the Fire, and united into one kind of Body, which does not happen in theſe very often. But give me leave to add one more Example to the ſame purpoſe. I have here an ounce of the pureſt Sil-

Of dry ones.

ver, and three ounces of the beſt Copper. Theſe I put into a Crucible, and melt in this Coal Fire, and now they are perfectly fuſed, pour them out into this little iron Mould, where we have a homogeneous Maſs of Metal very equably mixed together, and ſcarcely ſeparable again, except by the help of Lead in the Cupel. In this Operation, now, one Metal is the *Menſtruum* of the other, as ſoon as ever they come to be both melted. And then it is plain, the Particles of each of them unite rather with thoſe of the other Metal, than they do with one another, as betwixt all the Particles of the Silver, there is an equal diſtribution of Copper, and as notwithſtanding their different Gravities, they don't ſeparate from one another. Nor can this ariſe only from the action of the Fire, which may melt them indeed, and blend them together, but can never poſſibly mix them together in ſuch an equal proportion. This operation, too, farther teaches us, that the mercurial part of the Silver unites itſelf ſo ſtrongly with that of the Copper, that it will not afterwards part with it; for otherwiſe, the melted Silver would ſink to the bottom of the Crucible, and the melted Copper ſwim at top of it, and after they came to be at reſt, they would ſeparate into two diſtinct *Strata*, as we ſee Oil of Tartar *per deliquium*, and Alcohol, when they are mixed and ſhook together in a Veſſel, ſoon return into two perfectly diſtinct Bodies, which by no Art whatever can be mixed together. And here, which particularly deſerves our conſideration, both when they are in fuſion in the Fire, and afterwards concreted in the Cold, they continue throughout mixed exactly in the ſame proportion. Theſe Examples, then, Gentlemen, are ſufficient to give you a notion of the various manners in which dry *Menſtruums* act upon one another.

The cauſes of Solution concurring in *Menſtruums*.

If you pleaſe, then, carefully to examine the inſtances we have given, and conſider maturely what we have ſaid, you will have an idea of the Solution of Bodies by *Menſtruums*, very different from that which the Chemiſts and Philoſophers commonly have, who by the true Principles of things, have endeavoured to explain chemical Operations. For they have always imagined here ſome mechanical Acrimony, corroding by a univerſal mechanical Power; and when they have obſerved that a *Menſtruum* that corroded one Body, would not often corrode one that was ſofter, they have racked their Brains a thouſand different ways, to reconcile theſe contrary appearances. We, inveſtigating Nature by the help of Experiments alone, proceed in the following manner.

Firſt Fire.

Upon the moſt careful examination, then, into the concurring cauſes of Solution in *Menſtruums*, Fire firſt offers itſelf to our Obſervation. And this, if we conſider it in all the various degrees which Experience has diſcovered to us, will be found to be almoſt a univerſal Solvent, inaſmuch as it diſſolves almoſt all Bodies, if it is applied to them in a proper ſtrength. For if we proceed gradually from the warmth of a Man in health, to the utmoſt violence of *Tſchirnhauſen*'s *Focus*, and make Experiments upon different kinds of Bodies through the whole compaſs, we ſhall ſcarcely find any that will not melt, or be divided into their leaſt Particles, by one degree of Heat or another. For if ſome of them grow hard, as Bricks, in a certain degree of Heat, yet in a greater they will melt and vitrify, as is evident in the Furnaces made uſe of for fuſing Metals. And tho' ſome few, indeed, will not be melted at all in the moſt intenſe Heat that we are at preſent acquainted with; who knows, if this was ſtill farther increaſed, but theſe at laſt would diſſolve likewiſe. We muſt

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by all means acknowledge, therefore, that the power of Fire muſt always be very ſtrictly attended to in the proper action of *Menſtruums*. Without the aſſiſtance of this Element, certainly, the mercurial parts of Metals could never be ſo ſurprizingly united into one Maſs.

Next Attrition.

In the ſecond place, in order to underſtand the action of any *Menſtruum*, we muſt conſider likewiſe, whether there did not concur a ſtrong and continued mechanical attrition; for this may often ſupply the place of Fire, and effect in ſome meaſure what Fire would have done, had that been preſent. For whilſt Attrition attenuates, and divides Bodies, and reduces them into very minute particles, it gives them an opportunity of acting upon one another by theſe very ſmall corpuſcles, and thus mightily favours a very intimate Mixture. This appeared evident in the Grinding-Mill of Monſ. *Langelot*, which is ſaid to have ground Gold into a potable Liquor; concerning which, the celebrated Author, who has wrote a Treatiſe upon this ſubject, deſerves to be conſulted. And among the Obſervations of Mr. *Homberg*, we are told, that all Metals, Gold itſelf not excepted, have, by being rubb'd for a long time with pure Rain-water, been converted into a Liquid.

A ſeparation ſometimes happens by means of a repulſive force excited by theſe two.

In the third place, it is farther to be obſerved, that when the Bodies to be diſſolved have been melted into their ultimate Particles by the Fire, or been minutely divided by the Attrition juſt explained, or, in particular, have undergone the whole energy of them both together; then, if their Particles thus ſeparated are intimately mixed together, it often happens, that a repulſive force, which was latent before, diſcovers itſelf openly to our Obſervation; which is amongſt the greateſt ſecrets of the Chemiſts. An inſtance will beſt explain what I mean. Melt ſome very pure Lead in an iron Ladle, and add to it three times its weight of choice Mercury, and mix them together, and you will have a Compoſition, or *Amalgama*, of a bright Colour, like that of the pureſt Silver. Keep this by you for years, and it will remain exactly the ſame, without any alteration. If you afterwards rub it in a glaſs Mortar with a glaſs Peſtil, or in a wooden Bowl with a wooden Peſtil, you'll find to your ſurprize, that the whole Maſs will grow perfectly black; and if you then put Water upon it, and continue to rub it, and then pour off the Water, which will be black and turbid, there will again be a pure *Amalgama* left behind. This now will keep its appearance as before, and remain pure for a long time; and yet if you repeat the former Operation, it will again become black; nor will you, as I have learnt by Experience, be able to come at the end of your work ſo eaſily as ſome Authors promiſe you. Here then we ſee evidently, that the Mercury thus mixed with the Lead, does not at firſt repel this black Matter, either from the Lead or itſelf; but when by this mechanical Attrition, the attenuation, mixture, and application of the different Particles, become greater, and more intimate, there then ariſes ſuch a power in the Mercury and Lead upon one another, that the intimate mercurial parts of both come into the cloſeſt union, and by this means repel from them, or as the old Alchemiſts called it, ſpues out the heterogeneous matter, which could not be ſeparated from them by any other method, without a vaſt deal of difficulty. If this *Amalgama* now is diſtilled and cohobated with Mercury a great number of times, the action of the Fire will have the ſame effect, as the rubbing had before, and produce the ſame black Matter capable again of being diluted and ſeparated by Water. Here again, then, evidently ariſes a repelling power, by the efficacy of which, this ſeparation is obtained very eaſily. Whether this now can be effected in any other manner, I know not. Silence here is beſt: A word to the wiſe is ſufficient.

Or by Attrition. In the fourth place let me obſerve, that both the Particles of the Solvent, and the Solvend, when they are melted, or agitated by the Fire, attenuated by Attrition, and mixed together, often diſcover an attractive Power which before lay concealed, and by which they are then aſſociated together in a ſurprizing, and frequently a very efficacious manner, whence afterwards ariſe great variety of new Bodies, which never appeared before, and which can ſcarcely be produced by any other means. The Operation juſt mentioned, with the *Amalgama*, may ſerve here too for an Example: For in this there is effected, by this attractive Power, a wonderful Adunation of the mercurial Particles of the Metals, which diſcovers itſelf to the Operator, after the repelling force has ſeparated the heterogeneous Matter, which prevented the homogeneous Particles coming into a perfect union. This, therefore, being expelled in the manner explained, and the remaining part in both being perfectly depurated, the mercurial parts become intimately united together, and produce ſomething one would not expect.

Hence the production of a new Body. In the fifth place, if a *Menſtruum*, after it has diſſolved a Body, let the manner in which it effects this be what it will, I ſay, if this *Menſtruum*, after the Solution is over, can be totally ſeparated from the diſſolved Matter, ſo that they may both again exiſt diſtinctly, then the Body diſſolved appears by itſelf in a new form, and is for the moſt part converted into a *Calx*, or into ſome other kind of new Body.

Hence ſolid *Menſtruums* act as Fluids. From the whole, then, we ſee, that almoſt all *Menſtruums*, whether ſolid or fluid, at the very time when they are in action, are reduced to the nature of Fluids, Attrition, perhaps, alone excepted, which often, without any aſſiſtance, renders Bodies fit for Solution: But even in this caſe, that the Solution may be compleat, the Attenuation muſt be ſo ſubtil, that the Bodies rubb'd, put on almoſt the form of Fluids.

I'll now, then, give you an Example, in which all theſe cauſes, Fire, Attrition, a repelling force, an attracting one, and a mechanical one, act together in dry *Menſtruums*, and all their effects, *viz.* Attenuation, Concretion, Tranſmutation, and Separation, are produced at the ſame time; and in this Experiment I ſhall proceed in ſuch a manner, that it may ſerve you as a pattern for any of the like nature. I have here, then, 16 ounces of common Antimony purified only by fuſion, and then being ſuffered to ſettle as I ſhewed you before, which I have taken care ſhould be pounded and rubbed in an iron Mortar, till it is reduced to a very fine Powder. This Powder, now, you know conſiſts of a common Sulphur, intimately intermixed with another part which is called the metalline, or mercurial part of the Antimony, tho' there does not appear in it the leaſt ſign of theſe two different ſubſtances, even tho' you examine it with a Microſcope. I take then of the pureſt ſtony concretions of Rheniſh Wine, commonly called Tartar, 12 ounces, reduced likewiſe to a ſubtil white Powder; and of very pure Nitre 6 ounces, which, now it is finely powdered, you ſee is as white as Snow. All theſe Powders, then, I dry as thoroughly as poſſible, then mix them, and take care they are for a

conſiderable

considerable time rubbed well together in an iron Mortar, that by this means they may be intimately intermixed with one another. The compound Powder then weighing 34 ounces, I ſet by for farther uſe. I now again take 6 ounces of Tartar, and 3 of Nitre, reduced ſeparately as before into a fine dry Powder, and accurately mix them together, and from the acid Tartar, and ſalt Nitre, have a very ſubtil dry Powder, which ſtill impreſſes upon the Tongue an acid taſte. Now then pleaſe to obſerve. Into this Ladle, which I have placed on an open Fire where there is no Smoke, and which is now almoſt red hot, I throw in a little of this Powder of Tartar and Nitre, and you ſee the very moment that it falls into it, it puffs up, boils, throws out ſmall ſparks, burſts into a Flame, and leaves a white Maſs, here and there a little greeniſh, which is perfectly fixed and alcaline. On this then, I throw a little more of the Powder, and the ſame *Phænomena* happen over again; and thus I proceed till all the Powder is uſed. Here then we ſee, that when the acid vegetable Salt, and the ſaline terreſtrial Salt come to be expoſed to the Fire, they fume, ſparkle, burn, and are fixed into an acrid Alcali; and that all this is performed, almoſt, in a ſingle point of time. But by an Experiment, that I ſhewed you before, I made it appear, that if a fixed alcaline Salt is rubb'd with Sulphur till they are intimately mix'd, they will flame inſtantly in the Fire, and the Sulphur being totally diſſolv'd, will be converted into a new Body. Hence, then, you readily perceive, that if Tartar, Nitre, and Sulphur, mix'd in a ſmall quantity, are thus thrown into a Veſſel heated red hot, there will immediately be produced a fixed Alcali, which the Sulphur will inſtantly lay hold of, diſſolve, and convert into a Maſs of a peculiar nature. Having a right notion of this, therefore, let us now ſee what will become of our Powder of Antimony, Tartar, and Nitre, when that likewiſe is expoſed to the Fire. To this purpoſe, I have placed a ſtrong Crucible in the Fire, which was firſt gradually heated, that it might bear the ſudden application of a ſtrong Fire without cracking; and I have choſen one that will at leaſt hold three times the quantity of the Powder to be thrown in. The Crucible, then, I thus cover with a Tile to keep the Dirt out, and increaſe the Fire gradually, till it is all over red hot. In the mean time too, I take care to have the Powder of Antimony, Tartar, and Nitre, made pretty hot, but cautiouſly, that it don't take fire. I now, then, take off the Tile, and with an iron Ladle throw in about two drachms at once of this heated Powder; and the very moment it comes to the bottom of the Crucible it burſts into flames, ſmokes, ſparkles, flames, grows red hot, and lies quiet. I then proceed again to fling in the ſame quantity, which you ſee has the like effect, and ſo continue to the end, covering the Crucible every time, till the Ebullition is perfectly over. The whole Powder, then, being thus thrown in and deflagrated, I make the Fire ſo ſtrong, that all the matter in the Crucible may be melted, and flow like Water; and after that by putting in a Tobacco-pipe, I have found this to be the caſe, I keep it ſome time in this degree of Heat. In the mean time, I have by me a conical braſs Veſſel, which I make very hot, and then rub over on the inſide with a piece of Tallow Candle, ſo that the whole Surface may be covered with this pinguious Matter. And this I have found by Experience to be ſafer, than making uſe of Oil; becauſe if there happens to be ever ſo little Water in it, it may produce a terrible effect. The Matter then still continuing perfectly fluid, and the Crucible red hot, I take it out with a pair of Tongs, the Claws of which are suited to the figure of the Crucible, that there may be no danger of its slipping, and gently pour the melted Powder into the Cone, upon which you see, a Flame instantly bursts out like Lightning. This proceeds from the Tallow with which the inside was smeer'd over, which now takes fire, and by its Flame prevents the melted substance's concreting with the Vessel. I now let it stand till it is cold, and then turning up the Cone, and striking it, the whole Mass is discharged, as you see, into this Bowl, and is now divided into two parts that are perfectly distinct: The upper part of which, or that towards the Base of the Cone, is of a dark brown colour, weighs 14 ounces, and is what the Workmen call the *Scoriæ*: These are brittle, of a caustic taste, and brown colour, melt in the Air, and then become red, and consist of a fix'd alcaline Salt produc'd from the melted Tartar and Nitre, and the Sulphur of the Antimony, reduced by the Fire with that Alcali into one Body; which afterwards being fused with an intense Heat, was repelled by the other metalline part of the Antimony, and rose to the top, whilst that at the same time by its weight subsided to the bottom. This too you see here likewise, which is of a white bright colour like Silver, is very ponderous, and on its upper or broader part, has the figure of a Star: And, indeed, it would be of a true metalline Nature, were it not for its brittleness, which makes it readily fly asunder, and renders it capable of being powdered. In this one Experiment, then, you have had a specimen of every thing that I have been explaining to you in the action of dry solid *Menstruums*. For in the first place, by a mechanical Attrition, all the three Substances were reduced into exceeding small Particles, and hence were rendered capable of being intimately mixed together. In the next place, the Fire melted, moved, and blended them all three with one another. Then, thirdly, the Salt of Tartar, and the Sulphur of the Antimony deflagrating together, in an instant produced a fixed Alcali, which immediately laid hold of the Sulphur of the Antimony, and, by an attracting force, acting reciprocally between them whilst they were thus intimately mixed together, this fixed Alcali and the melted Sulphur were united into one Body, which was still in a state of fusion. In the fourth place, from the same Operation, there arose likewise a repelling power between the metallic Reguline part of the Antimony, and the alcaline Salt, which never suffer themselves to be united in the Fire, but repel one another, and dispose themselves into distinct *Strata*, according to their respective Gravities. Hence, then, we see plainly, the reason why the metalline heavier part sunk to the bottom of the Cone, whilst the alcaline sulphureous one rose to the top, and thus gave rise to two new Bodies, *viz.* the alcaline sulphureous *Scoriæ*, and a starry Regulus of Antimony. A mere mechanical Power, an attractive one, and a repulsive one, therefore, were the cause, in this Experiment, of the Solution and Separation. The mechanical Attrition, by reducing the Bodies into very small Particles, and thus vastly increasing their Surfaces, was the occasion of their having their points of contact greatly increased. The Fire proceeded farther to agitate them, and mix them together, excited, augmented, and continued their attractive and repulsive Power, dissolved the whole Mass, and all the parts of it, set fire to the Salt of Tartar, Sulphur and Nitre,

and

and thus very much increaſed the ſtrength of the Fire itſelf. The Tartar and Nitre, after the Deflagration was over, produced a true fixed alcaline Subſtance, the Nitre yielding a moſt acrid Alcali. This Alcali abſorbed all the remaining Sulphur, and diſcharged the metalline part of the Antimony from it, which it had no effect upon. And laſtly, the whole Maſs help'd to increaſe the force of the firſt, whence aroſe a more rapid motion and concuſſion, and at the ſame time, a Smoke, and Soot, by which means 16 ounces and 2 drachms of the original 34, were diſſipated and loſt, the *Regulus* weighing only 3 ounces and 6 drachms, and the *Scoriæ*, as I mentioned before, 14. If you have a mind, now, Gentlemen, to perform this Operation yourſelves, you muſt be ſure to do it with a great deal of caution, if you would expect it to ſucceed. For in the firſt place, if your Crucible is not ſufficiently large, the Matter will boil up in melting, and run over the edges. If the Matter is not reduced to an exceeding fine Powder, it will crackle and fly about. If the Powder is not thoroughly hot, when it is thrown in, it will chill the Crucible, and ſplit it. If you don't wait till the detonation of that you have thrown in, is intirely over, and the whole is grown perfectly red, nay, and is fluxed too, before you proceed, then the part that is not melted, will collect itſelf into a ſolid Cruſt upon the Surface, and will confine that which is underneath at the bottom of the Crucible, which being reſolved in the mean time into an Alcali, Nitre, and Sulphur, will have the vertues of a true *Pulvis Fulminans*, and will in a little time be diſcharged with a moſt prodigious noiſe, and daſh all to pieces; the danger of which can only be avoided by the cautions abovementioned. But again, if the whole Matter is not kept melted, and flowing like Water for ſome time in the Crucible before you pour it out, the pure *Regulus* will never be rightly ſeparated from the *Scoriæ*. If you don't make the Cone pretty hot, there will be danger of its ſplitting, when the melted Matter comes into it. If you don't rub it over with Tallow, the Matter often concretes with it, nor will ſuffer itſelf to be ſeparated afterwards. If there happens to be the leaſt drop of Water in the Cone, the Operation will prove exceeding dangerous, the Matter all flying about with a vaſt force and noiſe. If you don't pour the Matter in whilſt it continues perfectly fluid, neither the *Regulus*, nor the *Scoriæ*, will diſpoſe themſelves in their proper place: So many cautions are neceſſary to this one Operation.

How far the actions of *Menſtruums* are merely mechanical.

These things, therefore, being premiſed, we may now examine a little more nicely the actions of *Menſtruums*, both ſolid and fluid, upon their Solvends, ſo far as they may be underſtood and explained in a pure mechanical manner: And for the ſake of that valuable ſet of Men the Mathematicians, it will be worth while to endeavour to ſet this Matter once in a proper Light.

The hardeſt Bodies are diſſolved mechanically.

And that we may do this moſt effectually, pleaſe to conſider in the firſt place, that in all Nature, there is not any one Body that falls under the cognizance of our ſenſes, whoſe parts cohere ſo tenaciouſly, or rigidly together, that they may not be ſeparated from one another by a mere mechanical force, without the concurrence of any other cauſe. As an inſtance of this, let us take a Diamond, which has been called by this name, on account of its exceſſive hardneſs, which was deſcribed by the Ancients as being inſuperable, and yet we ſee is forced to ſubmit to the Saw of the Lapidaries, who can accurately too ſplit it aſunder, and at pleaſure grind and poliſh it into various Figures:

But

But to this purpoſe you know, the Workmen make uſe of nothing but pure mechanical Inſtruments, and a motion of the ſame nature.

By the ſofteſt Bodies,

But again, in this ſimple mechanical diviſion of Bodies, the moſt fluid, and conſequently to our ſenſes, the ſofteſt, is capable of wearing away, and diſſolving, the very hardeſt we are acquainted with. Drops of Water falling from on high, hollow the moſt rigid Stones, wear away Metals, and in ſhort, diminiſh every thing they fall upon. The force indeed of ſingle drops, appears to us as it were, nothing at all, and yet, when it comes to be conſtantly repeated, it produces very conſiderable effects. The ſofteſt Leather, by a continual Attrition, will poliſh the hardeſt Stones, Metals, and even Glaſs itſelf. The Surface of a wooden Wheel will conſume any Body whatever, applied to it as it runs round, into inviſible Particles. Hence, therefore, we may fairly conclude, that by a continued repetition of their action, the ſofteſt Bodies are capable of reſolving the moſt rigid into ſuch minute particles, as don't fall any longer under the notice of our Senſes.

Whoſe Elements are exceeding hard.

It will help us now to conceive more eaſily of this ſurprizing *Phænomenon*, if we ſuppoſe, with ſome Authors, that the inviſible ultimate Particles of all *Menſtruums* whatſoever, ought to be looked upon as hard, and almoſt immutable, altho' the Body they compoſe ſeems exceeding ſoft to our Senſes, on account of their receding very readily from their contact with one another. And this Opinion, indeed, by an induction of particulars, ſeems to be very much confirmed. The Elements of Fire overcome the hardneſs of all Bodies whatever; and yet they are prodigious ſmall, and let their action be ever ſo violent, never appear to be in the leaſt altered. No-body has ever obſerved the leaſt change induced upon a Particle of Air, tho' this Element often brings about ſuch various and powerful changes in other Bodies. Water, than which nothing is ſofter, whilſt in a ſtate of Fluidity, conſiſts of Particles ſo immenſly hard, that let them be compreſs'd by ever ſo great weight, or power, they have never been found to be altered. And the ſame, in the ultimate Particles of Earth, has appeared abundantly evident. The moſt ſubtil Spirits of Alcohol, how ſoft do they appear to the Organs of our Senſes; and yet who, after a hundred Diſtillations, Digeſtions, and Compoſitions, has ever diſcovered the leaſt ſign of any alteration in their Elements. And as for the Spirits of Salts, as they are called, which are chemically drawn from them, and are ſo exceeding acrid, if we examine them, what an incredible immutability do we find in them, and conſequently, as one may fairly infer, what an extreme hardneſs; tho' the Philoſophers imagine them to be ſharp like Needles, and hence eaſily mutable. That indefatigable Gentleman, however, Monſieur *Homberg*, having digeſted them for years with a conſtant Fire, and in cloſe Veſſels, has found them at laſt the very ſame without any alteration. *Du Hamel. l'Hiſt. de l' Ac. Roy.* p. 497, 498. That mild acid Vinegar alone, after four years, was changed into ſomething of a different nature.

Hence Fluids diſſolve the hardeſt Bodies mechanically.

There might other Arguments be produced to the ſame purpoſe, but what has been offered ſufficiently demonſtrates, that the ultimate Elements of the ſofteſt Fluids, if they are conſidered ſeparately, are very durable, and therefore very hard. And as this is very evident, ſo likewiſe we clearly learn hence, that the ultimate Particles of *Menſtruums*, if they are ſtrongly preſſed, and moved againſt

againſt the Corpuſcles that compoſe the Solvend, may produce ſuch an attrition as is capable, if ſufficiently repeated, of wearing away, and dividing the greateſt and hardeſt Bodies into their minute Particles; as we ſee in the hollowing of Stones by drops of Water.

And this happens particularly when the conſtant action of a ſtrong Fire produces ſuch a perpetual colliſion, and attrition againſt theſe Surfaces. In every ſolution, however, thus ſuppoſed to be mechanically performed by the Particles of *Menſtruums*, there is this conſiderable objection, that the Elements of the *Menſtruum* being driven againſt the ſurface of the Solvend, would eaſily recoil again, and hence could not produce any remarkable effect. **By Fire,**

And this, indeed, is in ſome meaſure true, but then their own proper Gravity, and the vaſt preſſure of the Atmoſphere, taken notice of in our Hiſtory of Air, will apply them very powerfully to one another. At the ſame time, however, it is very evident, that where *Menſtruums* act only by a ſimple, mechanical power, without any other concurring cauſe, they in reality effect but very little: And on the other hand, we know as certainly, that a ſtrong external application of a Fluid to a Solid vaſtly increaſes its diſſolving power, though all other circumſtances continue the ſame. The Bones of an old Ox will boil a great while in an open Veſſel, without any conſiderable alteration; and yet if they are boiled in *Boyle*'s or *Papin*'s Digeſter, they grow ſoft, and diſſolve in a ſhort time, tho' here there is only this difference, that in the laſt caſe the particles of Water are prodigiouſly compreſs'd againſt the Bones, and agitated upon them with a violent attrition. **And Gravity.**

Thus, then, we intelligibly enough conceive of the firſt mechanical manner in which ſome *Menſtruums* act, *viz.* by wearing away Bodies by attrition upon their external ſurface. But when the Particles of the Solvent do not only thus ſeparate the external Corpuſcles of the Solvend, but act likewiſe upon the internal parts, and thus diſſolve their whole Body; then theſe particles ſeem to inſinuate themſelves into the Pores of thoſe Bodies, and there effect the very ſame thing upon the internal Surface that forms thoſe cavities, as we made it appear they did before upon the external. There is one conſiderable difficulty, however, in this affair, and that is, rightly to comprehend the manner in which the Solvent thus enters into the Pores of the Body to be diſſolved. This, I confeſs, is not ſo clear as a body could wiſh; becauſe we have but a very few Experiments, where there is nothing but a pure mechanical action, and for this reaſon we are obliged to call in to our aſſiſtance ſome of thoſe, where there is a concurrence of a mechanical, and ſome other cauſes together. **Attrition upon the ſurface.**

In the firſt place, then, there muſt be ſome proportion betwixt the Pores of the Body to be diſſolved, and the particles of the *Menſtruum* by which the ſolution is to be performed: For if theſe Pores are large enough to admit the *Menſtruum* into them in a liquid form, then the caſe will be the ſame as we juſt now mentioned; if they are too ſmall, then the internal parts will ſcarcely be diſſolved. And hence it comes to paſs, that when the particles of a ſimple *Menſtruum* collect themſelves by a mutual aſſociation into ſomewhat larger Corpuſcles, they do not then ſo readily diſſolve the Bodies expoſed to them, as being ſcarcely able in this form to penetrate into them; though afterwards, if they are diluted with Water, and thus have their particles removed from con- **The firſt circumſtance requiſite.**

tact with one another, they may then be able to enter into these Pores from which they were before excluded. This you see in the following experiment. In this Urinal I have an ounce of the best Oil of Vitriol, of my own preparing, depurated by distillation from all its *Fæces*, and by ebullition, from all its Water. This Liquor is so pure, that in very cold weather it congeals into solid, chrystalline Glebes, and melts again with the warmth of a thaw. This Oil of Vitriol I have heated to the degree of boiling Water, by keeping the Urinal some time in Water that was boiling. Into this Oil, now, I throw 5 drachms of hot Filings of Iron, and mix them together by shaking the Glass; and you observe what a prodigious rarefaction is instantly produced without any Fumes or Ebullition, the matter, indeed, which is of a grey colour, appearing puffed up, but continuing at rest. But please to take notice of this second Experiment. I have in this other Urinal 1 ounce of the same hot Oil of Vitriol, to which I now add three ounces of Water, heated likewise, that they may be mixed without danger of breaking the Glass, which would happen, if the Oil and Water were put together cold; for then the sudden heat produced would make the Glass burst asunder. Into these 4 ounces of Liquor I throw 5 drachms of Filings of Iron; and there arises, you see, a prodigious Ebullition, Effervescence, and a Fume, that has a smell like Garlick, and the whole Body of the Iron is perfectly dissolved into a green Liquor. In the same manner the famous *Bohn* and *Boyle* tell us, Silver and Lead will not dissolve in the strongest Spirit of Nitre, though if it is diluted with Water, they will be corroded by it immediately. But that you may be judges of this yourselves, please to attend to the following Experiments. In this Vessel I have 1 ounce of the strongest Spirit of Nitre that can be made, into which I put half an ounce of *Minium*, and they remain quiet, without any Effervescence, and in the cold will continue so a considerable time. Again, I have here 1 ounce of the same Spirit of Nitre, but diluted with eight ounces of Water: To this I add $\frac{1}{2}$ an ounce of *Minium*, and they remain at rest as before. But again, in this Vessel I mix 1 ounce of pure Silver with 1 ounce of the same strong Spirit of Nitre; nor do these discover any motion or ebullition. And lastly, in this Glass there is 1 ounce of this Spirit mixed with the same quantity of Rain-Water, into which I throw 1 ounce of pure Silver; and these you see, likewise, in this degree of Cold continue perfectly at rest. But as soon as ever, now, the Fire begins to put these four mixtures in motion, there is presently brought about an agitation, solution, and ebullition, which appears in the pure Spirit to be weaker and slower, in that which is diluted, brisker and more efficacious. See *Boyle* upon this head, in his *Philos. Ess. Bohn. Chem.* p. 156. Let us now, then, Gentlemen, consider what we can deduce from these Experiments to our present purpose. In the first place, then, it hence evidently appears, that acid Salts, when they are converted into Spirits, as they are called, may be diluted with a greater, or less quantity of Water. Secondly, that by the concussion of the Glass this dilution is so much promoted, that by this means the Water may be very equably mixed with the Salts, though before, the Acid stagnated at the bottom, and the Water rested quietly at top; as the pinguious *Striæ* in one part evidently demonstrate. Thirdly, that between every two saline Particles, as many aqueous Particles, as the Artist pleases, may be in this manner interposed, if he will only add a proper quantity of Water. That hence, therefore, in the

the fourth place, it may be effected, that these Particles, thus diluted, shall not any longer be united into saline Glebes, but shall separately swim about amongst the Particles of Water, with which they are intermixed. Hence, fifthly, these saline Elements, thus swimming about in the Water, seem capable of insinuating themselves into the very small Pores of the Bodies to be dissolved; inasmuch as they now exist in their smallest form. In the last place, it is probable, that these acid, saline Particles, when they were not diluted with Water, associated with one another, and thus were in some measure concreted into coherent, little Masses, which by this means became too great to penetrate into these little vacuities. These things, then, being duly considered, the opinion we just now offered seems sufficiently probable.

In the second place, if we would rightly understand the powers of those *Menstruums* that perform their effects in a mechanical manner, it is necessary, by all means, to consider the figure of the solvent Particles: For it appears, by the mechanical demonstrations of the Geometricians, that mechanical actions depend principally upon the figure of the acting Bodies. For a Body, remaining perfectly the same in all other respects, but only changing its figure, becomes fit to perform a great many things, which it was not capable of before. This I generally explain by this simple Example. Take an ounce of Steel, and form it into a Sphere, a Cube, a Knife, a Lancet, a Polygon, a Dagger, a Pyramid, an Adz, a Saw, or a File, and will it not in every one of these shapes acquire a new, and very different power from what it had before? The same Body, therefore, being variously shaped, acts always with a new power upon the Body which it is made use of to dissolve. But by this means it often happens, likewise, that the capacity of the Pores become fit to admit Solvents of certain Figures, rather than any others. And hence it seems to come to pass, that the recipocal vertue betwixt the Solvent and Solvend, is often perfectly changed or destroyed, when either one or both have the figure of their surface altered. This, indeed, it is exceeding difficult to give an ocular demonstration of; as neither the ultimate Particles, or Pores of Bodies can scarce possibly be rendered visible: But if from what we observe in larger Bodies, we may be allowed by analogy to conclude concerning the more minute, we must infer, that this will likewise hold true in those Particles of Bodies which escape the distinct observation of our senses. Unless, perhaps, some persons may imagine, that the solvent Elements are not changable in any respect; though this I think does not appear so probable; as the Elements of Bodies seem to be one thing; those of Solvents another. In many, at least, it looks as if this mutability must be admitted. In the mean time, that a very efficacious power of acting arises between Bodies, from the mere figure of the ingredient, and admittent, the illustrious *Boyle* formerly evinced by the instance of a Key and a Lock, in which, solely from the size and figure, there is produced such a particular power of acting, as is peculiar to those two alone. Hence, therefore, we infer, that the proportion, likewise, between the figure of the solvent Elements, and the Pores of the Body to be dissolved, is the occasion of a great number of very particular effects in these merely mechanical solutions; and that hence, from the bulk and figure of these Particles, the most remarkable, corporeal changes are continually brought about. Lastly, by the figure alone of a given Body, very often are produced very surprizing effects, depending only upon that particular

The second.

 conformation.

conformation. If a metal Bell, for inſtance, is caſt into a proper ſhape, how wonderful are its operations? Suſpend it freely in the Air, and ſtrike upon it only gently with a Hammer, and its whole *ſeries* of Circles, quite from top to bottom, will recede from their circular figure, and every one of them run through an infinite number of *Ellipſes*, till they come to their internal limits, and will then run out again beyond their firſt circular figure into elliptical ones, till they come to their external limits, ſo that alternately cutting one another, perpendicularly to their diameters in theſe circles, they deſcribe by theſe undulations both ellipſes and circles. But theſe excurſions, now, are exceeding ſwift, and performed reciprocally backwards and forwards, and by this means agitating the Air, produce briſk undulations in this, likewiſe, to an incredible diſtance, and thus propagate ſounds and tremulous concuſſions, by which alone very ſurprizing effects are wrought upon the Bodies of Animals, Vegetables, and Foſſils. And all theſe changes depend intirely upon the formation of the Bell. The following Experiments, likewiſe, are uſually referr'd hither, in which it is ſuppoſed the figure of the Solvent is altered, with reſpect to that of its Solvend. Take an ounce of the choiceſt Oil of Vitriol, and drop into it gradually ſix times as much of the pureſt Alcohol of Wine, prepared without any Alcali, ſhaking the Glaſs after every drop. Digeſt theſe for a conſiderable time in a tall Veſſel accurately cloſed, and then very cautiouſly diſtill them till the mixture begins to grow black. When you obſerve this, fix on another clean Receiver, and patiently and prudently urge it with a very ſoft Fire; and there will riſe in this gentle Heat a ſuffocating, ſulphureous Phlegm, that excites coughing moſt violently, and with it a ſweet, fragrant, volatile Oil of Vitriol, weighing almoſt ſix drachms, which muſt be carefully ſecured. *Hoffman. Obſ. Phyſ. Chem.* If this, now, prepared in this manner, is poured upon Iron, it produces very different effects from what we obſerve from mixing this Metal with native Oil of Vitriol. The ſame, likewiſe, is true of the ſtrongeſt Spirit of Nitre, made ſweet according to art with three times as much Alcohol, and then put upon Iron. Nay, and that the pureſt Spirit of Salt, edulcorated in this manner, will not diſſolve Gold, but will take away its colour, was long ago obſerved by the great *Boyle*. The ſame ſweet Spirit of Nitre, too, will no longer diſſolve Silver, though before it corroded it ſo greedily. Theſe *Phænomena*, now, Authors of note have aſcribed to an alteration in the figure of the corroding Elements; for whether you impute it to the combination with the Alcohol, or the diſtillation, or both together, the form of the corrodents, certainly, will be always changed.

The Third. But whilſt we are conſidering theſe merely mechanical ſolutions, there ſeems to be ſtill a third cauſe, which may very much concur towards the activity of the Solvent; and that is, to ſuppoſe the ultimate Elements of the *Menſtruum* to be endued with a proper rigidity, and to be able to inſinuate themſelves in ſuch a manner into the Pores of the Body to be diſſolved, that one part may be fixed in it, whilſt the other ſtands out above the Surface. For if we imagine this to happen all over the porous Surface, and thus conceive it to be grown rough with theſe *Spicula*, which are thus inſerted but are not able to proceed any farther; then if a motion is excited in the *Menſtruum*, the agitated particles will ſtrike upon the exteriour parts of theſe Wedges, and that, every moment in various directions. Hence, then, muſt neceſſarily ariſe in theſe particles a power of cleaving and dividing aſunder the

Corpuſcles of the Solvend; as we ſee timber cleft to pieces by the aſſiſtance of Wedges. And that this, now, is the caſe in *Menſtruums*, is certainly exceeding probable; eſpecially if we conſider, that in theſe ſolutions thoſe ſurfaces that were ſmooth before, almoſt always grow rough and unequal. And indeed in mechanical ſolutions, this third cauſe ſeems to be the moſt efficacious; as we can clearly conceive of the active power of thoſe inſerted, and variouſly agitated Wedges; as the ultimate Elements of the Solvent are infinitely numerous; and as the Pores of the Solvend are diſtributed through every point of its Surface, as appears evidently from the fineneſs of the Particles when they come to be ſeparated.

Laſtly, a fourth cauſe that promotes mechanical Solutions, is Fire, For this it is that principally agitates, applies, and renews the application of the ſolvent Particles, whenever theſe happen to be qualified in the manner above-explained. This it is that, by its concurrence, puts the whole in action; without this the three other cauſes would be intirely without effect. A Wedge though it is fixed into a piece of Oak, has no manner of efficacy towards cleaving it aſunder, if the external percuſſion of the Beetle is not ſuperadded. And thus, tho' the Elements of the Solvent, in ſize, rigidity, figure, weight, and elaſticity, are perfectly ſuited to the pores, reſiſtance, and hardneſs of the Body to be diſſolved; though they are brought into contact with it; tho' they have one of their extremities fixed into it, whilſt the other part ſtands out above the Surface; I ſay, though all theſe circumſtances concur together, they will be able to induce no change upon the Solvend, unleſs the active percuſſion of Fire comes in to their aſſiſtance. Nor does Fire only act thus directly upon theſe *Menſtruums*, but it aſſiſts them, likewiſe, as it puts in motion and agitates the Air, which preſſes upon them with a prodigious weight, and thus applies their Particles to one another, by which concuſſion it produces an attrition upon the ſurfaces of the Bodies to be diſſolved. And hence the elaſticity, weight, and agitation of the Air excited by Fire, aſſiſts, likewiſe, the powers abovementioned; as does alſo concuſſion and attrition. This then, Gentlemen, is all that pure Mechanics can furniſh us with, that I know of towards underſtanding the actions of *Menſtruums*. This ſome Gentlemen, of great authority, have thought ſufficient to explain all the *Phænomena* that have ever been obſerved in their Operations. But, with ſubmiſſion, though we are ready to acknowledge, that in all the actions of every kind of *Menſtruum* whatever, all theſe mechanical powers are preſent, and do aſſiſt and co-operate; yet ſtill we cannot for this reaſon allow, that they alone, without the concurrence of any other cauſe, are capable of perfecting the whole Operation.

The fourth.

Nay, on the contrary, we take the liberty to aſſert, that it very ſeldom happens, that any *Menſtruum* whatſoever acts with all its energy, by the aſſiſtance of theſe cauſes alone. And this we think is ſo evident to an unprejudiced inquirer, that the incomparable *Newton* was obliged, from the obſervations he had made, to add ſome others of a quite different nature. But that the Geometricians may not charge us with aſſerting this raſhly, and without ſufficient grounds, let us examine the matter a little deliberately. When a Body, then, is immerſed, and is at reſt in a Fluid, endued only with mere mechanical properties, and this Body has no power, with regard to this Liquid, but a common mechanical

Mechanical force alone not ſufficient.

mechanical one, what mechanical Operation will then naturally follow? Why the fluid Matter being at rest, will, from its weight, and the subtlety of its parts, surround and compress both the external surface of the Body, and the internal one of the Pores, which it is capable of penetrating into. And hence, according to the laws of Hydrostatics, the consequence will be nothing more than a bare compression of the parts, without any division, or so much as the least alteration of its figure; unless the Body should happen to be soft, and yield but little resistance, and at the same time should have its Pores full of a Fluid lighter than the surrounding one, and capable of being condensed or expell'd; for then, the Mass being condensed, would have its figure, bulk, and specific gravity altered, and by this means would rather come to a more settled state of rest, and cohesion, than to one of dissolution. But suppose, now, that by the application of Fire, the Elements of the *Menstruum* were put in agitation, why then, too, if both the Fluid and Body immersed, considered separately, are homogeneous, the effect of the *Menstruum* will be pretty nearly the same; for the Fire acting equably upon all the Elements of the Fluid together, will still continue to press the Body equally on all sides. When it is raised, indeed, to such a degree, as to make the Fluid boil, and produce those unequal and explosive motions that are the consequence of it, it may then, by these irregular percussions, rub off somewhat from the surface of the Body, especially if any Particles happen to stand out above the rest. But this, now, of how little consequence it can be of in the Solutions we daily see performed by *Menstruums*, every body that knows any thing of the matter must easily conceive; especially if we consider, that Hartshorn will not be so much dissolved by being boiled for a long time in Water, in which it is every way surrounded, as it will by being suspended in such a manner, as to be exposed to its Vapour; as the alchemistical solution of Hartshorn evinces. But then let me caution you, that if any Matter contained in the Pores of the Solvend should be dilated by the Fire, disploded in Bubbles, and so break through the inclosures where it was confined, and thus divide the Body, this solution must not be ascribed to the mechanical action of the *Menstruum*, but to the rarefying force of the Fire acting upon this elastic Matter. Whilst I have seriously weighed all these things, I have frequently doubted with myself, whether the Air itself, in which are Oils, Salts, and Spirits, or any other *Menstruum*, whether fluid or solid, ever operates in their solutions of Bodies by pure mechanical Principles; especially considering that they themselves are scarcely ever simple and perfectly pure: And upon examination I have found, that there are intermixed with them all various parts of different powers, which have their proper and peculiar vertues, by which they attract, repel, and change Bodies after various manners. Whoever, therefore, ascribes more to a mechanical power than the All-wise Creator has allotted to it, is certainly in the wrong: This, as every thing else has its proper limits, within which if we keep, we shall act wisely, and may so far safely make use of this cause for explaining the Operations of the Chemical Art. These then, Gentlemen, are my sentiments upon this head; which the love of truth has drawn from me. How distant these are from the charge that has been publickly fixed upon me, that I pretend to explain all chemical Operations by mechanical Principles, you yourselves are judges. This certainly is imposing upon the World, and imputing to me me what is vastly different from my way of thinking, and what I constantly oppose, as, I believe, there is no man living less pleased with this opinion than myself.

Having thus, then, dispatched the Doctrine of *Menstruums* that act by a mechanical power, I come now to examine those which execute their office by some particular vertue, and do not operate by any of those qualities with which the Author of Nature has endued Bodies in general. And these, in reality, are so numerous, that there are scarce any that do not come under this head. It will be necessary, therefore, to digest this vast multitude into certain Classes, prefixing to each of them some distinguishing character, to which they may be reduced. And this method will have this evident advantage, that it will both assist the memory, and give us an opportunity of referring any new ones, that may be found out, to some that were known before, and thus, from the affinity of their nature, easily understanding the force of their action. Of *Menstruums* that act by a particular vertue.

Of WATER *and* WATERY MENSTRUUMS.

In the first place, then, I shall treat of Water, and watery *Menstruums*; which will make up the first Class.

Water, then, congealed with Cold, being mixed with dry or fluid Salts, volatile or fixed alcalious ones, volatile or fixed acid ones, and compound ones, as also with fermented vegetable Spirits, both dissolves, and is dissolved; and in this sense, therefore, why may it not be referred to solid *Menstruums?* This it does in the most intense cold, and always by this means excite a geater degree of it. See p. 97. and following, where this affair has been handled already, and therefore may be here properly omitted. Ice a *Menstruum*.

The proper dissolving action of Water, however, strictly so called, begins then, when this Element continuing still in a state of fluidity, is in the very next degree to freezing. This, therefore, according to our former observations will be, when *Fahrenheit*'s Thermometer stands at about 33 degrees; for then a hoar-frost begins to be formed in the Air. But that great Mathematician *Romer*, during the severity of the Winter 1709, is said to have observed at * *Gedanum* the same Thermometer, of which he himself was the first inventor, fall from the freezing point 33 to the degree 1; and consequently the Cold had then increased 32 degrees beyond a freezing one. But as this place is in 40 degrees North Latitude, and therefore 50 degrees from the North Pole; as the cold always grows greater and greater, the nearer you approach to the Pole; and as no body has ever yet been able to get thither, the excessiveness of the Cold proving fatal long before one can come near it: Hence we certainly know, that the Cold about the Pole must be greater than any that has ever yet been observed, though to what degree it rises there it is not possible to determine. But rather when it is a Fluid.

This, however, which is sufficient for our present purpose, we may be absolutely sure of, that through the whole extent of Cold, from the degree 32 to those unknown limits, pure Water can never perform the office of a liquid Its force different in different degrees of Heat.

* If our Author means *Dantzick* here, which is the only place that I know of that this word signifies, that lies in about the latitude 54, and, consequently, but 36 degrees from the Pole: This does not at all, however, invalidate the force of the argument.

Menstruum.

Menstruum. But as Water, now, by the application of Fire to it, may be heated to 214 degrees; hence its action, as it depends upon Fire, may be so far increased, but no farther, so long as it is upon the surface of our Earth, and exposed to the open Air; for under these circumstances it is not possible to give it any greater degree of Heat. If we remember, however, that Water is capable of receiving so much more Fire into it, as it is compressed with a greater weight of the Atmosphere, then we may clearly conceive, that the power of Water, when increased by Fire, in the deepest recesses of the Earth, may be so immensly great, that its dissolving force thus augmented may be greater than that of any other *Menstruum* that we are here acquainted with. But be this as it will, this we are sure of, that Water with us, as Water, has its dissolving power confined within 32 and 214 degrees of Heat.

But limited. To the very great happiness, therefore, of the present age, we are able to measure the power of Fire upon this first *Menstruum.* And here it is very entertaining to take a view of the various methods of Nature's working in these different degrees of Heat; for in many solutions performed by Water, its dissolving power increases in proportion to the Heat to which it is exposed, and remits, and grows less again, as that is diminished. Thus we find, for instance, that Water 33 degrees hot will contain a certain quantity of Sea Salt dissolved in it, which, thus residing in it, will prevent its being frozen with that degree of Cold, in which pure Water begins to be congealed; for the interposed Salt seems to hinder the Surfaces of the Particles of Water coming into contact with one another: But if the Cold comes to be increased much above the degree in which pure Water freezes, then the salt Water likewise begins to be reduced into a less space, and the Salt, being pressed out by the contracted Water, begins to collect itself into little chrystalline Grains at the bottom of the Vessel. And if afterwards the Cold grows gradually sharper and sharper, the Water will by degrees discharge more and more Salt, till at last, being pretty nearly freed from it, it will be intirely converted into Ice: And here, in every degree of this increasing Cold, there will be more Salt separated from the Water than there was before. On the contrary, now, if in Water 33 degrees hot you dissolve as much Salt as ever it will take up, and then increase the Fire till you make it boil, throwing in a few grains of Salt upon every new degree of Heat, you will then find, that it will gradually dissolve more and more Salt, till the Brine begins to boil, but then will dissolve no more, though you keep it boiling for a considerable time. In the former case too it should be added, that Water which discharges its Salt by means of Cold, and then freezes, when afterwards it comes to be thaw'd, will dissolve again the same Salt that was separated from it.

As appears by Experiments. But that you may have ocular demonstration of the truth of this, please to attend to the following experiments. In the first place, then, I take an ounce of pure dry Sea Salt reduced to powder, which I put into this clean glass chemical vial, and then pour 3 ounces of clean Water gently down the sides of the neck, and set the Vessel by in the degree of Heat which the Thermometer at present stands at. In this other Vial I have exactly the same quantity of Salt and Water as in the former, and hold it in the same degree of Heat, but this I shake very briskly about, adding now and then a small quantity of Salt, till it won't dissolve any more. This third Vial, likewise, is furnished with Water

and

and Salt, as the other two. In this brafs Kettle, now, which is upon the Fire, and has Water in it, I put the fecond Vial which contains the Water and Salt diffolved by concuffion; and this third, which was not fhook at all; and by gently increafing the Fire gradually heat the Water. You perceive, now, evidently, that as the Heat grows greater and greater, the Salt in the Vial that was not fhaken, begins to be more and more diffolved, and that much fooner, and in a much greater quantity than that is in the firft Vial, which I fet by in the prefent heat of the Air: So that now, within a fhort time, the diffolution of the Salt in this vial which is at reft, is equally effected by the application of Fire to it, as you faw it was before in the fecond cafe by fhaking the Veffel. But into this Vial, now, which has the Salt diffolved by concuffion, as the Heat gradually increafes, I continually throw in a few grains more of Salt, and this I continue to do till the Water in the copper Veffel begins to boil; and you fee there is now a confiderable quantity of Salt diluted in this Water, befides what it could diffolve, when the Vial was fhaken about, though it was agitated very ftrongly. Having thus, then, thrown into this Vial, ftanding in the boiling Water, fo much Salt, that the Water in it will not, in that degree of Heat, diffolve the laft Grains I put in, I now take out the Vial with its Water thus faturated with Salt, by means of the Heat of the boiling Water, and wiping it clean, fet it by, that it may gradually cool. As the heat of the Water, now, decreafes, the Liquor which before was pellucid, begins, you perceive, to grow opake, and turbid, a Pellicle forms itfelf upon its Surface, the Salt is precipitated to the bottom; and now it is reduced to the temperature of the furrounding Atmofphere, it has difcharged almoft as much Salt as it had diffolved more in the Heat of the boiling Water, than it had in the external Air. Having thus, then, obferved thefe Experiments, pleafe now to turn your eyes to the firft Vial, which I fet by with 3 ounces of Water, and 1 of Salt. And here you fee part of the Salt is diffolved at the bottom, whilft a confiderable part of it remains intire, as before. And that part which is thus diffolved is not mixed with the Water, but continues at the bottom of the Glafs, in form of a heavy, pinguious, and, as it were, tenacious Liquid; and if it is not fhook, will continue in that manner for a long time. If you fhake it about, however, it diffolves in the appearance of little Eels, and becomes difperfed through the incumbent Water, nor ever feparates from it again, and fubfides to the bottom. This, now, being thus fhaken from the bottom, another portion of the Salt is diffolved, and keeps at the bottom too as the former did, till it is agitated and mixed with the Water that is lefs falt, and fwims at top of it; and the operation will be found to proceed in the fame manner, till almoft all the Salt that was put in is diffolved in this quantity of Water. In order, now, to make thefe Experiments, you fee I have made ufe of two glafs Vials, whofe necks are fo long, that nothing could exhale from the Brine in the belly of them, whilft they ftood in the boiling Water; which is neceffary to be obferved: And you took notice, that I heated thefe necks, left being expofed cold to the hot Vapour of the Water, they fhould fly to pieces.

Corollaries hence deducible.

If you pleafe, now, we will take a view of fome of the *Phænomena* which offer themfelves to our obfervation in thefe fimple Experiments, and which deferve to be properly confidered. 1. Then it appears hence, that neither the Particles of the Salt, or the Water, are any ways changed in this Operation, but that they are only so united together, that the Water is now come into contact with the Salt, in the same manner as the Elements of the Salt and the Water, separately considered, were in contact with one another; which kind of solution is called mere mixture. 2. That the Heat, in proportion to its Strength, increases the mixing power in such a manner that both the Solution is performed quicker, and a greater quantity of Salt is dissolved in the same quantity of Water; and this is constantly the case, so long as the Water is capable of admitting any farther degrees of Heat. 3. That aqueous *Menstruums*, which are perfectly saturated with Salt, if they are afterwards exposed to a greater degree of Cold, grow turbid, and deposite some saline Corpuscles; but upon being restored to their former Heat, recover their transparency, and dissolve again the Salt they had discharged. 4. That the Water is condensed by Cold, and the Salt dissolved in it compacted into chrystals, which melt again upon the return of the Heat. And this is true, to such a degree, that even Oil of Vitriol itself, that is perfectly dephlegmated, will continue fluid in a Vessel accurately stopp'd, but by an increase of Cold will be condensed into a solid Mass, which in a warm Air will dissolve again spontaneously. 5. That boiling Water, when it is thoroughly saturated with Salt, is heavier than that which is pure. Hence it comes to pass, that this Brine, whilst it is boiling on the Fire, appears by the Thermometer to be hotter than simple boiling Water. And hence, if a glass Vessel, with this Brine included, is set in boiling Water, the Brine can never be made to boil by the heat of that Water, but requires a greater degree of Heat before it will discover any signs of ebullition; tho' if pure Water was thus put in boiling Water, that likewise would boil immediately, as you have had the pleasure of seeing. 6. So far, therefore, the cause by which Water is a solvent *Menstruum*, is Fire, of which being deprived, it ceases to act. The truth of this, conglaciation evidently evinces; for this beginning at the degree 32, and descending 72 degrees lower (p. 100) the Cold through all the degrees of that decreasing Heat more efficaciously expell'd almost all kinds of Salts dissolved in the Water, and that to such a degree, that even Spirit of Nitre itself became concreted into icy Glebes. Hence, then, we evidently demonstrate, that as Cold gradually increases, it in proportion separates Salt more accurately from Water, and expells it perfectly when it comes to be thoroughly frozen. The same cold too deprives Water of the power of dissolving Alcohol; for in the Winter of the Year 1729, I exposed Ale, Wine, Vinegar, and Brine, in large flat Vessels, to that severe Cold, and the Frost reduced almost all the Water of these Liquors into a soft, spongy kind of Ice, and united the strong, generous Spirits into one Liquid; so that piercing the icy Crust, one might pour out a fragrant, and very sapid Liquor, now separated from the Water, with which it was before diluted. And the more intensly the Cold was increased, this separation was constantly so much the greater. Cold, therefore, deprives Water of that property of a *Menstruum* by which it dissolves Alcohol and acid Salts. And it is exceeding probable, that the greatest Cold, possible in nature, would condense Water into such a Body, as would have no dissolving power at all; but such a Cold as this we are not acquainted with. 7. Hence we see, seventhly, that the proper power of Water, by which it is capable of dissolving Salts, or any other Bodies, and keeping them dissolved in it, and united with it, is not of itſelf ſufficient for this purpoſe, but abſolutely requires the aſſiſtance of Fire to be able to retain them in a ſtate of ſolution. 8 What has been delivered, if it is applied to the animal Fluids, the human in particular, will be of excellent ſervice to us, tho' it is but very little attended to. For among all the Fluids that are obſerved in a ſound Body, Water is the principal, and much the greateſt in quantity, and is always found intermixed with every one of them without exception. In this, therefore, the Elements of all the other animal Humours are diſſolved, and circulate together with it, and are kept by it in a proper ſtate of fluidity. And hence does it not evidently appear, what ſurprizing alterations this Water, which is ſo obnoxious to Cold and Heat, muſt induce upon theſe Humours? Examine the Blood drawn out of the Veins, and how wonderfully do you find it changed from itſelf by only being expoſed to a gradually increaſing Cold? Obſerve this Urine, which was made but a few hours ago by a healthy man that was faſting, and yet you ſee, in this cold ſeaſon, it has already depoſited a thick ſediment at the bottom of the Urinal. But pleaſe to attend, now, whilſt I gradually heat this Water over the Fire; and you perceive it diſſolves the *Fæces* that were ſeparated from it, and that in a ſhort time it becomes juſt the ſame as when it was made. Hence, therefore, let us learn, what conſiderable alterations may be brought about in the living Body, by the variation of the heat of the Water contained in it. And whilſt we are upon this head, I can hardly help abſolutely inferring, that the diſſolving Power which Water has as a *Menſtruum*, always increaſes exactly in proportion to the augmented Heat, till it comes to a ſtate of ebullition: This all the Obſervations we have propoſed confirm the truth of.

The power of Fire in Water various.

But how dangerous is it, to pleaſe one's ſelf with generals in Phyſicks, to recede ever ſo little from Experiment, or too haſtily to come to concluſions? For there are other Experiments, and thoſe not a few, which would induce one to believe, that the diſſolving power of Water decreaſes in proportion as its Heat increaſes; an undeniable demonſtration of which I ſhall now exhibit to you. In this Urinal I have ſome clean Water warm'd to the heat of the human Body. Into this I throw theſe Balls made of wheaten flower, work'd with Water into a ſoft, tenacious Paſte; and don't you obſerve how they melt, are diluted, diſſolved and mixed with the Water, and render it turbid? Into this other Urinal, now, which ſtands over the Fire, and in which the Water boils, I put ſome more of the ſame Balls; and theſe you perceive do not diſſolve, but on the contrary, though they are thrown about by the force of the boiling Water, grow hard, nor have any of their Corpuſcles beaten off. But again, with this Water, warm'd as before, I mix the white of a new-laid Egg; and you ſee it diſſolves, and when it is diluted in the Water, diſappears: But now as I make the Water gradually hotter and hotter, it begins, you perceive, by the Heat of this Water now in a greater motion, to be formed into fibrous concretions, and at laſt grows totally hard. Here, therefore, you have an ocular demonſtration, that upon increaſing the Heat from one certain point, the white of an Egg begins to harden, and grows continually harder and harder; and yet, from a certain limit of Cold, to that degree of Heat in which the coagulation firſt appears, upon every freſh addition of Heat, it is more and more diluted. The ſame thing holds true in Dough, our Blood, and that of other Animals.

Substances soluble by Water in every degree of Heat. First, Salt.

Hence, therefore, we must reduce into Classes those Bodies which are always certainly dissolved by Water, in every degree of Heat that can be communicated to it. Of this kind, then, are 1. All *Sal-Gems*, Fountain Salt, Sea Salt, Nitre, and *Sal-Ammoniac*, as well the *Cyrenaican* and *Ægyptian*, as the factitious. 2. All pure, volatile, alcaline Salts, whether spontaneously produced by putrefaction, or artificially procured by distillation, from Animals, or Vegetables. 3. Every kind of fixed alcaline Salts prepared from Vegetables by burning them. 4. All sorts of acid Salts that are naturally generated, either in the vegetable, or fossil kingdom. And to these we must add all vegetable Acids, procured by a proper fermentation, when by this fermentation there is a production of Spirits, and particularly when by a double fermentation those Spirits are prepared, which are commonly called Vinegar. And again, hither must be reduced those Acids, which by distillation are procured from most kinds of Woods, hard and ponderous ones in particular, as Oak, *Guaiacum*, Sassafras, and the like; as likewise all Vinegars, which, by distillation, have acquired the name of distilled Vinegars. The condensed Vapour, too, of burning Sulphur belongs properly to this Class; as well as that Acid which by a very strong Fire is drawn from Alum, Vitriol, Nitre, *Sal-Gem*, and Common and Fountain Salt. 5. Compound Salts, artificially produced by combining together alcalious and acid Salts to a perfect saturation. And these are very numerous, on account of the variety of the fixed, volatile Alcali's, the great number of vegetable and fossil Acids, and the diversity even of those of the same kind. But though all these, now, thus prepared, will dissolve in Water, yet let me caution you, that among these, that which goes by the name of vitriolated Tartar is dissolved by it with the most difficulty, and will very quickly again harden in it into a solid form. 6. Those singular and surprizing Salts, the Borax's, may likewise be diluted in Water, but not easily, and not without a large quantity of Water, and a strong Heat continued a good while; and hence, if either the Water is lessened, or the Heat abates, they presently form themselves again into solid Masses. 7. Native, vegetable Salts, produced from their Juices, by dilution, filtration, inspissation, and then letting them stand a good while quiet, as the essential Salt, as it is called, of sorrel, and others; all which are so easily dissoluble in Water, that they can scarcely be kept from melting of themselves. 8. And lastly, the Salts of Vegetables, which are generated from Wine, or the Juices of Plants perfectly fermented and depurated, adhere to the Casks, and go by the name of Tartars. These, if they are pure and hard enough, will continue dry in the Air, nor will dissolve in their own Wines. In Water they are diluted with difficulty, not without a great Heat, and twenty times their weight of Water; and as soon as ever either the quantity of Water, or the Heat necessary to keep it boiling is diminished, they immediately run into little solid Glebes. But except Borax, Nitre, Tartar, and vitriolated Tartar, all the other Salts will not only dissolve in Water, but are in their nature so averse to being kept dry, that they even run with the Water they attract out of the common Air; the pure acid Salts, and the volatile and fixed Alcaline readiest of all. As for the acid ones, certainly, it is exceeding difficult to exhibit them pure and dry, nor can it be done, except when it is vastly cold. And when you take fixed alcalious Salts out of a melting Fire, if they are exposed even to a dry Air, as soon as ever their Heat abates a little, they immediately grow

damp

damp with the moiſture they draw out of it. Hence, therefore, it evidently appears, that theſe Salts have a ſecret power of attracting Water into their dry and bibulous Subſtance. In the action therefore of Water, by which it dilutes theſe Salts, there are two Powers, which ought carefully to be diſtinguiſhed from one another, conſpiring together, one of which diſſolves, the other attracts, and both in conjunction make up the efficacy of an aqueous *Menſtruum*. Here, however, we muſt not omit taking notice, that there are ſome Salts, which when they are alone, are vaſtly greedy of Water, and yet when they are combin'd together form a third, which admits it with a great deal of difficulty. What, for inſtance, attracts Water more greedily than Oil of Vitriol; or what parts with its Water harder than the Alcali of Tartar? And yet if you accurately mix theſe two together in ſuch a proportion, that the Compoſition ſhall by no ſign diſtinguiſh itſelf to be either acid or alcaline, you will then have a dry Salt that will diſſolve in Water but ſlowly. The ſame thing is obſerved to hold true in other ſaturated Salts, thus produced by combination, tho' perhaps in a ſomewhat leſs degree. But farther, in order to the perfect Solution of all theſe Salts, there is required a certain proportion of Water, which if you do not keep up to, there will be ſome Salt remaining undiſſolv'd at the bottom. And when Water, in a certain degree of Heat, is ſo thoroughly ſaturated with any particular Salt, that it will not diſſolve any more of it, yet this *Lixivium*, thus impregnated, will in the ſame temperature take in ſome other Salt of a different nature. Thus, for inſtance, if you put Sea-Salt into Water that is ſaturated with Nitre, you will find the Water will diſſolve a great part of it, tho' it would admit no more of the Nitre. And even then, when it is thus ſaturated with theſe two, you may afterwards add *Sal-Ammoniac* with the ſame ſucceſs.

Secondly, ſaline Subſtances.

In the ſecond place Water, as a *Menſtruum*, diſſolves all thoſe Bodies, which from the large mixture of ſome Salt in them, are called ſaline. All theſe contain one of the Salts abovementioned, which makes up the greateſt part of them, being intimately united with ſome other parts, which are neither Salts, nor of a ſaline nature, but belong to ſome other claſs of Bodies. To this kind we may reduce; 1. All natural *Sapo's* of Plants, which we have before taken notice of and explain'd. Of this ſort we there told you, are the ripe juices of all kinds of ſummer fruits whatever; in all which the Water, Oil, Salt, and Spirit of the Vegetables, are moſt accurately mixed and concreted together, and all which are readily diſſolv'd in Water. (See p. 39.) 2. Some ſingular concreted juices, different from the former, which are generated, and brought to perfection in ſome particular part of the Plant. Pulp of Caſſia, Manna, Honies, and Sugars, are referr'd hither. Theſe, indeed, may in ſome meaſure be reckon'd among the former, tho' they differ in the marks juſt mention'd, and evidently contain leſs Water. They are *Sapo's*, however, abounding in an Oil and Salt compounded together; and hence they are capable of being perfectly diluted with Water; even the Gums themſelves not excepted. 3. The more liquid juices of Vegetables, which circulate in their proper Veſſels through every part of them. Of this ſort are the Fluids that run from the inciſions made in the Birch, Walnut-tree, and Vine in the ſpring ſeaſon. All theſe, of which in different Plants there is great variety, are *Sapo's* too diluted with a great deal of Water; and hence are thoroughly diſpoſed

diſpoſed for a farther diſſolution in an aqueous *Menſtruum.* 4. All the humours of Animals hitherto obſerved, are very eaſily diſſolved in Water, except the fat alone. None of theſe native Humours, however, are more greedy of Water than the Bile, as I learnt formerly, when I endeavoured, with a gentle Heat, to inſpiſſate ſome of it freſh taken out of an Animal, in order to form it in Pills, and render it fit for keeping. But what was the conſequence? Why the Maſs ſpontaneouſly diſſolv'd in the Air. 5. All Soaps made of an expreſs'd vegetable Oil, a fix'd vegetable Alcali, and the igneous part of Quick-Lime, mix'd together by the help of boiling Water, and then by a proper coction inſpiſſated into one Maſs pretty cloſely concreted together. As likewiſe thoſe Soaps which are prepared from diſtilled vegetable Oils, compounded with a very acrid igneous Alcali, very dry, and very hot, made likewiſe with the ſharpeſt ſtony quick Lime: Theſe are made by ſimply mixing theſe Subſtances together, and then expoſing them in a low place to the open Air. To this head, likewiſe, belong thoſe very choice Soaps prepared in a more curious manner, from the pureſt diſtilled Oil united with a ſimple volatile alcaline Salt, without the admixture of any Water, and perfected by a gentle, cautious, ſecret, repeated Sublimation, which then produces a moſt excellent Medicine. And laſtly, thoſe artificial Soaps the moſt ſubtil of all, made by a proper combination of the moſt perfect Alcohol, with an exceeding pure volatile alcaline Salt. Theſe, if they are manag'd in a proper manner, are changed into a very volatile, ſaline, ſaponaceous, ſulphureous Snow, which generally, tho' improperly, is called the *Offa Helmontiana*, by *Raymund Lully*, (*Spiritus Vini acuatus Sale-Ammoniaco*) *Spirit of Wine ſharpened with Sal-Ammoniac.* To which likewiſe we may refer one more, which they prepared from Alcohol, and Tartar intimately united together, by ſome method which was kept a ſecret. In all theſe Soaps, Chemiſtry is continually finding out ſome new, and very efficacious *Menſtruums*, which are uſed very ſafely to excellent purpoſe in the healing Art. Now this is particularly remarkable in theſe, that tho' Oils, when they are alone, won't admit of a union with Water, yet they will be diſſolv'd by it when they are thus combin'd with Salts. Salts, when they are by themſelves, attract Water; and ſo they do Oils. Hence, therefore, we learn the methods by which Oils may be diluted in pure Water. 6. To theſe ſaline Bodies may be referr'd, ſixthly, with regard to an aqueous *Menſtruum*, Vitriols as the Chemiſt calls them, or Chryſtals, which are generated, when the Solvent Salts, Acids in particular, divide Metals into their ſmalleſt Particles, and adhering to them very tenaciouſly, become concreted with them into little Glebes, which are intirely diſſoluble in Water, without any *Fæces* remaining, ſo long as they retain this true vitriolic form. Of this kind are the Mageſteries, Sugars, Salts, and Vitriols, as they are called, of Gold, Silver, Lead, Mercury, Iron, Copper, and Tin, whilſt they continue compounded of the acid Solvent, the Water, and the Particles of the Metals mixed together in ſuch a proportion, that they remain clear and pellucid, like Glaſs, or Chryſtal. The greater quantity now of the ſolvent Acid is added to the Metal formed into Vitriol, the eaſier always will it afterwards be diluted in Water. But if the Water is diſſipated from the Vitriol by a gentle Heat, ſo as to render the Glebules opake, then the metalline Particles preſently diſpoſe themſelves in ſuch a manner, that they will not be ſo eaſily diſſolved in Water

ter as they were before. Nay, if you continue to dry these Chrystals in this manner, they will at last not be capable of Solution at all, tho' they will still retain a considerable part of their solvent Acid. An evident instance of all this we have in Mercury. If you take an ounce of this Fluid, which is absolutely indissoluble in Water, dissolve it in an ounce and a half of good Spirit of Nitre, and then slightly inspissate it, you will have a Liquor which you may dilute with pure Water as long as you please. When you have let this Liquor stand quiet for some time, it will at the bottom shoot into Chrystals, which are exceeding caustic, whitish, and semi-pellucid, and will dissolve, instantly, and totally, in Water. Dry these now into a white, yellow, red, scarlet Powder, and then Water will not intirely dissolve them. In this respect, therefore, Water dissolves those Metals no further than with regard only to the Acid that adheres to the metalline Surfaces; and for this reason, the Water immediatly lets go the Metals as soon as ever they are by any means deprived of their Acid. Hence Metals, when they are dissolved in Acids, and then plentifully diluted with Water, may be rendered potable, be received into the human Body, be there mixed with its Fluids, and act upon its Solids, and by this means bring about those effects which it is able to perform upon either of them. And the effects, indeed, of these, are frequently observed to be very considerable; as by their acid and metalline quality they act upon both these parts very powerfully. This efficacy, however, remains no longer than whilst they continue in this fluid form; but as this depends chiefly upon the adhering Acid, when that is remov'd, their potability or miscibility is destroy'd likewise, and they are converted into a *Calx*, and Powder. Hence, then, we understand, how long medicinal vitriolic Waters continue efficacious, *viz.* so long as a solvent Salt is able to keep the dissolved Metal diluted and sustain'd in a large quantity of Water; for as soon as by the inactivity or poorness of the Salt, they come to deposite an Ocre, they immediately grow flat and good for nothing. What now has been said of the action of an Acid, with regard to Water, will hold good likewise in Metals dissolved in alcalious Salts; as Copper, for instance, when it is dissolv'd in a strong Spirit of *Sal-Ammoniac*, gives a violet Tincture, but being again deprived of its Salt, is wonderfully chang'd, and turn'd into a dirty Powder. The same thing, likewise, is observed in those Solutions, which are performed upon Metals by native or compound Salts. Thus *Sal-Ammoniac*, or Sea-Salt, will by certain methods dissolve Metals in such a manner, that they will afterwards suffer themselves to be diluted with Water: And so long these likewise are capable of producing a great many effects in the human Body, but in such a manner, that here too their action is limited particularly to their solubility in Water. But as in every other part of Natural Philosophy, so here likewise, it is very difficult to lay down a general rule that will in all cases be found to hold good: For the Solution of Antimony, made with the strongest Spirit of Sea-Salt which adheres to the corrosive Sublimate of Mercury, called Butter of Antimony, is thoroughly saturated with an Acid; and hence, according to the Doctrine laid down, one would be apt to imagine, that it might be easily dissolv'd in Water; whereas, we find on the contrary, that if you pour Water upon it, the antimonial part turns immediately into an exceeding white *Calx*, which being fused with a ſtrong Fire, produces a very beautiful *Regulus* of Antimony, which cannot be diſſolved in Water by any Art whatſoever.

Thirdly, terreſtrial Bodies diſſolved in Acids.

But to proceed to thoſe Bodies which are purely terreſtrial. Theſe likewiſe, if they are firſt corroded by Acids, may be perfectly diluted in Water, and lie there ſo concealed, that the whole Liquor ſhall appear perfectly pellucid; and hence theſe too are capable of operating in this form. Take Chalk, for inſtance, when it is plentifully corroded by an Acid, and you may dilute it in Water at pleaſure. And, indeed, I ſcarce know any Earth that may not be diſſolved in ſome Acid or other, and under this change impoſe upon our Senſes. Hence, therefore, we may conclude, how little we can judge of the purity of Water, with reſpect to any Earth that may be contained in it, purely from its perfect tranſparency: Nay, the true ultimate Earths, produced from the Bones, Fleſh, Shells, and other parts of Animals, may be thus diſſolved in Acids; and therefore, all theſe too, may, in this ſenſe, be ſo far diluted in Water itſelf, and afterwards, by various methods, be recovered from it again.

Not Alcali's.

But tho' earthy Subſtances, when they are thus corroded by Acids become by this means diſſoluble in Water, yet we ſee on the contrary, that when they are intimately united with Alcali's, they are no ways capable of this Solution. This we ſee evidently in Glaſs, which is compounded of an Earth and an Alcali intimately blended together, whoſe union the cloſer it is, the leſs will Water be able to affect them. What a vaſt difference do we here find then in Earth, with regard to its Solution by Water, as it is corroded by one of theſe Salts, or the other? Alcali's diſſolve it more ſubtily into a fix'd, pellucid, very hard Subſtance, which ſo powerfully reſiſts the diſſolving power of Water, that there is no Subſtance, which in this reſpect, exceeds it. It appears to me, however, ſtill more ſurprizing, that the very ſubtil, volatile, alcaline Salts of Animals, ſhould by their union with an Earth, form a Maſs that will bear the action of boiling Water without being diſſolved: But the Stone that is generated in Animals is ſuch a Body, conſiſting of theſe Principles, and an Oil combined together. This, to the great unhappineſs of many poor creatures, in whatever part of the Body it happens to be formed, is capable of propagating itſelf, and increaſing in its magnitude; for it has a power of abſorbing and uniting to its Maſs, a Matter ſimilar to itſelf, from thoſe animal Humours which are neareſt to putrefaction, as the Bile, and the Urine, in which the Salts become almoſt alcalious; and theſe again lay hold of the fine Particles of Earth that are abraded from the human Body in the courſe of circulation, and thus by aſſociating with them, produce new ſtony Elements, and thus continually increaſe the terrible monſter.

Hence we learn the reaſon of the natural action of Animals.

Whilſt I ſeriouſly now conſider theſe things, I can't think but there appears an evident reaſon, why the All-wiſe Author of Nature, has made all the Elements of Animals, a very few excepted, of the aceſcent kind: For the acid Salts, by this means, predominating in the Stomach, diſpoſe the Nutriment to a much happier Solution than the contrary wou'd; as the hard parts of the Food for their coheſion depend principally upon an Earth, and hence wou'd by alcalious Salts be reduced with more difficulty into a liquid Chyle. But as ſoon as ever now the Chyle is prepared, and from this there is a matter to be ſeparated, that is proper for the formation of the Solids, then this aceſcent quality,

quality, neceſſary before in the Chyle, is intirely altered, and the Salts become of an alcaleſcent nature, which, uniting with the terreſtrial Elements they meet with, compoſe a Maſs not diſſoluble in Water, but fit to contain and keep the Fluids within their proper bounds. Bones, we experience, if they are immers'd in alcalious Fluids, retain their firmneſs; whereas, if they are kept in Acids they grow ſoft, even ſo far as to become flexible, as the great *Ruyſch* told me he had often taken notice of in his anatomical Inquiries. This, it is certain, is very evident, that when the power which the human Body has of converting Acids into Alcaleſcents, comes to fail, then the Bones, Cartilages, and Teeth, become lax, weak, ſoft, and flexible; as in ricketty Children, in particular, falls continually under every ones Obſervation. Hence may Surgeons and Phyſicians learn, how imprudent it is to make uſe of the ſharper Acids for whitening the Teeth; for tho' they flatter us with a preſent beauty, yet the Teeth by this means ſoon grow inſenſible, looſen, and drop out. How much better, therefore, for this purpoſe are the milder *Lixiviums* of fix'd Alcali's well diluted, by which the earthy Particles of the Teeth will be no ways injured.

Fourthly, Sulphurs united with Alcali's.

After theſe, Sulphurs offer themſelves next to our Examination, which tho' they are abſolutely indiſſoluble in Water, ſo long as they are alone, yet ſuffer a perfect ſolution in it when they are intimately united with Alcali's. And hence again we may beſt underſtand the nature of ſulphureous Waters; for what I obſerved to you before concerning metalline medicinal Waters, holds true here likewiſe. But volatile alcaline Salts alſo, can ſo reſolve Sulphurs, as to render them capable of being diluted with Water: And hence it is evident, that Water aſſiſted by Alcali's, may be able intirely to diſſolve Sulphurs. And as this happens often in thoſe Sulphurs that lie intimately concealed within Metals, and Semi-metals, by this means, tho' before they were latent, they then come to light, and diſcover themſelves openly. And hence it comes to paſs, that ſuch Preparations, which are trifling to Perſons acquainted with theſe things, are ſold about for the profoundeſt *Arcana*: And in this manner even Princes themſelves have been impoſed upon. Thus we ſaw a Liquor prepared from Antimony, ſold under the grand Title of a *Panacea*. A few drops of this taken in a glaſs of Wine, was immediately to cure diſeaſes without any ſenſible effect: And, indeed, in ſome caſes it was of ſervice. But theſe ſecrets, when they come to be known, generally loſe all their reputation, and theſe monopolizers no longer enjoy the gain of their boaſted myſteries. After a proper Examination of the matter, I found this to be the Preparation. Upon native Antimony, reduced by long rubbing to a very fine Powder, pour twice the quantity of Oil of Tartar *per deliquium*, or the Alcaheſt of *Glauber*; then digeſt them together in a tall Bolthead for a conſiderable time, and pretty hot, and the liquid Alcali will gradually diſſolve the Sulphur that lay concealed in the Antimony, and thus will extract a red kind of a Tincture, which has an igneous taſte, a diſpoſition anti-acid, is heating, aperient, diuretic, and diaphoretic. But to confeſs ingeniouſly, one may at once have as good a Medicine, by boiling common powder'd Sulphur in a *Lixivium* of a fixed acrid alcaline Salt; as this Sulphur is perfectly of the ſame nature with that in the Antimony; and as the metalline part of the Antimony is no ways affected by the Alcali. If you take powdered Antimony too, and according to art manage it with an alcaline Spirit, prepared from *Sal-Ammoniac*, you will thence likewiſe procure a golden ſulphureous Tincture, as formerly the illustrious *Boyle* plainly made appear, that such a one might be prepared with simple Sulphur. But to what purpose is it to discover these cheats? Mankind love to be deceived; the rich frequently don't value things except they pay for them; and as for avarice, and extravagant pretensions, there's no pretending to restrain them.

Fifthly, the most tenacious Resins.

Those Bodies, likewise, that consist of so tenacious a *Gluten*, that they absolutely resist the power of Water, may nevertheless, by being intimately united with either fixed or volatile Alcali's, be brought to be intirely dissolved in it; for by this means they lose their tenacity so repugnant to this Element, which they then admit betwixt their separated Particles, and so suffer themselves to be diluted by it. And hence we observe, that the putrified Urine of Animals, the *Fæces* of burnt Wine, all sorts of Soaps, Bile, Honey, Sugar, and the Yolk of Eggs, if they are mixed with these Bodies, make such an alteration in them, that they afterwards become dissoluble in Water; so that the power which Water has of washing and scouring, depends almost upon these alone. To this head belong Oils, Balsams, Colophonies, Resins, and Gum-Resins, all which at last come by this means within the reach of the efficacy of Water, tho' they were perfectly indissoluble in it before. These then, Gentlemen, are the chief things that occur to me concerning the power of Water, as a dissolving *Menstruum*, that I can honestly deliver to you as matters of fact; nor do I know any thing more upon this head, but what may be referred to what has been delivered. I am well enough acquainted with those things, which the top Masters of this Art have advanced in their Writings; but the love of truth, and that integrity which is the distinguishing character of a good Man, and which I wou'd endeavour to have a proper regard to, won't suffer me to lay them before you as true. For to deal honestly with you, I am in doubt myself, whether they have not attributed more to their inventions, than was really in them. But let that be as it will, for my own part, I confess ingeniously, that I never have been able to discover those singular *Arcana*, which they make such a boasting of. If you please, however, I'll just mention to you the Doctrine of *Van Helmont* upon this Subject; and that asserts plainly, that all Bodies are by the *Alcahest* alone converted into a Salt, that has perfectly the Weight of the former Body, and may be intirely dissolved in Water. If this was the case, it must necessarily follow, that the power of Water must extend universally over all Bodies: Nor, indeed, to those who suppose that all things were produced from Water, is it so surprizing, that all Bodies whatever should be resolved into Water, Fire alone excepted, which, perhaps, for that very reason, they suppose not to be corporeal. I observed to you, indeed, myself, when I was explaining the mechanical power of Water in Solutions, that this, tho' of so exceeding soft a nature, if it falls from high, will in time divide every kind of Body whatever into exceeding small Particles; but that these, when thus separated by the motion of the Water, continued afterwards mixed with it, I cou'd never understand. I mentioned likewise what Monsieur *Homberg*, a Gentleman of uncommon assiduity, and undoubted veracity, has told us concerning Water's dissolving all sorts of Metals by being rubbed with them: But I cautioned you at the same time, that the Air had a free communication with them, which always makes an addition of almost every kind of Salt, especially in the Laboratories of the Chemists. For my own part, Water seems to me to furnish only a Vehicle for the Elements

of

of Bodies, by which they may be capable of entering into Animals and Vegetables, and there be mixed and applied, and bring about whatever is necessary, either for the support of their life, or increase of their magnitude: If this alone is wanting, the whole remains a dry unactive Mass. And this seems to be the extent of its power.

The Doctrine, then, of Water, as a Solvent, being thus laid down, it will be necessary to say very little of watery *Menstruums*; as it would be almost only repeating the same things over again. A few Observations, however, which perhaps deserve to be taken notice of, I shall here subjoin. Aqueous *Menstruums*.

Hail falling in Summer time, after great Heat and Thunder, and catched in a clean Vessel, has a different power from any other Water whatever; for this, of all Water, is the purest, as it was carried to a vast height in the Air, was congealed in the upper Regions of the Atmosphere, and thus in a solid form descended to the Earth. Hail.

Snow that falls in Winter, when it is exceeding cold, and there's no Wind, if you collect it in a high sandy desart place, and take it just from the top as soon as ever it comes down, produces the purest Water next to Hail. Snow.

Dew is a confused mixture of a great many things together; for in this are aqueous, spirituous, saline, and oily Vapours, and dry Exhalations of every kind whatever. And on this account it differs prodigiously from every other aqueous *Menstruum:* For it is generated only after a long continued Heat has scorch'd up the Earth; and consequently, when the Rays of the Sun, by their great strength, have carried up into the Air Particles more fixed than those of Water, which afterwards, when the Heat begins to abate, descend again upon the Surface of the Earth, Water, Plants, and Animals, and fill the dry and parched ground with a fresh supply of moisture. And hence, as I told you before, the virtues of it can scarcely be determined, or reduced under any head. And indeed it is a collection of such different Principles, that I don't wonder many persons should have imagined that there lay concealed in Dew, the latent Matter of a universal Salt, from which might be produced a Salt, which they call'd (*Congelatus mundi Spiritus*) *The congealed Spirit of the World.* But I pass by these things, to proceed to the other *Species* of *Menstruums*, adding nothing more than this one caution, that the Water in the Air very often performs the office of a *Menstruum*, where persons unwarily imagine, that the effects are owing to the proper efficacy of the Air. Dew.

Of Oils, and oily Menstruums.

Of the Character and Nature of Oils, I treated before, in the History of Animals and Vegetables, when I laid before you the different parts into which their compound fabrick might be resolved, p. 38, 43, and again, when I was examining the *Pabulum* of Fire, p. 175, 208, Oil then, to be considered now properly as a *Menstruum*, is a fluid Juice, or that may by a gentle Heat be rendered so, pinguious, inflammable when it is hot, and by no means miscible with Water. If any one imagines, that Alcohol ought to be ranked among the Oils, 'tis excepted only by the last property, as this will readily enough mix with Water: In all the other qualities of Oil, it perfectly agrees with it. All Oils, now, that have ever fallen under our Observation, are either native, as they exist in the Bodies they are generated in; or are prepared by Oils.

Art, the chemical one in particular, and then are always changed from their natural difpofition. Nor can we help making this diftinction between them, as on account of their furprizingly different efficacy as *Menftruums*, they are abfolutely diftinct from one another. Oils, then, or native oily Juices, are every where difcovered as fuch, both in the Foffil, Animal, and Vegetable Kingdoms: When Art, which makes fome alteration in them, is called in to feparate them from their proper repofitories, it effects this, firft by boiling pinguious Subftances in Water, by which means the Fat being melted, and freed from its confinement, rifes to the top of the Water, and may be there collected, not a great deal altered from its proper nature. A fecond method of procuring them, is by pounding the oily Subftances very well, and then putting them between two hot iron Plates, and with a Prefs preffing out the Oil. And in this cafe too, if you don't make the Plates too hot, the Oils will be very little different from the native. Sometimes they are feparated likewife by bare melting them; and then the Bodies that abound with the oily Matter, are gently torrified with a proper Fire, by which means their Oils and oily Subftances are forced out, and fo collected. This, in the Preparation of Pitch from the Coniferous Trees, is fufficiently evident. Upon this head the Treatife of *Axtius* deferves to be confulted. Laftly, thefe Oils are drawn from Bodies by Diftillation, and that either by carrying them up by the help of Water, or Fire alone; or drawing them off (*per latus*) obliquely, as in the retort; or determining them downwards, which is called *per defcenfum*.

That do not congele.

In thefe laft Oils, which for the future we fhall call diftilled Oils, it is almoft conftantly obferved, that they have never been found to have been frozen in the greateft degree of Cold, but have always retained their fluidity. But among the expreffed Oil, fome have been obferved to harden with a fharp Cold into a folid Mafs, compofed of little Spheres united together, as is fufficiently known in Oil of Olives, Rape Oil, and many more; whilft others, as we fee in Linfeed-Oil, won't congeal even in a fevere Froft. With regard now to this remarkable difference in thefe Oils, I have not, upon the moft careful Examination, been at all able to difcover what fhould be the caufe of it: I refer it therefore to fome fecret quality, which we are forced to acknowledge, difcovers itfelf only by Experiments, nor can be reduced to any known Law. It is a vaft happinefs, however, to mankind, that fuch a matter fhould have this property of continuing liquid in a moft intenfe Froft, which at the fame time, by means of a Wick once fet on Fire, is capable of fupplying us with light. But here we muft farther obferve, that the proper diffolving action of thofe Oils that will thus freeze, begins then only, when they are in the very next degree to congealing, but ftill appear in their liquid form: As therefore, fome of thefe Oils freeze fooner than even Water itfelf; hence their diffolving power is, with refpect to Cold, included within a narrower compafs than that of Water. Thofe Oils, on the other hand, that keep fluid in the greateft natural Cold, always retain their diffolving faculty. Hence, therefore, it appears at one view, that it is impoffible to fix any one certain point of Heat, from which the power of Solution of all Oils in common fhall begin; tho' this in any one *Species* of Oil may be nearly determined, when once it has been accurately obferved. If we confider now this property of Oils, how furprizingly do we find, that Oil of Linfeed, tho' it retains its fluidity in the fevereft

Froft

Froſt, has really at that time no more heat in it, than the hardeſt Ice, or any other frozen Oil?

But farther, if you apply Fire to Oil, and increaſe it very cautiouſly and gradually, when it comes to a heat of 212 degrees, which is that of boiling of Water, it is then very far from boiling. Water, now, when it once comes to boil, cannot, by the application of the ſtrongeſt Fire, have any more heat communicated to it; but Oil from the degree 212 grows gradually hotter and hotter, and before it boils is found to have admitted 600 degrees. No wonder, therefore, that boiling Oil ſhould be ſo much hotter, and burn more terribly, than boiling Water. But here, too, we obſerve, that all Oils, if they are expoſed to the ſame Fire, don't boil equally ſoon. Thoſe, for inſtance, that are lighter, and more ſubtil, boil eaſier, and acquire leſs heat; whilſt others take up more time, and grow hotter: Thus rectified Oil of Turpentine boils pretty ſoon; Linſeed Oil with more difficulty. Hence, then, we perceive how difficult it is to determine the power of Oil as a *Menſtruum*; for in Oil of Linſeed, for inſtance, this power begins at the greateſt degree of known Cold, and increaſes to the degree 600, and in every degree of increaſe it always acquires a new active vertue, and that, whether you apply it to the ſame Body in different degrees, or to different Bodies in the ſame degree, or different ones. In both theſe reſpects, therefore, you ſee there is an infinite latitude. But to make theſe things evident by ocular demonſtration,

Admit of a great deal of Fire.

In the firſt place, then, you ſee this braſs Kettle, which contains ſome pure Rain-water. Into this I ſet three Boltheads, as near as poſſible of the ſame ſize, and figure, and filled nearly to the ſame height, one with Alcohol, another with diſtilled Oil of Turpentine, and the third with Oil of Olives: And in the Water, with them, I place one of *Fahrenheit*'s mercurial Thermometers. I now apply Fire under the Kettle, and keep the Water continually ſtirring, that it may be heated as equably as poſſible. The Water in the Kettle, now, has at preſent acquired a heat of 175 degrees; and now you ſee the Alcohol in the firſt Glaſs boils pretty ſtrongly; this, therefore, I remove. The Water being kept frequently ſtirred, and growing hotter and hotter, has now arrived to the degree 213; and that you ſee, now, boils likewiſe; nor does the Mercury in the Thermometer dilate itſelf any farther, though, as you obſerve, I increaſe the Fire, ſo as to make the Water boil very violently. But the Oil of Turpentine, now, does not give the leaſt ſign of any ebullition in the ſecond Glaſs; nor the Oil of Olives in the third. Here, then, you perceive this ſurprizing difference: Alcohol, though a very ſubtil, inflammable Oil, boils a great deal ſooner than Water; Oil of Turpentine, which is ſo much lighter than Water, and pretty ſubtil too, is not at all put in motion with the heat of boiling Water, though this Oil is inflammable likewiſe; nor has the boiling Water more effect upon the Oil of Olives: Neither inflammability, therefore, nor levity, nor volatility, can be the occaſion of this difference, ſince Oil of Turpentine is ſo volatile, that it riſes in diſtillation with boiling Water.

This appears by one Experiment.

But pleaſe to attend to a ſecond Experiment. With the very ſame *Apparatus* as before, inſtead of Water, I have put in the Kettle the ſtrongeſt Brine of Sea Salt that can be procured by boiling Water. To this, now, I apply Fire, as in the other caſe, and keep the Brine ſtirring, too, in the ſame manner. You ſee, now, here again, that as ſoon as the Brine comes to be heat-

Another.

ed to 175 degrees, the Alcohol boils as before; which therefore I take away. The Thermometer is now risen to the degree 218; and now the Brine begins to boil, likewise; which, therefore, you perceive requires 5 degrees more to bring it to this state, than pure Water. The Thermometer, however, in this case, will still continue to ascend gradually a little higher; because in this strong ebullition the Water continually evaporates, and the remaining Liquid of consequence grows denser, which at last would be nothing but mere Salt. In this Experiment, therefore, when we have once observed the degree of heat at which the Brine begins to boil, it is sufficient. The Oil of Turpentine, in the mean time, and the Oil of Olives, discover, as yet, no signs of ebullition.

A Third. But to proceed to a third, which I shall perform with a great deal of caution. In this small Vial, the Bulb of which is of an equable capacity, and the neck pretty long, I have put some Oil of Turpentine, which fills $\frac{2}{3}$ of the Bulb. The whole Vial, now, both Bulb and Neck, I heat gradually and equably, lest otherwise it should fly when it comes near to the Fire. The Glass, then, and Oil being thus heated, I hold it over the clear Coals in this Chafing-dish, bringing it continually nearer and nearer to the Fire. Are not you surprized, now, that it don't yet begin to boil? But observe it, now it just touches the Fire, and you may perceive an ebullition: And you see, too, it don't boil gently, but vehemently; and at the same time makes a considerable noise. And though I have now removed the Vial from the Fire, you observe the agitation, noise, and ebullition, continue a good while in the Oil, though both Alcohol and Water presently cease boiling when they are taken off the Fire: But you'll want to know what degree of Heat this Oil acquired before it began to boil: This you may discover in the following manner. Take some Linseed-Oil, in a brass Vessel, place a mercurial Termometer in it, and the Vial with the Oil of Turpentine, and set it over the Fire; you will find, then, that the Oil of Turpentine in the Vial will boil a good deal sooner than the Oil of Linseed in the Vessel, and at the same time the Thermometer will indicate the degree, which, if I remember right, I found to be 560. As this Oil, now, in boiling sends off its more volatile parts, the *residuum*, which will be thicker, will require presently a greater heat to cause an ebullition. And this more difficult ebullition, and necessary communication of a greater Heat, will increase every moment, in proportion to the spissitude of the remaining Oil. Hence, therefore, it will not appear surprizing to the Physicians, that these thick Oils, when they are put in agitation, produce such a prodigious Heat; which Observation, if I am not much mistaken, is both exceeding beautiful and useful. But these agreeable speculations carry me beyond my purpose.

A Fourth. But to proceed to a fourth Experiment. I have here in this Vial some Oil of sweet Almonds fresh drawn, which, after all the cautions observed in the former Experiments, I at last set on the open Fire, till the Glass is ready to melt; and now you see the Oil begins to boil, not before. And the motion you perceive of this Oil, when it boils, is quiet, equable, and without noise, and continues so to the end; and yet the Heat of this is more than 600 degrees.

The quantity of Fire in Oils. From the consideration, now, of the Latitude in which Oils will bear the application and increase of Fire, which is almost three times greater than that of boiling Water, we very easily perceive, that the dissolving power of Oil, considered confidered as it depends upon Fire, muft be proportionably fo much greater in Oil than in Water. For as moft Oils retain their fluidity at the firft degree of heat in the Thermometer, in which Water begins to freeze at about 33; and as the compafs of Heat which Water can pafs through, whilft fluid, is but 180 degrees, *viz.* from its freezing point 33, to that of its ebullition 213, whereas from the firft degree of Linfeed Oil's fluidity to that in which it boils is at leaft 600: Hence it evidently appears, that the poffible power of the Fire in that Oil, is to the fame in pure Water, as 10 is to 3; which what mortal living could poffibly have difcovered a *priori?* But if we confider farther, that many Oils, when they are infpiffated, will take in ftill a good deal more Fire, we fee, that the power of Fire in Oils will be ftill farther extended.

In the mean time, however, this is moft certain, that if any of the parts, or the whole Bodies of Animals or Vegetables are accurately immerfed in Oil, they will keep them without alteration, fecure from diffipation, fermentation, or putrefaction; and they may be preferved in this manner, though the heat of the Air fhould be as great as has ever been naturally obferved. Infects, too, that are fo very troublefome in this particular, will be kept off, likewife, by the Oil that fwims at top; fo that by this means they will remain intire, as long as they are thus defended. And, indeed, when thefe fubftances have been fo long immerfed in Oil, that they are perfectly penetrated in all their parts, they then feem to have acquired an almoft incorruptible nature, and may be preferved a prodigious while. This appears evidently in Bodies that have been thus treated; upon which principle depends chiefly the art of embalming; of which by this means we difcover both the origin and efficacy.

The power of warm Oil upon Animals and Vegetables.

But when Bodies, now, are fuddenly thrown into boiling Oil, they prefently acquire a hard, and almoft ftoney Cruft over them, which is of the fame colour that they get by being expofed to the open Fire, *viz.* yellow, red, and at laft black. The other part, in the mean while, that lies under this Cruft, being agitated by the prodigious heat of the ambient, boiling Oil, and having its motion at the fame time repell'd, ftopp'd, and as it were fuffocated, is furprizingly altered, concocted, digefted, and maturated, and at laft grows confolidated, and is exceedingly well fitted for keeping a long time. But when the fubftances, that are thus immerfed in Oil boiling hot, are full of aqueous Juices, as Flefh or Fifh dried on the out-fide, then thefe humours being agitated under this Cruft, with more than a boiling heat, the parts grow very tender, retain all their juices, and become exceeding well fitted for digeftion and nutrition. And Meats thus prepared too, are very durable; for all the principles of Bodies, treated in this manner, being intimately united together, and helping to render one another more perfect, produce a fubftance fecure againft any inconvenience from external caufes.

The effect of boiling Oil upon the fame.

From what has been faid, then, we may by the way deduce fome truths, which one would fcarcely have expected. In the firft place, then, it appears hence, that the degree of heat which Fire is capable of communicating to Bodies, is not in proportion to the denfities of the Bodies heated. Secondly, that the fame Body, if it is gradually rendered denfer, will admit a greater quantity of Fire, in proportion to the increafe of its fpecific gravity. Thirdly, that a Body's being capable of taking in a larger quantity of Fire, does not depend

Corollaries hence deducible.

depend upon its combuſtibility. Alcohol, when it once comes to boil, admits no more Heat or Fire; nothing in nature is more combuſtible than Alcohol; and yet there is no Liquor that we know of, which will not receive more Heat than this. Here again, then, we ſee how difficult it is to come at general truths; and that the true properties of Bodies muſt be determined by an examination of the particulars. From theſe things, then, thus firſt demonſtrated, we may deduce a great many Corollaries, of which this is a remarkable one, that we may diſſolve ſome Metals intimately in ſome ſorts of Oils, ſo that by this means there ſhall ariſe a Mixture, which will not eaſily again be reſolved into its principles. By this Art there have been ſome valuable ſecrets found out, both in Mechanics and Phyſick, which we could not want, without a good deal of inconvenience.

Upon Metals.

But to return to our Experiments. A fifth, now, I am going to make before you, that I never exhibitted in this manner before. Into this Vial I have put half an ounce of *Minium*, and now pour on it an ounce and a half of Oil of Olives, which, by ſhaking, I mix thoroughly together. And you ſee I have made choice of the ſame ſort of Veſſel I made uſe of and deſcribed before, and have uſed the ſame caution in gradually heating it at a diſtance. I now hold the Bulb of it juſt over the Fire, till the Oil begins to boil, and you perceive, now, the Liquor is boiling hot, the powder of the *Minium* is diſſolved, mix'd with it, and compounded with it, into one Maſs. But at the ſame time, you obſerve, likewiſe, that this Mixture was not effected till the Oil was brought to a prodigious degree of heat, which the *Minium*, then, was no longer able to reſiſt. Hence, then, we learn how to prepare a Balſam of Metals, and a Cement, that will powerfully reſiſt Water. But a ſixth, which is a new one, likewiſe, and more ſurprizing, I perform in this manner. Into this Vial I have put half an ounce of Shot, and I now pour upon it an ounce and a half of Oil of Olives; and, with the ſame caution as before, ſet it over the Fire. Who, now, would have believed what we at preſent ſee? *viz.* that the Lead melts and runs, like Water, at the bottom of the Glaſs, though the Oil don't boil, nor ſo much as emit any Vapour. Hence you ſee Glaſs is melted with more difficulty than Lead. But now, whilſt I hold it in a ſtronger heat, and the Oil begins to boil, you obſerve, the Metal begins, likewiſe, to be diſſolved by it. Glaſs, however, you ſee, will not be diſſolved by Oil, let it acquire whatever degree of heat it is capable of. Hence, therefore, we ſee why melted Lead burns leſs violently than boiling Oil; and for this reaſon it will bear being handled immediately, if the perſon's hands are incruſtated over with a very dry Chalk. If any perſon, here, has a mind to imitate this Experiment, let me warn him to do it with a great deal of caution, or otherwiſe it may prove a very fatal one: For if a drop of Water ſhould any ways come into the Vial, it would all burſt to pieces, with a vaſt *impetus*, and bring the Operator into imminent danger. Let me warn you, likewiſe, that the Vapours which ariſe from boiling Oil are ſometimes of a watery nature, which being collected in the neck of the Glaſs, and trickling down again in form of drops of Water, would occaſion the ſame misfortune; for Lead in fuſion is vaſtly impatient of Water. A ſeventh Experiment let us make with Tin; of which I have here half an ounce, mixed with an ounce and a half of Oil of Olives, which, in the ſame manner as before, I ſet over the

the Fire. You ſee, now, the Tin runs like Water at the bottom of the Glaſs, and though I put it in, in Filings, it is collected into one Maſs. You perceive, likewiſe, that it now begins to be diſſolved and mixed with the Oil. But eighthly, and laſtly, I have here a compoſition of Lead and Tin mixed together in equal proportion, whilſt they were in fuſion. Of this Maſs I have taken half an ounce and poured upon it an ounce and a half of Oil of Olives. I keep it now upon the Fire, as before, till it boils. You ſee, then, the metalline Maſs melts and runs a great deal before the Oil begins to boil, and ſooner than either the Tin or Lead would have been melted alone. There are many more curious things of this nature, but I muſt proceed no farther upon this head, as I have been rather too prolix already.

Give me leave, however, juſt to mention a few things to you, that follow from what has been ſaid, and are worth taking notice of. Firſt, then, Oils are diſpoſed to receive and retain a great deal of Fire in them before they thoroughly boil. Secondly, there is not any one known Fluid in Nature, to which more heat may be communicated, than to Oil; for all *Lixiviums* and Oil of Vitriol boil ſooner, and grow leſs hot; Mercury, too, ſooner in ſome meaſure, or perhaps equally. Thirdly, Oils may be urged with a prodigious force of Fire, before they will be diſperſed into Vapours, and riſe out of the Veſſel in which they are contained. In the fourth place, Oils are capable of communicating their heat to the Veſſels in which they are boiled; and hence, tho' you may boil Water in a leaden or a tin Veſſel, yet you can't boil Oil in the ſame before they will melt. Fifthly, Oils communicate their heat to Metals that are put into them. Sixthly, it is not eaſy to give Oil a greater degree of heat than what it naturally acquires when it is made to boil. If any perſon has a mind to increaſe this collection of Fire in Oils, he muſt contrive ſome method to compreſs it in its Veſſel, with a greater force than that of the common Atmoſphere, and then, indeed, the heat will be augmented proportionably, as we took notice before in Water and Air. And hence we eaſily conceive, that if Oil, when in the deep receſſes of the Earth it is compreſſed by a vaſtly increaſed Atmoſphere, ſhould happen there to meet with any great Fire, it might conceive an immenſe heat. And if then, whilſt it was thus prodigiouſly hot, it ſhould chance to have Water break in upon it, what Earthquakes might be hence produced? Without doubt vaſtly exceeding all imagination: May any thing now of this kind poſſibly happen in Mount *Ætna*, *Veſuvio*, *Hecla*, and other *Vulcano's?* Certainly, amongſt other cauſes, this deſerves ſome regard with the Philoſophers. Seventhly, liquid Oils will not permit a greater heat to be communicated to the Veſſels that contain them, than they actually have in themſelves; and conſequently will prevent Fire's melting any Veſſel that requires more than 600 degrees of heat to effect it. And eighthly, and laſtly, here again we obſerve, that the wiſe Author of Nature has ſet limits to Fire, that in Oil, a Matter vaſtly inflammable, it might not grow inſuperably violent.

Corollaries hence deducible.

But farther, in explaining the diſſolving power of Oils, it is abſolutely neceſſary we ſhould add this conſideration, that the expreſſed crude Oils of Vegetables always contain ſome Water. This is evidently ſeen in expreſs'd Oil of Almonds, by boiling it in a Bolthead; for then the watery Vapour that ariſes, being ſtopp'd upon the Sides of the long neck, is there plainly collect-

Oils act by their Water.

ed in form of drops; and these afterwards running down again into the boiling Oil, produce a pretty extraordinary motion, noise, and crackling within the Glass. Hence, with respect to this latent Water, Oils act differently upon their solvend Bodies, in different degrees of heat; and the cracklings likewise that are produced during the ebullition make some variation in the solution. And for this reason, when by boiling a good while the Water is expelled, the power of an oily *Menstruum* is considerably altered, nor dissolves Bodies in the same manner as a crude one.

And their occult Acid. But those Oils, likewise, besides a Water, generally contain some subtil Salt, for the most part a volatile, acid one, which in many of them almost discovers itself by its Smell, and is of an exceeding penetrating nature. These Salts appear, and show themselves in form of acid Spirits, which collect themselves together like Water, separate from the Oil, nor will easily suffer themselves to be mixed with it again. It is not so easy, however, to disengage this Acid from its Oil; for if you take the native Oil that spontaneously oozes out of the Firr, Larch-Tree, or Pine, and gradually melt it over the Fire, then, from the beginning to the end, both in a small, and the greatest degree of heat, this acid Spirit will be separated from it; though at the beginning, indeed, with more ease, and in greater quantity. And the same thing holds pretty nearly, more or less, in the others.

And by both together. Whenever, therefore, the Chemist would accurately determine the dissolving power of these Oils, he must always first carefully consider, whether the effect performed by the Oil was not owing rather to the Water, or the Acid, than to the proper Oil itself; for otherwise we may be liable to run into very great errors. The Painters inform us, that those Paints that are dissolved in boiled Oil, are much readier taken in than those that are mixed with crude, and that the Paintings with the former dry pretty soon, whereas, those Colours that are mixed with crude Oil, lose more of their native beauty, and are a great while a drying. And in the same manner, that particular power, which the softest Oils are said to have, of dissolving Metals in a gentle heat, seems as if it ought chiefly to be ascribed to their latent Acid, and by no means to their true oily part. Thus, for example, if you mix the soft Oil of Olives, with a very fine powder of Iron, Brass, or Lead, and then digest them together for a good while in a gentle heat, part of the Metal will be dissolved and mixed with the Oil, will give it a colour, and often impregnate it with some remarkable vertue. But to suppose this to be the real dissolving power of Oil, as Oil, is to extend it beyond its proper limits; for when, by a continued ebullition, it is thoroughly freed from this adhering Acid, it then retains this power no longer. And thus the Polishers of Brass and Iron have long observed, that if these Metals, when they are polished, are exposed to the Air, they can't be kept from contracting Mould and Rust, by only rubbing them with crude Oil, though they may be very well secured by boil'd, especially if there is a little Ceruss, or Lead Ore, boil'd in it, by which all its acidity is absorb'd, and it is excellently well fitted to defend the beauty of such Bodies. And that there is in distilled Oils the same Acid the egregious *Hoffman* has demonstrated by an elegant Example, in his valuable *Physico-Chemical Observations*. p. 56. 57. Where, by rubbing distilled Oil of Lavender-flowers, and distilled Oil of Turpentine, with Salt of Tartar, he observes a neutral

neutral Salt to be hence produced, arising from this Alcali, and an Acid drawn out of the Oils. And lastly, even a gentle distillation of these Oils, will extract some Salt from them; as we see in Oil of Turpentine and Juniper, which being treated in this manner, yield something of an Acid.

And as for Oil distill'd from alcalescent, or putrefied Vegetables, or the parts of any Animal whatever, this abounds so plentifully with volatile alcaline Salts, that these are separated from them, in large quantities, by a gentle Fire, and appear in solid little Glebes, as white as Snow. If you would attempt therefore to explain the proper vertues of Oils, you must first carefully free them from all their Salts, and then, by examining them when they are pure, you may be able to judge of their vertues without danger of mistake. A volatile Alcali often in them.

But before we treat of Oils as *Menstruums*, it is still much more necessary and useful, to consider how long Oils do actually continue Oils. And here there occur many surprizing *Phenomena*: For Oils, either prepared with Water *per Vesicam*, or drawn with a dry Fire in a Retort, whether sweet-scented, or fetid, if they are cautiously distilled in a Retort to a dryness, the Vessels being kept accurately closed, they leave an Earth at the bottom, gradually lose their viscidity, and grow more subtil, fluid, and transparent. And if you repeat this operation to the fourteenth time, or oftner, you constantly have an Oil different from the former, and every time some remainder, till at last you thus procure a penetrating anodyne Medicine, mighty efficacious in some grand diseases: But every repetition, likewise, you have a different *Menstruum*. And hence *Van Helmont*, the Father, in his *Aurora Medicinæ*, published in *Dutch*, p. 188, by a repeated distillation of human Blood with Spirit of Salt, till no *Fæces* remain, thinks he prepares a diaphoretic Medicine, which like a *Menstruum* dissolves all those preternatural viscidities in the human Body, which often give rise to fatal obstructions. The famous *Hoffman*, too, confirms the preparation of such a Medicine, and highly extols it for its vertues. *Obs. Phys. Chem.* p. 59. And another Author, tho' less indeed to be depended upon, was bold enough to assert, that in such an Oil as this you have a universal Medicine. But these things the Chemists of former ages have given us an account of. And indeed this is certain, that from Oils treated in this manner, such *Menstruums* are procured as have an excellent and scarcely imitable dissolving power. Upon this head, *Raimund Lully* and *Isaac Hollandus* have given us whole processes, which are fully enough described, and deserve consulting. Simple Oils

And lastly, every kind of these Oils contains farther something vastly subtil, and volatile, which resides in them, but still may be separated from them: This we treated of formerly, under the title of the *Spiritus Rector*, or *Archæus*. This Spirit is active, odorous, sapid, the Son of Fire; and is the true cause of incredible effects. This being generated in the Oils, and held down, and retained in them, endues them with a singular vertue, very efficacious, and scarce to be found any where else: And hence, when it comes to be perfectly separated from them, it leaves them vastly less active, nor hardly any longer distinguishable from one another. And as from many of them it spontaneously exhales with a gentle heat, it soon mixes itself with the Air, and leaves them effete, and incapable of performing what they could before. Thus then I have said enough of Oils to enable us to come to a And a *Spiritus Rector*.

certainty about their effects, considered as simple and homogeneous. And, indeed, the dissolving power of pure Oils seems chiefly to consist in their being able to admit a prodigious heat into their substance, and communicate it to other Bodies.

What true Oils dissolve.

In the first place, then, Oils will mix with Oils; most of them with all others. Some, indeed, there are, that will not mix so easily, as appears in the distillation of Turpentine and Amber, where the Oils that rise in different degrees of heat, are found to be different in weight, thickness, colour, and situation, nor suffer themselves to be readily mixed together. The rest mix very easily. Secondly, true resinous Bodies melt, and are then sufficiently dissolved in Oils. As, thirdly, are most sort of Gums, especially if they have any thing of Resin mixed with them. Fourthly, Oils that are thicken'd, or, as they are called, Balsams, Tears, and Colophonies, are all diluted in Oils. As, likewise, fifthly, Sulphurs themselves, whether found naturally in the Mines, or produced by Fire, and that both liquid and solid; for these all suffer themselves to be dissolved by Oil, even though they lie concealed in other Bodies. Thus Antimony, if it is reduced to Powder, sublimed into Flowers, and then boiled with Oil, will in a short time yield a thick, red Balsam of Antimony, arising only from the Sulphur of the Antimony, resolved in the Oil, whilst the reguline part remains unaffected, but deprived of its Sulphur. And the same thing holds true, likewise, in other semimetals, that abound with Sulphur.

Of proper spirituous Menstruums, or Alcohol.

Alcohol among the secret *Menstruums.*

Those Alchemists, who were reckoned among the Adepts, throughout all their Writings make mention of Spirit of Wine. And this, when it was reduced to the greatest subtlety, they made use of, in the preparation of all their other secret *Menstruums*. This is evident in the *Circulatum* of *Paracelsus*. And for this reason, the indefatigable *Weidenfeldius* was induced at last to believe, that these Adepts have plainly enough described all their *Arcana*, except their philosophical Spirit of Wine, which, was it once come to be known, every thing would be sufficiently clear. Whether this, however, be really the case, I have reason to doubt; and, indeed, it is easy to make it appear, that the Spirit of Wine, which these famous Authors describe by its proper marks, is the very same that we have at present. This its subtlety; volatility; the manner of its preparation; its fragrance; the streaks that run down in its distillation; its burning away without any Water remaining; the burning of a Cloth wetted with that Spirit; its union with Salt of Tartar; its adunation into the *Offa Helmontiana*; the extraction of the subtil Sulphur of Animals, Vegetables, and Fossils with it; and lastly, its balsamic property of preserving Bodies, and securing them from putrefaction, abundantly demonstrate. Besides these properties, however, that we find in our Alcohol, these great men, I confess, ascribe other vertues to it, which at present we are not able to discover, as in particular its power of dissolving Salts: But then it still remains a doubt, whether this difference arisesfrom our not knowing the proper Spirit, or from our not knowing some secret, but necessary method of preparing these Salts. Let this, however, be as it will, it is certain, there is often in those things something very surprizing. Some of the top Masters in Chemistry have publickly declared in their Writings, that it is not poſſible to unite Alcohol with a pure fixed Salt; and no wonder: For if the leaſt moiſture conceivable has infected either the Alcohol, or the Salt, they can never be perfectly combined together: But when pure Alcohol, and perfectly dry Salt of Tartar are mixed together, a ſaturated tincture is ſoon extracted, and there is a true combination of the Alcohol and Tartar. For theſe Reaſons, then, we can't ſufficiently inquire into the nature of this Liquor, to which, on account of its excellence, we give the firſt place among ſpirituous *Menſtruums*. This Alcohol, then, is obtained from nothing but Vegetables; and from them, only by Fermentation and Diſtillation. The beſt is prepared from Wine, *Hydromel*, and Malt Liquor. Theſe Liquors themſelves, if they are thrown upon Fire, put it out; and yet the Fluids that firſt riſe from them in diſtillation, which are ſomewhat pinguious, limpid, ſapid, and odorous, and are then called Spirits, upon the application of Fire to them, burſt into a Flame, and burn away, tho' they are ſtill very readily mixed with Water. And when afterwards by proper methods the Water is intirely ſeparated from them, they then become true Alcohol, which we deſcribed before, when we treated of the *Pabulum* of Fire, p. 187, & *ſeq*. Hence Alcohol, upon every account, ſeems to be an exceeding ſubtil vegetable Oil, which, whilſt it was thicker, conſiſted of Particles, which ſtrongly attracted one another, collected themſelves into drops, repell'd Water, and refuſed to be mixed with it, but being converted into Alcohol, have loſt a good deal both of their attractive and repulſive power. Hence Oil comes to be called Alcohol, when it will mix with Water, and at the ſame time will totally burn. The Oils of Animals and Vegetables, likewiſe, may be altered and attenuated, in ſuch a manner, by a perfect putrefaction, as to be become ſo ſubtil and volatile, as to take Fire, whilſt they are diſperſed in the Air. Nay, and by repeated diſtillation, thoſe Oils, in particular, come to be ſo exceeding fine, that they will bear in ſome meaſure to be diluted with Water, though not ſo readily as the former Spirits. Before, now, we can pretend to give any account of the diſſolving power of theſe Spirits, we muſt firſt determine what this Spirit is: For the common Spirit of Wine, we know, conſiſts of a good deal of Water, a liquid, volatile, acid Salt, a diſagreeable Oil, and Alcohol: Rectified Spirit of Wine contains leſs Water, the ſame volatile acid Spirit as before, leſs of the nauſeous Oil, and more Alcohol: Perfect Alcohol, prepared by itſelf, is compoſed of Alcohol, and ſomething ſtill of a liquid Acid: This Alcohol, once drawn off gently by diſtillation, from a fixed alcalious Salt, becomes perfectly pure. No body, therefore, concerning theſe things, ſhould pronounce too raſhly.

May be united with a fixed Salt.

1. Pure Alcohol diſſolves Water, and is diſſolved by it; as likewiſe all aqueous Fluids. 2. And hence all Wines, of what ſort ſoever. 3. All ſpirituous, fermented Acids; of which kind are all ſorts of Vinegars. 4. All pure Oils. 5. All true vegetable Reſins. 6. Gum-Reſins for the moſt part. 7. Pure volatile alcaline Salts. 8. Fixed alcaline ones, when they are perfectly dry. 9. Moſt *Sapo*'s. 10. Sulphurs, diſſolved and opened in alcalious Salts.

What Bodies it diſſolves.

But native, compound Salts it does not affect, as Sea Salt, Nitre, and *Sal-Ammoniac*; nor pure Earth; nor Sulphur; nor Mercury, Metals, Semi-metals, Gemms, or Stones.

What not.

Of

Of the Menstruums called Spirituous, both Alcaline and Acid.

Chemical Spirits an ambiguous term. A great many of the Chemists have referred two sorts of *Menstruums* to the oily and spirituous ones, which ought rather to be placed amongst the saline, or the compound. And this happened, because they almost always had some appearance of oilyness, and at the same time were generally found to be volatile, liquid, and very subtil. Under this name of Spirits, therefore, went some Alcali's and some Acids, as they both appeared volatile, subtil, and subpinguious, tho' they were still, in reality, as different as almost any two things whatever. Nay, and even among the particulars of each kind too, there is observ'd a very great diversity. Let saline spirituous *Menstruums*, therefore, be divided first into Alcaline and Acid; for this distinction is absolutely necessary. Then let the alcaline spirituous be distinguished from another, as some of these are of a compound nature, others of a simple one. The most simple of these consist of Water, and a very subtil volatile alcaline Salt, which together compose a kind of limpid, thin, subpinguious Liquor; of this kind is the pure alcaline spirit of *Sal-Ammoniac*. And to this head belong an infinite number of others, produced both from Animals and Vegetables, when they are perfectly freed from all their Oil; for these may be prepared by Distillation from the hot antiscorbutic Plants, from every putrified Plant, and from every part of the animal Body, and are every where to be met with among the curious Chemists. But those, now, which are more compound, consist chiefly of Water, a Salt, which we shall by and by describe, and a fetid Oil; and they may be resolved into these Principles. These appear to be of a more pinguious nature than the former. These last Spirits, therefore, as they are called, are composed of a volatile alcaline *Sapo*, diluted in such a quantity of Water or Phlegm, that it is not capable of dissolving any more. And as for those Spirits, which for the most part are volatile acid Liquors, these likewise among the Chemists have obtained the name of Spirits, because these, in the same manner, are volatile and subtil, and in Distillation produce, as they run down, a kind of pinguious *Striæ*. All these, however, upon Examination, appear to be acid Salts diluted in pure Water; for even Oil of Vitriol itself, which is considerably fixed in the Fire, will, if it is distilled some number of times with boiling Water, become great part of it volatile. And the case is the same with Oil of Sulphur *per Campanam*.

A great many of these belong to Salts. Upon these considerations, therefore, I think it will be much the properest method, to separate these abovementioned from the spirituous *Menstruums*, and place them among the saline, which is what I shall now proceed to.

Of the simpler saline Menstruums.

Salts necessary to be known. Whoever is not acquainted with the tastes of Salts, will never arrive at the knowledge of our *Arcana*, is a maxim amongst the Alchemists: And no wonder, as a great many Salts are vastly efficacious in the Solutions of Bodies. And if we can put any confidence in the greatest Masters of the Art, that famous Solvent the *Circulatum* of *Paracelsus*, was made from Salt. This, however, is past all dispute, that in the class of *Menstruums*, Salts obtain every where the principal place. For this reason, I have for a long time taken a great deal of pains in these things, to see if I cou'dn't discover in them what was certain and useful; that I might at last reduce this Doctrine, often exceedingly confused, into some kind of order, and then candidly communicate it to you.

By Salt, therefore, we mean a Body that may be diluted in Water; that may be melted in the Fire if it does not first fly off; and that affects the Tongue with that sensation which we call Taste. What Salt is.

When this, now, is either artificially, or naturally perfectly pure, and without Mixture, it appears to consist of Glebules so minute, that its single Particles are not capable of being distinguished by the most accurate Microscopes; and consequently, even these will give us no light at all into their figure. Nay, farther, when these saline Bodies are resolved into their pristine ultimate Elements, from whence they were concreted, they then seem to become perfectly volatile, and when they are separated from one another, and freed from every thing else, disperse themselves about, and mix with the Air. This we saw sufficiently plain from Experiments, whilst we were treating of Earth, p. 369, *&c.* When these ultimate Elements, therefore, of pure Salt, are so concreted into Masses, as to offer themselves to the examination of our Senses, they then always have something else intermixed with them, which serves as a *Vinculum*, to bind and hold these volatile Particles together; and this in particular is Water, and Earth, which are capable of keeping them thus in union for a long time, and forming them into such large Corpuscles. Hence, therefore, we very evidently perceive, that as the first Elements of Salts can scarcely ever be confined in Vessels, so very little can be asserted concerning their chemical, or other vertues. In the mean time, however, when they come to appear in a durable form, then, as compound Bodies, we may be able to come at some certainty about them. The Elements of these insensible.

In order to this, then, let us examine into the principal difference that is observed among them. And this I think in the first place, ought chiefly to be ascribed to the real difference that there is in their constituent Elements: For tho' we can't come to examine these, when they are separate, and alone, yet without dispute, tho' all agree in their volatility, yet each sort has always some distinct and proper vertue. But secondly, this difference may arise from the diversity of the other Principle, which being united with the former pure Salt, composes the Salt that falls under our Observation; for what reason is there, that this, in various Salts, may not be of a different nature? All kinds of Salts, therefore, we distinguish into such as differ 1. In their saline Principle. 2. In their uniting *Basis*; or 3. In both together. And then in respect of this saline Principle, and this first Division, I reduce Salts, and consequently, saline *Menstruums*, conveniently enough into the following Classes. 1. Into fixed Alcali's. 2. Volatile Alcali's. 3. Native vegetable Acids. 4. Fermenting vegetable Acids. 5. Fermented vegetable Acids. 6. Vegetable Acids procured by Combustion. 7. Vegetable Acids procured by Distillation. 8. Native fossil Acids. 9. Fossil Acids by burning. 10. Fossil Acids by Distillation. 11. Native Salts, called neutral ones, as Borax, Nitre, Fossil-Salt, *Sal-Gem*, Fountain-Salt, Sea-Salt, and *Sal Ammoniac.* 12. Other Salts that are compounded of these. All these Salts, therefore, must now be examined in order, that we may ascribe to every one of them its proper and peculiar vertues, and by this means come to a true knowledge of them, as they may be made Kinds of Salts.

use

use of in the Solution of Bodies. To begin then in the first place with the fixed Alcali.

Of a fixed Alcali, as a Menstruum.

A fixed Alcali. The word *Kali*, made use of upon the *Eastern* coast, and in *Egypt*, signifies a certain Herb, abounding in Salt, that grows about the sea-shore, and the banks of the *Nile*, and on those too of that famous River *Belus* in *Syria*, as *Pliny* assures us from ancient Authors. This Plant, if it is burnt in an open Fire, when it is come to maturity, produces Ashes that are remarkable for their salt acrid taste, and thus evidently demonstrate how full they are of Salt. If these Ashes are boiled in Water, they yield a strong, acrid, salt *Lixivium*, consisting of the Salt that is drawn out of them into the Water, which being properly poured off, there remains at the bottom of the Vessel another greyish part, which will not dissolve in the Water, nor will burn in the Fire, but is perfectly insipid, and of an earthy nature. If this *Lixivium* then is evaporated to a driness in an iron Kettle, there is left behind a white solid Mass, of a most acrid caustic taste, and perfectly soluble in Water. Since, therefore, *Lix* in the *Latin* Tongue signifies Ashes, and *Lixa* a maker of Ashes, hence *Pliny* very properly says, *Cinerum Lixivium*, L. xxxix. C. 99. And, *Lixivium Cinis*, L. xiv. C. 2. 25. L. xv. C. 18. But *Columella* calls a *Lixivium*, the Water when it is impregnated with this Salt, and filtered. L. xii. C. 41. All these Salts, therefore, for the future, may very conveniently be called *Lixivious* Salts. By terms, however, received into the Art, they are called an Alcali, alcalious, or alcaline Salts. Some likewise call them *Soda* or *Zoda*. From this Salt, and the *Calx* of all Stones that strike Fire with Steel, may be prepared a *Frit* for the making of Glass. For Soaps, they use the same made sharper with quick Lime, and any oily Substances whatever. The best of this sort of Salt, comes to us at present from *Alexandria* in *Egypt*, and *Tripoli*. As all our Physical knowledge, now, arises originally from what our Senses discover in natural Bodies, hence all the distinctions of them must be taken only from such sensible signs: Nor can we distinguish Bodies in any other manner. I now, therefore, proceed to lay down the following Characters of an Alcali, which I think are abundantly sufficient, both for the Chemist, and the Philosopher.

Its Marks. 1. This Alcali, therefore, owes its origin to a vegetable Substance. 2. It is only procured thence by the action of such a Fire, as by burning converts it into Ashes. 3. When it is prepared in this manner, it is always of such a nature, that it will remain a considerable time in the Fire, and thus demonstrate its fixity. 4. In a moist Air, it perfectly melts away and deposits some *Fæces*, being absolutely impatient of long dryness, tho' it is carefully enough preserved in any close Vessel whatever. 5. If you taste it, it impresses a Savour upon the Tongue, joined with a Sense of Acrimony, and that a caustic one; and it excites at the same time a Taste of Urine, on which account these Salts have, tho' not so properly, been called urinous Salts. For the proper Taste of this Salt does not resemble that of Urine, as the first application plainly demonstrates: But when this has been in the Mouth some time, and by its Acrimony has drawn out the *Saliva*, then the neutral animal Salts which are in the *Saliva*, by the power of the fixed Alcali, are deprived of all their

 acid,

aid, and thus become volatile and alcaline, and then impreſs upon the Tongue a diſagreeable urinous Taſte, of which this is the true origin. 6. This Salt, when it is perfectly pure and unmixed, has not the leaſt ſmell of any kind, being exceedingly fixed in the Fire itſelf: But as it is vaſtly greedy of every Acid, if it meets with any Body in which there is a volatile alcaline Salt retained by an Acid, and concealed without any Smell, it then immediately abſorbs the Acid, and the latent Alcali being by this means ſet at liberty and rendered volatile, diſperſes about an alcaline Smell, which is then falſly aſcribed to the fixed Salt. This appears evidently upon throwing a fixed alcaline Salt into warm freſh Urine, upon which the Liquor, that was inodorous before, inſtantly emits a diſagreeable alcalious Smell. 7. Another property of this Salt is, that if it is mixed with any Acid whatever, it preſently produces an Ebullition and Effervescence; and afterwards is ſo intimately united with it into one Maſs, that if the Saturation is compleat, the compound, ſo long as it continues ſo, diſcovers no ſign, either of an Alcali or an Acid, but there is always by this means produced a third Salt, which the Artiſts now o'days chuſe to call a neutral one. 8. If a pure fixed Alcali is mixed with the Juice of the Turnſole, Roſes, or Violets, it preſently changes their natural Colour, which is a kind of Purple, into a Green. 9. When the ſame is applied for ſome time to a warm human Body, and conſequently one that exhales ſome Moiſture, it excites an acute Inflammation, attended with all its Symptoms, which ſoon turns to a grey, hard, dead, and often black Eſcar, and therefore is capable of producing at laſt a true Mortification. 10. All theſe Salts have a power of deterging and getting out ſpots; which is never found to be the caſe in thoſe called neutral. Theſe then are the Marks by which theſe Salts may be known and diſtinguiſhed from all others; and by theſe we ſhall be able to avoid any confuſion in this Hiſtory of *Menſtruums.*

Such alcaline fixed Salts may be procured likewiſe from any crude, freſh Vegetable, burnt to Aſhes, and treated in the ſame manner as we mentioned of the *Kali*. Out of ſome Plants, however, by this management, you can get but very little: Of this kind are thoſe, which when they are crude, have ſuch a pungent Smell, as ſtings the Noſe, and makes the Eyes water; for almoſt all the Salt of theſe Plants is volatile, and is diſſipated, and flies off with the Heat of the Fire. Garlic, the bulbous vomiting Roots, Onions, Scurvygraſs, Ladies-ſmock, Rocketts, Hedge-muſtard, Creſſes, Radiſhes, Rapes, Squills, Leeks, Muſtard, and the like, I refer hither; in which nature has ſo far perfected their alcalious Salts, as to render them volatile, as in Animals. Its origin.

Theſe *lixivious* acrid Salts, now, have been known to the ancients in almoſt all ages. *Ariſtotle* tells us, *Meteor* II. C. 3. that the Aſhes of burnt Reeds, and Bulruſhes, boiled in Water, yield a plentiful Salt. And *Varro de R. R.* L. i. C. 7. informs us, that ſome of the Inhabitants upon the *Rhine*, having neither Foſſil nor Sea-Salt, inſtead of them, made uſe of a ſalt Coal, which they procured from ſome ſorts of Wood: From which it is pretty plain that they knew, according to *Tachenius*'s method, to prepare theſe Salts in ſuch a manner, as to make them leſs acrid, and to come nearer to the nature of the native neutral ones. Hence *Pliny* aſſerts, L. xviii. C. 28. that Aſhes themſelves have the qualities of a Salt, but are milder. And L. xiv. C. 26. that the burnt *Fæces* of Wine have the vertue of Nitre. And L. xvi. C. 11. he Well known to the Ancients.

ſpeaks of the nitrous Aſhes of burnt Oak. Nay, and they made uſe of it in Phyſic too, as we learn likewiſe from the ſame Author, L. xxxvi. C. 69, where he ſays, Aſhes, when they are drank, have medicinal vertues. All theſe authorities, then, to which more might be added, if neceſſary, ſufficiently evince, that the knowledge of Alcali's is not to be look'd upon to be ſo modern as ſome Perſons imagine.

Prepared by Fire only. As far, now, as ever I have been able to inform myſelf, there was never yet diſcovered one native Salt with which the preceding Marks wou'd agree, all theſe alcaline Salts being procured from vegetable Subſtances by the action of Fire alone. But from the firſt time that ever Vegetables came to be burnt in the world, theſe Salts have been always produced, provided the Vegetables were reduced to Aſhes. Hence, therefore, in all ages and places where this has happened, there muſt have been a prodigious quantity of this Salt generated, which always at laſt with the Aſhes ſinks down to the Earth. In the revolution, therefore, of ſuch a vaſt number of years, this Salt, one ſhould think, muſt have poſſeſſed great part of the Earth, and diſcovered its proper Nature, as we ſee the mountains of Salt do in the Iſland *Ormus*.

Periſh again. But as this, now, is found by no means to be the caſe, nothing can be more certain, than that the Salts of burnt Vegetables, when they inſinuate themſelves into the Earth, often, indeed, render it fruitful, but in the mean time, ſoon loſe their alcaline nature, put on the form of a new Salt, and then continue to act in that character.

Not in Plants naturally. And upon this head, we ought particularly to conſider, that no Plant that ever grew upon the Earth, if it was ſuffered by time to grow dry and carious, wou'd ever yield one grain of a fixed Alcali: But on the contrary, they have been always found either to have been diſſipated into ſuch minute volatile Particles, as eſcape the Obſervation of our Senſes, or elſe to have left behind them a certain Matter, which upon examination appear to be mere Earth. This univerſal Experiment, therefore, confirmed in all ages, evidently demonſtrates, that Nature, whether you regard their Fluids or Solids, has never intermixed a fixed Alcali in the Compoſition of Vegetables. Hence, therefore, we aſſert again, that fixed alcalious Salts are produced by the action of the Fire, and not by any natural vegetating Operation. But this is ſtill farther evinced by the following Experiment, which conſtantly ſucceeds in the ſame manner. Take any of thoſe Vegetables, which if they were burnt wou'd yield a large quantity of a fixed Alcali; let theſe be brought to putrefaction according to art, ſo that their whole Subſtance ſhall be perfectly putrid; and they will by this means become exceeding fetid, and great part volatile; and if they are then burnt in an open Fire, won't yield one grain of fixed Salt, but will produce only ſome white, inſipid, perfectly earthy Aſhes; in which, if you expect to find any Salt, you'll be deceived. You, Gentlemen, therefore, who conſider this Experiment in a proper manner, muſt be of my opinion, that fixed alcaline Salts of Vegetables, which are the only fixed alcaline Salts we at preſent know of, ought to be looked upon as abſolutely the creatures of the Fire; and no doubt but you will think that they are as much ſo as Glaſs, which is made from the moſt lixivious Aſhes, melted with the intenſeſt Fire: But as no perſon living ſuppoſes that Glaſs is really procured from the Vegetable, when it it is thus put in fusion with a strong Fire, so certainly we must confess the case is the very same with this Alcali.

And hence, in the latter part of this Work, I shall demonstrate, that these alcaline Salts may be very easily resolved into a considerable part that is saline, hard, bitter, and almost vitrescent; into a simple Earth; and into an alcaline Salt, that is stronger and more pure: And thus we shall again see, that these Salts are by no means simple Bodies; but that they are compounded of different parts united together; and that this conjunction of these Principles into one Mass that appears so homogeneous, is owing intirely to the strength of the Fire. Hence, then, it will follow, that Nature never acts by fixed alcalious Salts, as by her proper Instruments, unless only when she receives them first prepared by the Fire: And that even in this case, when she makes use of them thus prepared in bringing about her designs, she then only operates by them, as they are compounded of the three abovementioned Principles; to which, however, as a fourth part, there still seems to remain somewhat of an Oil, as many Arguments induce one to believe. Arises from different parts, united by the action of the Fire.

And hence again it appears, that as these fixed alcaline Salts are more and more disengaged by a separation of their constituent Principles, the Salt that arises hence will be continually different; for that which remains after a former separation, will always be of another and more simple nature, and consequently, will have a different power of acting. Take Pot-Ashes, for instance, which yield the best of this sort of Salt. A great part of these is a bitter, hard, pellucid Salt, that does not so readily dissolve in Water. Separate this carefully according to Art, and you will then be able to obtain a purer Alcali, which is fitter than the other, for a good many Operations that are perform'd by Alcali's, which will not succeed so well, if the former Salt remains mixt with the latter. And here we must carefully observe, that these alcaline Salts too, are often surprizingly changed by some other Body's falling in among them, whilst the Vegetables are burning, which being likewise of a fixed nature, may be united, and remain with them in the Ashes. Suppose, for instance, that some Nitre should happen to come among them; then this being fixed with the other vegetable Salt, would produce an Alcali, on which, if you poured Oil of Vitriol, it would emit a fetid Fume, that would smell of Spirit of Nitre; which never is the case, if the Alcali is pure. The same you easily conceive of Sea-Salt, and many others. And lastly, to render this Doctrine of Alcali's still more clear and compleat, we must take notice, that the very burning of the Vegetables, as it is performed in a different manner, will produce different Salts: For it is a known truth, that if the same Vegetable is burnt at once in a brisk strong Fire, it will yield another Salt from what it does, when it is slowly consumed by a smothering one, as we see in the Preparation of the Salt of *Tachenius*. But we must now proceed to give you an account of the principal alcalious Salts, which are made use of in the chemical Art. Consequently various.

Among these, then, the commonest sort is that which is called *Potas*, or Pot-Ashes. This is brought yearly by the Merchant's Ships in great abundance from *Coerland*, *Russia*, and *Poland*. It is prepared there from the Wood of green Fir, Pine, Oak, and the like, of which they make large piles in proper Trenches, and burn them till they are reduced to Ashes. These being pre- The Alcali of Pot-Ashes.

ſently ſifted, were by the Ancients called *Lix*; by the Moderns *Cineres Clavellati*, which name ſeems to come from the *Clavæ*, or Billets, into which the Wood is cleft, to make it burn more readily, whence *Clavula*, and then *Clavella* ſeem to be derived. Theſe Aſhes are then diſſolved in boiling Water, and when the Liquor at top, which contains the Salt, is depurated by ſtanding quiet, it is poured off clear, and makes the *Lixivium*. This, then, is immediately put into large copper Pots, and is there boiled for the ſpace of three days, by which means they procure the Salt they call *Potas*, (which ſignifies Pot-Aſhes) on account of its being thus made in Pots. This Salt, whilſt it is hot and dry, muſt be put up in Caſks, the Wood of which is dry, and has no Oil in it, and by this means it may be kept dry; otherwiſe, if it is expoſed to the Air, eſpecially a moiſtiſh one, it will run into a pinguious Liquid, which is very heavy, won't admit Air, is alcalious, and exactly like Oil of Tartar *per deliquiuum:* And by this very action, it depoſites again freſh *Fæces*, and that in a very conſiderable quantity too; for I myſelf have, in this manner, got 6 drachms of theſe *Fæces* the firſt time from one pound. When this afterwards is diſſolved by ſucceſſively pouring hot Water upon it, and by ſtanding is depurated from its *Fæces*, and the pure Liquor that is at top is accurately filtered, then, if it is inſpiſſated to half the quantity by exhalation in a very clean glaſs Veſſel, and afterwards ſuffered to ſtand quiet in a cold place, it will ſoon form upon the Glaſs little hard Glebes, of a regular figure, pellucid, that never diſſolve even in a dampiſh Air, are diluted with difficulty in Water, are brittle like Glaſs, of an exceeding bitter Taſte, and very much reſemble that Salt, which in making Glaſs is thrown up to the top, and is called the Gall of Glaſs: This therefore is of a very particular nature: And by this method, one may obtain a great quantity of this Salt. But even in this way of preparing this Salt, you have again terreſtrial *Fæces* to the quantity of 4 ſcruples in a pound: And thus at laſt you have the alcaline Salt in the remaining Liquor ſufficiently pure. This, now, if it is inſpiſſated quite to a dryneſs, produces a white alcaline fixed Salt, with which, and pure Sand, is made the fineſt ſort of Glaſs. If this pure Salt now is expoſed for a good while to a ſtrong Fire, it will melt, and then always becomes more acrid, and being expoſed to the Air in a glaſs Plate, will again diſſolve and depoſite *Fæces*. And if theſe Operations are repeated, as I mentioned before, in our Hiſtory of Earth, the whole Salt will become volatile, and at laſt will be intirely reſolved into an imperceptible exhaling part, and terreſtrial *Fæces:* And thus again, both its Acrimony, and its dryneſs, will be deſtroy'd. But it often happens during the repetition of this Operation, that the Alcali changes its firſt nature, and is converted into a neutral Salt, which eaſily melts in the Fire like Wax: And hence ſome Chemiſts have vainly pleaſed themſelves, that they were Maſters of that great ſecret, an incerated fixed alcaline Salt, which the ancient Chemiſts ſo highly extolled. But this only happens from the volatile acid in the Air applying itſelf to this Salt, and being united with it, by which means a new kind of Salt is produced, compounded of this Alcali, and this Acid, and hence eaſily flowing in the Fire, but deprived of all its alcaline vertue. But otherwiſe, the fixed Alcali, procured in the manner we have deſcribed, has above all others, every mark which we laid down in defining an Alcaline. This Salt, therefore, we may fairly fix as a ſtandard for all of this kind, by the character of which we may examine any Salts that we are in doubt about, whether they belong to this Claſs, or no. And thus again is confirmed what we advanced before, that alcalious Salts, produced by burning, are made up of three Principles, and thoſe very different ones too, *viz.* a pure Alcali, a bitter Salt, and a pure Earth. The true ſaline part here, now, is greatly leſs, than any one would imagine, and when it is alone, is volatile, eſcapes the notice of our ſenſes, and hence, hitherto, we are not come to a knowledge of its proper nature.

The Juice preſſed from Grapes that are ripe, ſpontaneouſly ferments; and during this operation it is properly called Muſt. After this fermentation is over, and its thicker *Fæces* are depoſited, and it has ſtood quiet in the Pipe, it becomes liquid, fine, and homogeneous. This we call Wine; which has now depoſited abundance of thick *Fæces:* Theſe go by the name of the Lees, or the Mother, and were firſt diſperſed through the Muſt, then work'd up into Flowers, and Yeaſt, and afterwards fell down, and were continually collected more and more at the bottom. The Wine, when it is thus become fine, if it is drawn off from the Lees into a clean Veſſel, leaves all theſe thick *Fæces* behind it; from which, by preſſing them ſtrongly through thick, canvas Bags, they procure a turbid Wine, which they uſe for making the ſtrongeſt Vinegar. The *Fæces* then that ſtill remain in the Bags, dry, and formed into Cakes, if you burn them, will be conſumed into Aſhes. Theſe, if they are ſifted, diſſolved in Water, and depurated from the ſubſiding Earth, yield a clear *Lixivium.* And this, laſtly, by inſpiſſation, in great Pots, produces a Salt, very like the former, but purer, and more acrid. This, then, is a ſecond ſort of Pot-aſhes, which by the preceding fermentation ſeems to be rendered more ſubtil than the former. And this is a ſecond general method of procuring an Alcali from every ſort of Wine whatever. An Alcali from the Lees of Wine.

If the Wine, now, after it is fin'd and drawn off as above into a clean Pipe, ſtands a good while after it is thus perfectly fermented, and fine, there will then begin to appear little ſhining Bodies in it, like little Particles of Glaſs, which gradually uniting together into larger Glebules, diſperſe themſelves equally round the Veſſel, fix themſelves upon every part of it that the Wine reaches to, and thus by degrees incruſtrate over its whole Surface with a kind of ſtony Matter, called, for this reaſon, very properly, by the *Germans*, Wine-ſtone; by the Chemiſts, Tartar. This is always of an acid taſte, and produced only from Wine, when it has been fermented, and depurated. Betwixt this and the Lees, now, there is a great deal of difference; for this, in particular, hardens into the form of a Stone, that always continues liquid; this fixes to the upper, lower, and, in ſhort, every part of the Veſſel; that intirely falls to the bottom. This Tartar, now, according to the ſort of Wine from which it is generated, is red, grey, white, more or leſs pure, and more or leſs acid. Acid, rough Wines yield a greater quantity of it; the ſofter and ſweeter, a leſs. If this Salt is put into a clean glaſs Veſſel, and with a ſand heat very gradually and cautiouſly urged, it gives a *Spiritus Sylveſtris*, that diſperſes itſelf about, and is not to be confined; then other Spirits but a little acid; afterwards pinguious and thicker; and laſt of all an Oil, that is the moſt penetrating of any we know of. A fixed Alcali from Wine.

When

Prepared by simple distillation.

When these, now, are all drawn off, there then remains a very black Mass at the bottom of the Retort, which is perfectly alcaline, and exceedingly acrid; and this is the only method that I am acquainted with of producing a fixed, alcaline, acrid, vegetable Alcali in a close Vessel; for all other vegetable substances whatever, being exposed to the strongest distillation in a Retort, produce, indeed, a black Coal, but never, to my knowledge, afford an alcaline Salt, till this Coal is afterwards burnt in an open Fire. But if you then take out this black, alcaline, tartareous Coal, and burn it, you will have a white, alcaline Salt, the most acrid and purest of all the fixed Alcali's. By this surprizing Experiment, then, we evidently see, how much fermentation promotes the production of an Alcali, though at the same time it always heightens, nay, and seems almost to generate an Acid. Both Alcali's and Acids, therefore, are more readily produced by the assistance of fermentation, than without it; which observation, certainly, is of very great consequence, though you will scarcely find it taken notice of.

All Alcali's, however, from whatever vegetable, or in what manner soever produced, when by the strongest Fire they are at last brought to their greatest alcaline perfection, become so perfectly of the same nature, that they can scarely be distinguished from one another. There is one, indeed, but a very trifling circumstance, wherein they differ, observed in making Glass, and that is, that Glass made with the very same Flints, but different, fixed Alcali's, shall often have some diversity in their colour, so that that which is prepar'd with the Alcali of Flints, shall be different from that made with any other. But it is very well known, how small a matter will make a very considerable alteration in the colour of Glass; as even pounding the Salt in a metal or marble Mortar, will produce a difference. Hence I have sometimes been ready to doubt, whether some metalline Matter might not possibly insinuate itself into Vegetables, and being naturally fixed in the Fire, leave something in their fixed Salt, that might afterwards discover itself in the Glass. Iron, it is certain, insinuates itself into many Bodies; and, perhaps, it may not be so intirely repugnant to the nature of Copper to do the same.

A fixed Alcali from Nitre.

But the Chemists have discovered another particular method of producing a true fixed Alcali, which we have accurately described by *Glauber*, as follows. Take some pure Nitre in a clean Vessel, flux it till it runs like Water; and it will then scarcely have any visible motion. When it is in this condition, throw a little bit of live Coal into it, and in an instant it will produce a great noise, run about upon the Surface of the Nitre, consume, and then the Nitre will flow quietly again, as before. When every thing is still, throw a bit more in, and you will have the very same *Phænomena*. Repeat this Operation till the Nitre makes no more noise, or is set on Fire by the Coal, and then all that remains will, in every sensible, physical, and chemical property, be a fixed, alcaline Salt; for it has a caustic acrimony; it causes a urinous taste in the Mouth; it raises an ebullition with all known Acids; if it is saturated with Acids, it is converted into a compound Salt, whose nature is determined by the Acid it is mixed with; it has the same effect in changing of Colours, with the preceding Alcali's; the very same precipitations are likewise produced by it; and in the solution of certain Bodies, it discovers

diſcovers a perfectly ſimilar, not to ſay the very ſame efficacy. In this Salt, however, there is yet conſtantly obſerved ſome difference from the former, as it always retains ſomething of Nitre that is not perfectly changed from its priſtine Nature. This, indeed, don't commonly diſcover itſelf till you pour ſome of the beſt Oil of Vitriol upon it; but then there immediately riſes a Vapour, which by its ſmell of Spirit of Nitre, or *Aqua Fortis*, demonſtrates, that there is ſtill ſomething remaining in the alcaline Maſs, which, by the action of the Oil of Vitriol, riſes from the Nitre itſelf. Nay, and even the Oil of Vitriol, too, generally grows black when it is mixed with *Glauber*'s Alcali, whence it appears, that there is ſtill left likewiſe ſome of the Coal, which was thrown in and conſumed. *Glauber*, therefore, was certainly in the right, in believing this Alcali of Nitre to be in ſome meaſure different from other vegetable Alcali's; but when he extols its vertues ſo highly above all others, it's poſſible he was a little too fond of his own diſcovery.

But a third, and the moſt expeditious way of producing Alcali's in a ſhort time, and great quantity, is as follows. Take of the beſt and drieſt Tartar, and Nitre reduced to a fine powder, an equal quantity, mix them together, and throw them, a little at a time, into a clean iron Ladle, made almoſt red hot, and there will be excited, as we ſhew'd you before, a momentaneous deflagration, and there will be immediately produced a white, alcaline, fixed Salt. This, too, is like a vegetable Alcali in every mark; but ſtill it has the ſame peculiarity as the former. For here if you go to make vitriolated Tartar from it, there immediately ariſes a ſmell of *Aqua Fortis*, and the Matter turns blackiſh; a certain ſign that there is ſomething of Nitre remaining, in this caſe, as well as the former. See the egregious *Hoffman. Obſerv. Phyſ. Chem.* p. 241.

The ſame from Tartar and Nitre.

And laſtly, there is another, and a pretty ſingular manner, too, of preparing a fixed, igneous Alcali, in a moment, almoſt, from Nitre, and is as follows. After the Sulphur is ſeparated from Antimony, almoſt as clear as is poſſible, there remains the pure metalline part, which is called *Regulus*. Take this ſhining Subſtance, put it into a clean Crucible, melt it in the Fire, and when it is perfectly in fuſion, add an eighth part of the pureſt, drieſt Nitre. You'll then be ſurprized to find, that this Nitre, which uſed to flow ſo eaſily in a ſtrong Fire, cannot now be brought to flux, without the application of ſuch an intenſe Heat, as is neceſſary for the fuſing of Copper. But you'll here perceive, likewiſe, ſomething more extraordinary, and that is, that when it is urged with ſuch a degree of Fire as will melt it, it immediately acquires a golden colour, and when the whole is poured out into a melting Cone, it riſes to the top, and appears like a golden Cake. This, now, if it is ſeparated by ſtriking the Cone, is vaſtly impatient of drineſs, and is of ſo acrid, alcaline a nature, that it is perfectly igneous in almoſt every effect: Nor has the greateſt Maſters in the Art ever found out any method by which one may communicate to Salt ſo great a degree of Acrimony. And here we may obſerve, that Nitre, which is the coldeſt of all Salts, and has not the leaſt mark of any Alcali in it, when it is thus fuſed with the metalline part of Antimony, acquires this Acrimony, purely, as it were, by contact. It is credible, now, in this caſe, that the Sulphur of the Antimony is, by this means very intimately united with the Nitre;

Laſtly, by contact with Antimony.

Nitre; for if you take the Salt, thus produced, whilst it is exceeding dry, and hot, and throw it into very pure Alcohol, this presently extracts a very red Tincture from it, whose caustic quality is so great, that it can scarcely be born. This sudden alteration, now, I have observed equally to happen, whether the *Regulus* is made with Iron, according to *Suchtenius*'s method, or with Tartar and Nitre, in the common one. But this will not be effected so long as the external Sulphur adheres to it, the Experiment then only succeeding, when this part being separated, the remaining reguline part is perfectly fus'd with the Nitre. The quick change, now, that is here brought about, which we meet with no where else, is so much the more surprizing, as Nitre with Sulphur never becomes alcalious, but is converted into a bitter *Sal-Polychrest*. And what still makes it more extraordinary is, that Nitre, if it is kept a vast while in fusion by itself, will remain the same without any alteration. Nor will Nitre, as we mentioned before, produce an alcaline Salt with Antimony, so long as it retains its Sulphur; though when that is removed, it will with the *Regulus* generate it by simple fusion. Hence, therefore, from the combination of Bodies together in a certain manner, we see what sudden and unknown effects may be produced, which it was not possible to have foreseen; and hence again we infer how likely we are to fall into errors, if we proceed too hastily upon general Principles. But once more, we here observe farther, how easily Nitre grows alcalious through its whole substance, *viz.* as it were, by mere contact; in as much as it is not mixed with the melted Antimony, but precisely flows at the top of it, being perfectly expelled from it. And lastly, we may take notice, that this Salt, which is fluxed by itself so very readily, in an instant, is so altered in its nature, that it becomes the most difficult to flux of any we are acquainted with. Thus then, Gentlemen, I have laid before you all I have been able to discover in any Authors, concerning the origin of fixed Alcali's, and the division of them into proper classes, founded upon it, to which I have likewise added some of their vertues.

The efficacy of a fixed Alcali.

The order of our subject leads us now to examine into all those physical operations which these Salts are observed to perform. And that I may do this the most to advantage, give me leave to take notice to you once more, that though from the vast number of Vegetables that are perpetually burning, Nature is constantly employed in generating fixed Alcali's; yet, notwithstanding the infinite quantity that is thus produced, there is not the least appearance of them any where to be found in the Earth; whence it follows, that these Salts must either perish, or be continually changed in their nature. In perfect fixed Alcali's, then, upon examination, the following properties appear to belong in common.

First attracts Water.

1. They attract Water very powerfully, to a great distance, and from every known Body in which it resides. This is plain from ocular demonstration; for when such an Alcali is taken out of a strong Fire, if it is suffered to remain in a very hot Air, just by the Fire, where we can by no other art discover the least sign of Water, it will even there grow moist, and dissolve: And if it is then put into a clean, dry, glass Vessel, and dried over the Fire, and the Vapour that exhales, is catched, and condensed in an Alembic, it will yield again the pure Water which the Alcali had drawn into it.

Other

Other Salts, now, if they had been moiſt before, would have been deprived of their Water in the very ſame place, where the dry Alcali attracted a moiſture. Theſe Alcali's, therefore, are true magnets to Water; this they diſſolve, and unite with them; by this they are diſſolved and ſtrongly united with it; and hence, when they are once diſſolved in Water, a Heat as great as that of boiling Water won't perfectly dry them again.

Take, for inſtance, Oil of Tartar *per Deliquium*, put a mercurial Thermometer into the Veſſel with it, and expoſe it to a Heat of 214 degrees, and you will find the Salt will not be dried. Nay, if you have a mind to effect this, you muſt put it into a metal Veſſel, and keep it continually ſtirring in a Heat of more than ſix hundred: Hence, we ſcarcely know any Body that parts with its Water with more difficulty. I had a mind, now, to inquire into the power by which an Alcali thus attracts Water, the quantity which it takes in, and the ſpace through which this power is capable of exerting itſelf. Retains it very ſtrongly.

To this purpoſe, then, I took an ounce of a fixed Alcali, exceeding pure and dry, and putting it in a clean glaſs Baſon, expoſed it to a dry Air, in a ſubterraneous place, that was every way incloſed, nor in the leaſt diſturbed by any Wind; and I found, in a little time, that the Water was attracted out of this ſtill Air, to the broad ſurface of the Salt, and it continued to be ſo, till the Salt had drawn in near three ounces of Water, but being then thoroughly ſaturated, it did not imbibe any more. Hence, then, I learned evidently, that this quantity of Water, which was thus attracted to the ſurface of the Salt, required at leaſt ſix cubic feet of Air to ſupply it: For if we ſuppoſe the weight of Air to be to that of Water, as 1 to 1000, and a cubic foot of Water to weigh 64 pounds, then all the heavy Bodies in a cubic foot of Air will weigh $\frac{8}{125}$ of a pound. Let us imagine, now, only half of theſe heavy Corpuſcles to be pure Water, the other half, all the reſt of the Bodies that are contained in the Air, and then it appears, that in a cubic foot of Air there will be about half an ounce of Water. If this Salt, therefore, is capable of attracting this Water from ſo great a ſpace, we diſcover a new and very ſurprizing power in Nature. Hence *Sendivogius* ſaid, very juſtly, the more Alcali's are burnt, the more Water theſe calcin'd Bodies attract out of the Air. If you are rather of opinion, however, that in this caſe the Water which is in the Air at a diſtance, comes into that Air which is neareſt to the Salt, and ſo is exhauſted of its Water, I will not contend with you; but this, in the mean time, I am certain of, that the Air, where the experiment was made, and from which the Water was ſeparated, was exceeding ſtill. Draws it from a great diſtance.

But to come at the ſame thing ſtill more exactly, I took a large glaſs Bottle, very clean, hot, and dry, and into this I put ſome pure Salt of Tartar, very hot and dry, likewiſe, and reduced to Powder in the manner above deſcribed. I then preſently ſtopt the Mouth of the Bottle with a dry Cork, and covered it over with a Hog's Bladder, well rubb'd with Oil, and made very ſupple, which I tied over it; and I afterwards found, that the Salt, which adhered to the ſide of the Glaſs, was grown moiſt with the Water contained in that ſmall quantity of Air that was included with it, tho' the Air was hot and dry, at the time that the Bottle was cloſed. And very efficacious.

Secondly, repels Air. 2. But with reſpect to Air, now, Alcali's ſeem to have a quite contrary power; for as they attract Water, ſo they ſeem to repel pure elaſtic elementary Air. Indeed one would be apt to think otherwiſe: For if a fix'd alcaline Salt, when it is perfectly red hot, nay, in fuſion, is poured into an iron plate, it will ſoon attract ſome Water into it; and as this Water is drawn out of the Air, one would imagine, it ſhould attract the Air along with it, eſpecially, as it formerly appeared, that when Water is by any means deprived of its Air, it always ſpontaneouſly takes in more. Nay, and for this reaſon it would farther ſeem probable too, that the Salt ſhould attract Air into it, *viz.* that all the Air that was in it before muſt have been expell'd by the intenſeneſs of the Fire in which it was melted. On theſe accounts a perſon would be apt to infer, that a great deal of Air muſt be drawn into, and lie concealed in theſe Salts; and yet if you examine Oil of Tartar *per Deliquium* at the Air-pump, it does not give any indication of Air's coming out, nay, even though you make it hot. Hence, therefore, again every body would conclude, that theſe Alcali's do not only repel Air, but that they likewiſe even expel that which is lodged in the Water; and hence, that there is in theſe Salts a power of repelling Air, and driving it from among them.

Or, perhaps, attract it exceeding ſtrongly. But you may remember, Gentlemen, that whilſt this point was before under examination, we brought it to this concluſion, that it was almoſt probable, that Alcali's attract Air into them exceeding ſtrongly, and ſo cloſely unite it with them, that they do not let it go again, until it is forced from them, by a ſtrong Fire, or being put into an effervеſcence. *Vide.* p. 303, 310. Upon a careful conſideration, therefore, of theſe oppoſite appearances, I am in a doubt, whether, under this ſecond property of Alcali's, I ſhould conclude, that they perfectly repel Air; or that they unite it ſo intimately with them, that ſcarce any Body attracts it more ſtrongly, or fixes it more cloſely. One of theſe two muſt certainly be the caſe; which of them is ſo, I dare not aſſert. Thus you ſee the extraordinary iſſue of ſo many Experiments, performed in a proper manner, *viz.* a fluctuation between two opinions, that are diametrically oppoſite to one another. This, however, is the nature of true Philoſophy, nor can we any other ways come at a right knowledge of it. Theſe uncertainties, in the mean time, have this evident advantage, that they put others upon farther inquiries.

Do not repel Alcohol. Theſe pure, acrid, fixed Alcali's, if they are mixed with the choiceſt Alcohol, when they come firſt out of the Fire, attract it into them, and unite it with them; but if there is the leaſt mixture of Water in it, then the Water is immediately attracted, and the Alcohol repelled; nor can they afterwards be united, by any method whatſoever. Nor can this union be effected, if the Alcohol is pure; but there is Water in the Salt. In this manner, therefore, pure Alcali's elegantly divide ſtrong Spirit of Wine into two parts, that are not miſcible with one another, *viz.* into a Water ſaturated with the Alcali, and into a pure Alcohol ſwimming at top. And thus, again, plainly appears the reciprocal attractive force betwixt the Water and the Alcali. For take a pint of the pureſt Alcohol, put into it but a very ſmall quantity of Water, and then throw in ſuch a dry, alcaline Salt, and the Alcali will in an inſtant draw into it that little portion of Water, upon which there will appear a kind of of tenacious Oil about the ſides of the Glaſs, and at the ſame time, the combination of the Alcohol, and Water, will be perfectly prevented. Hence then we ſee evidently, how many, and what ſingular, phyſical operations may be performed by means of fixed Alcali's, when they act upon thoſe Fluids that are prepared by fermentation, conſidering them as acting, either by an attraction or repulſion of the Alcohol, or by an attraction of the Water alone. Nay, and theſe Alcali's act upon theſe Liquors yet in another reſpect: For as every Spirit drawn by Fire from any ſort of Wine has always a volatile Acid intermixed with it, hence the Acid being greedily attracted by the Alcali, the Spirit by this means becomes much more pure, as it is now freed from its inherent Acids, and conſequently will be very different both in its nature and vertues, from what it was before this Operation. And the Alcali itſelf, likewiſe, will at the ſame time be intirely altered, will become a compound of an Acid and Alcali, and if it is perfectly ſaturated in this manner, will produce *Sennertus*'s *Sal Purgans de Tartaro.* To this Obſervation, laſtly, we are indebted for a preparation of pure Alcohol, without diſtillation, or any aſſiſtance of Fire: For mix only a ſufficient quantity of Pot-aſhes with common Spirit of Wine, and ſtir them about till they are thoroughly mixed together, and the Water will run into the Alcali, and the Alcohol will ſwim at top, which, by a gentle decantation, will come off good the firſt time. If you doubt, however, whether it is quite pure or no, only put ſome more Aſhes into the Alcohol thus prepared, and by ſtirring them about, and then pouring the Liquor off, you may eaſily make it ſo. In this Operation, however, the Spirit of Wine always diſcovers a pinguious Oil, which before appeared neither in the Spirit of Wine, nor the Alcali, but is then only generated when they are thus mixed together.

In the fourth place, the power of theſe Alcali's manifeſts itſelf particularly upon diſtilled vegetable Oils. For if the moſt acrid, pure, dry Alcali is thrown very hot into a diſtilled Oil, it attracts it violently into itſelf, with a mighty hiſſing noiſe, and unites it ſo well with its Subſtance, that there is immediately produced a kind of Soap, which is ſtill combined more cloſely, and brought to greater perfection by this mixture's being ſet in a ſubterraneous place; for by this means both of them become ſemi-volatile and form a Maſs diſſoluble in Water, which is endued with excellent medicinal vertues, and is the *Ens parvum Sapientum*, the *Sapo Helmontianus*, the *Sal-Volatile Tartari Starkeianum*, and the *Corrector Matthei.* This ſort of Medicine was very famous, firſt in *England*, and afterwards all over *Europe:* For it powerfully ſoftens and reſolves almoſt every kind of viſcid concretion that is generated from the humours of the human Body: Hence it incides and attenuates the *Saburra* that clogs up the Veſſels, and at the ſame time it gently ſtimulates the Veſſels themſelves, and makes them act with a moderate *impetus*, and thus in both ways proves an aperient, and by Perſpiration, Sweat, and Urine, carries off the Matter of the moſt ſtubborn chronical diſeaſes. If it is digeſted too with ſimple Subſtances, it alters them, and quite changes their natural diſpoſition, and by this means ſubdues the virulent efficacy of many of them, and imbues them with new vertues. Its medicinal power, however, as a univerſal medicine, which is the common fault of Chemiſts, has been too much extoll'd. But here let me caution you, that this combination can never

Attract diſtilled Oils.

be effected, if there is the least Water, either in the Alcohol or Oil, and consequently, never by cold Salts. Nor will it succeed, if but a small portion of the alcaline Salt stands above the Oil, and thus, by coming to the Air, grows ever so little moist.

And expressed ones. Alcali's are easily united likewise with the express'd Oils of Vegetables, or even Animals, as is commonly seen in boiling them into artificial Soap by the assistance of quick Lime, Water, and Fire. And the Substance thus produced is wonderfully efficacious in a great many things, which wou'd otherwise be performed with a great deal of difficulty: But the chief of these are mention'd already under the former head.

And Acids likewise. But alcaline Salts, in a particular manner, attract all kind of Acids whatever, whether produced in the Animal, Vegetable, or Fossil Kingdom, and that, whether dry or moist, pure or diluted. And this power of Alcali's, by which they thus attract Acids, is vastly greater than the same with respect to Water: For in this action, by which they unite these Acids with themselves, they violently expel the Air that resides in the Salts, whence arise such numbers of Air-bubbles, which suddenly appear, and then burst asunder. Nay, and by this very combination, they even repel Water itself from them pretty considerable; and when they are thus saturated, they will easily suffer themselves to be dried, or deprived of their Water, which before, when they were separated, they retained very tenaciously. Pure acid Oil of Vitriol, for instance, when it is alone, you can scarcely, by any Art, free from its Water; Oil of Tartar not without a great deal of difficulty: And yet when you mix them together, the Water is expelled in such a manner, that a Salt almost dry appears in the Vessel under it; as is evident in the Preparation of *Tartarus Vitriolatus*. The same is true of other Acids likewise, when they are combined with an Alcali: And from this consideration, many abstruse things in the Doctrine of *Menstruums* may be easily understood. But this Power, by which Alcali's thus attract Acids, is limited and confined within certain bounds; and hence there appears a vast diversity among them, tho' this, indeed, is more owing to a difference in the Acids than in the Alcali's. This affair, the knowledge of which is exceeding useful, the egregious *Homberg* has very happily explained, as indeed he has every thing else he has attempted, in the *Mem. de l'Ac. Roy. des Sc.* T. I. p. 52. A few of the Observations, therefore, which he has there given us, with your leave, I will here lay before you. One ounce of Salt of Tartar, absorbed all the Acid from 14 ounces of the best distilled Vinegar; and hence, after it was dried, it was increased in its weight 3 drachms, 36 grains; the remaining part of the Vinegar being mere insipid Water. By this means, then, we discover the proportion there is between the Acid, and the Water of the Vinegar. From Spirit of Salt, the same absorbed 2 ounces 5 drachms; and hence became 3 drachms, 14 grains heavier. From Spirit of Nitre, 1 ounce, 2 drachms, 36 grains; its weight being thereby increased 3 drachms, 10 grains. From *Aqua Fortis*, it took up 1 ounce, 2 drachms, 30 grains; gaining hence 3 drachms, 6 grains, in its weight. From Oil of Vitriol, 5 drachms; the increase of its weight, 3 drachms, 5 grains. As these, therefore, are the principal Acids, we may easily infer in the first place, that Acids, tho' very different in their specific Gravity, when they have saturated an Alcali, are observed to have the same weight; for Vinegar, which is the lightest Acid

of

of all these, increased the weight of the same Salt of Tartar, as much as the Oil of Vitriol, which is the heaviest, and most pure: The same too is true of the rest, the difference between the greatest and least increase of weight, being no more than 31 grains, and that only in Vinegar, arising from the *Tartarus Regeneratus*'s being dried with a vast deal of difficulty. 2. Hence, therefore, Acids seem to differ chiefly in the quantity of Water they are diluted with, since the pure Acid, when it is extracted, discovers always the same weight. If 14 ounces, therefore, of the strongest Vinegar, cou'd by any contrivance be reduced into 5 drachms of Acid, by separating the Water from it, and collecting together the Acid without making any alteration in it, wou'd then this collected Acid be as strong as Oil of Vitriol? This is certain, it wou'd be then capable of saturating the same quantity of Alcali. 3. We hence see, Thirdly, how great a part of these Acids is Water; and that, therefore, it is probable, Fourthly, that if these acid Salts could be obtained pure without any Water at all, they would then appear in a solid form. This, however, has never yet been accomplished: Very intense Cold has come nearest it of any thing, but not quite completed it. Hence likewise we may conceive what surprizing effects alcaline *Menstruums* may produce, when they act upon Solvends that have any latent Acid in them; or upon those that are actually consolidated, and held together by an Acid, and hence when this Acid is absorbed, fall again into their constituent Elements. How great an Effervescence is by this means excited? What a production of light Bubbles, that presently mount up, and are continually bursting, and by this means cause a hissing noise, and generate a very elastic Air! But all these sudden effects cannot be understood without a right notion of the Doctrine of Alcali's. But I must here take notice, however, that when this affusion of an Acid to an Alcali is performed gradually and cautiously in warm Liquors, and in a large Vessel, and if at the same time the Vessel is shook after every instillation of the Acid; then you will come at last to that temperament in which there will be no farther Ebullition: And this is called the point of Saturation. If you afterwards proceed to pour on the Acid, there will be no more agitation excited, then there is upon mixing Water with Water: And then the Compound thus produced, is neither Alcali nor Acid, but a neutral one concreted of both, which acquires its name from the Acid that saturated the Alcali. Hence the Acids have been called Males, and the Alcali's Females, and the Compound of them both, Hermaphrodites: The Alcali, the *Vacuum*; the Acid, the Implent: The Alcali the Chaos, and the Acid the impregnating Spirit. This extraordinary Ebullition and Effervescence, now, that arises between the Alcali and the Acid from the violent expulse of the Air and Water, may be owing possibly to these Bodies impetuously driving out whatever lies between them, when they rush strongly into mutual contact: And then this wou'd not arise from any disagreement, but an association of Principles. Will you hence, therefore, be induced to believe, that Acids abound plentifully with Air, but that Alcali's are without it? Certainly, the strongest Alcali, taken very hot out of the Fire, and hence probably deprived of all its Air, will, if it is thrown into an Acid, produce a prodigious Effervescence. Is this the reason then, that Acids, when they are predominant in Animals, are so very flatulent? Do the Salts produced from a combination of Alcali's and Acids, lose the greatest part of their

Air,

Air, and are they hence found to be ſo little flatulent in the human Body? Are for the ſame reaſon, Acids alone, or at leaſt aceſcent Bodies, diſpoſed to ferment? And does there hence, in fermentation, ariſe ſuch a tumultuous Air? Does fermentation hence naturally tend to the generation of Acids; Fire, when it burns openly to the production of Alcali's? And does hence Fermentation, the Parent of Acids, perform its work with a ſmall degree of Heat, whilſt a greater is neceſſary to diſpoſe Animals by putrefaction to become alcalious? But to proceed: We farther obſerve then, that when theſe Salts are once perfectly ſaturated, they continue afterwards at reſt, nor generate any new motion, tho' you perſiſt in pouring upon them either Acids or Alcali's. Among the natural cauſes, therefore, by which motions are excited in the Univerſe that did not appear before, we muſt reckon Alcali's and Acids, at the time when theſe are mixed pure together, which ceaſe again, as ſoon as ever this combination is compleat. Nor can we at all doubt, but that in the action of theſe alcaline *Menſtruums* upon Acids, the Water is expelled out of them as well as the Air, when they thus unite together; for tho' they are perfectly fluid when they are mixed, yet they harden in the very act of combination into little ſaline Glebules, and appear in the Water in the form of pellucid Chryſtals, the watery Liquid being driven out, and ſwimming at top. Nay, and when the Saturation is quite perfect, the Water may be drawn away pure, and without any ſaline Taſte, which being all ſeparated, the remainder is converted into a white, mealy, opake, dry Powder. Theſe compound Salts too, are eaſily dried with a gentle Fire; whereas the ſimple Alcali's and Acids, by whoſe combination they are produced, either cannot be dried at all, or not without the greateſt difficulty. And again, tho' theſe compound Salts thus prepared, part with their Water eaſily; yet it is vaſtly difficult, by the aſſiſtance of Fire alone, to ſeparate either the alcaline or acid Salts, ſo as to procure them quite pure. If any one, for inſtance, has thus made a *Sal-Ammoniac*, from an alcaline Spirit of *Sal-Ammoniac*, and Spirit of Sea-Salt, he may, indeed, ſublime it, by expoſing it to the Fire, but he will not thus be able to ſeparate it into the ſaline Principles of which it was compounded. The ſame likewiſe is true of *Tartarus Vitriolatus*, *Sal Marinus Regeneratus*, *Nitrum Reſuſcitatum*, *Tartarus Regeneratus*, and others. There are, however, ſome methods found out, by which one may obtain this reſolution of compound Salts, into their conſtituent alcaline and acid ſaline Principles; and the knowledge of theſe will lead us into ſome of the moſt ſecret Arts of Chemiſtry. In order, therefore, to get a proper inſight into thoſe, let us proceed to examine ſome farther properties of Alcali's.

The attraction of Acids by Alcali's various.

Alcali's, therefore, attract all known Acids; tho' at the ſame time we muſt take notice, that they attract ſome much more powerfully than others. This aſſertion is abundantly confirmed by Experiments. If to an Alcali perfectly ſaturated with Vinegar, or *Tartarus Regeneratus*, you pour Spirit of Nitre, or Sulphur, or Vitriol, then the latent Alcali will attract into it that Acid, and repel from it the acid of the Vinegar with which it was before ſaturated; and hence a Liquor, which will be nearly Spirit of Vinegar, may be afterwards drawn from this Compound with a moderate Heat, there remaining a conſiderably fixed, regenerated nitrous Salt at the bottom of the Veſſel: and if you put to it Spirit of Salt, Sulphur, or Vitriol, the Alcali will in the ſame manner

ner attract them, and let go the Acid of the Vinegar. Again, if you take an Alcali rightly ſaturated with Spirit of Nitre, and mix it with Spirit of Sea-Salt, there will ariſe in diſtillation an *Aqua Regia*, and a nitrous Salt will be left at the bottom, but changed from its former nature. And if upon an Alcali perfectly ſaturated with Spirit of Salt ſo that it is become Salt, you pour Spirit of Nitre, the Compound, by diſtillation, will yield an *Aqua Regia* likewiſe, and the Salt that remains at the bottom will be of a nitrous kind, containing an inflammable matter that will make it deflagrate, but yet will be ſomewhat different in its nature, both from the Salt and the Nitre. In theſe two caſes, therefore, as between the acid of the Nitre, and that of the Salt, there is no ſuch great difference with reſpect to their acid quality, each of theſe Acids ſeems in ſome meaſure to have diſlodged and driven out the other, by which means they both riſe mixed together, and both of them likewiſe, with the Alcali for their *Baſis*, help to make up the *reſiduum*. If you take an Alcali ſaturated with Spirit of Nitre, and pour upon it Oil of Vitriol, a pure Spirit of Nitre is immediately expelled, and the acid of the Vitriol continues united with the alcaline part of the Nitre, and makes a Salt at the bottom, which has in ſome meaſure the nature of *Tartarus Vitriolatus*, tho' it differs from it in ſome of its qualities; but it has ſcarcely any thing in common with Nitre. And laſtly, if upon factitious or natural Sea-Salt, you pour Oil of Vitriol, there preſently fumes up a very volatile acid Spirit of Sea-Salt, that poſſeſſes almoſt all the known vertues of it, except that it fumes more, is more volatile, and its Vapour is of a ſuffocating nature, till it is corrected by a repeated depuration. All theſe Experiments, therefore, certainly evince, that thoſe Acids, which are naturally contained in a leſs quantity of Water, have a power of uniting themſelves with Alcali's, ſuperior to that of thoſe, which are naturally diluted with a greater. And this Rule, as far as I know, holds true, and may be laid down univerſally, that ſtronger Acids always expel from their reſidence in Alcali's, thoſe Acids which leſs powerfully adhere to them. And then, Secondly, theſe ſtronger Acids always unite themſelves with that Alcali from which the weaker Acid was expelled, and take poſſeſſion of the place in which that was ſeated before. Thirdly, the Salt thus regenerated, loſing the diſpoſition it had from the firſt Acid, which is now removed, puts on very nearly the nature of that Salt, from which was drawn the laſt Acid which is now united with the Alcaline part. In the Fourth place, however, it muſt be confeſs'd, that betwixt the Salts thus produced, and thoſe native Salts from which thoſe Acids were drawn, there is always ſome pretty remarkable difference. Thus, for inſtance, the *Sal Mirabilis Glauberi*, which is prepared by diſtillation of Sea-Salt, with the beſt Oil of Vitriol, is of a very different nature from that which is obtained from Oil of Vitriol, and Oil of Tartar combined together into *Tartarus Vitriolatus*: Which is likewiſe obſerved in others. And again, the Salt which is procured by diſtilling *Glauber*'s Spirit of Nitre, is quite another thing from his *Sal Mirabilis*, tho' both theſe are ſuppoſed to be produced from the ſame Acid and Alcali. This rule, therefore, which has been laid down by the moſt famous Chemiſts, *That Acids always convert Alcali's into their nature in ſuch a manner, that from theſe Compounds may be conſtantly regenerated thoſe Salts, which before yielded thoſe Acids*, is too general, and muſt be underſtood with ſome reſtriction. In the Fifth place, I obſerve farther, that when theſe Acids thus poured upon compound Salt, expel thence the Acids that were united with them before, and unite themselves with the remaining Alcali's, this new combination is effected without any considerable Effervescence: For the first Acid quits its place, and the last succeeds it without much conflict, notwithstanding there arises such a prodigious ebullition, when a pure Alcali is mixed with a pure Acid. Nor does it appear, that any Air is generated by this adunation, tho' in the other case it was expelled in so large a quantity. Does this happen, then, because the Effervescence that was excited in the preceding Saturation, had expelled all the Air, so that now the new Acid does nothing more than enter into the saturated Alcali thus deprived of its Air, and remains there without either expelling any Air, or attracting any? This certainly seems confirmed by this Observation, that if that second Acid is expelled by a stronger Acid, and is then mixed with another Alcali, it will with that raise as violent an Effervescence as the first did; so that in this Operation there shall be produced again the same Heat, Noise, and Air, whilst in the compound Salt there was scarcely any such appearance. Hence then we understand, the wonderful *Metempsychosis* and *Palingenesia* of these acid Salts: By these many philosophical arts may be invented and cultivated: By these, many unheard of changes may be brought about in natural Bodies, of which there are at present no instances, nor any known Instruments, and of which, consequently, no account can be given from any other principles which mankind has hitherto been acquainted with. These things, Gentlemen, it was absolutely necessary to lay clearly before you, whilst we had Alcali's under consideration as solvent *Menstruums*; for in the application of these to various Bodies, you will meet with an infinite number of *Phænomena*, which without the knowledge of this Doctrine, you could not possibly account for.

Problems hence raised.

There are some other things, likewise, which occur upon this head, that one would be still farther induced to suspect, but which require, however, a more mature inquiry, before they can be admitted as certain: These, therefore, with your leave, I will here add by way of Problems? Do all fixed Alcali's owe their origin to Fire only, as their generating cause? Do all volatile Alcali's depend alone for their production, on a degree of Heat that is necessary to putrefaction? Is it possible in nature, that a fixed, or a volatile Alcali, if exposed to the open Air, can long continue an Alcali? Or will they, by every where meeting with an Acid, or an oily Substance, be converted into a neutral Salt, or a *Sapo?* Does not the same thing happen to them likewise in Vegetables, and in the Bodies of Animals? Is there not by this means continually produced a very large quantity of compound Salts, and of those in particular which will arise from an Alcali, and that Salt whose acid is every where distributed? As natural Acids, therefore, or those which are generated from Vegetables by Fermentation, are always, and every where present, does it not hence happen, that this compound Salt is most frequently of the nature of *Tartarus Regeneratus*, or of that of the *Spiritus Ophthalmicus Minderiri*, which arises from the combination of a pure volatile alcaline Salt, with distilled Spirit of Vinegar, which is not acrid, but vastly penetrating and active, tho' at the same time not endued with much Taste. But amongst all these things, there is nothing, that for very weighty reasons, deserves more to be examined into, than the origin and nature of those Salts, which on account of their commonness and use we

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are the moſt acquainted with of any, *viz.* Fountain-Salt, *Sal-Gem*, Sea-Salt, and Nitre. Concerning theſe, we would particularly inquire, whether they are produced by a combination of the Acid, into which they may be chemically reſolved, with a fixed vegetable Alcali? Or whether, on the contrary, they are ſimple Bodies, juſt as nature has generated them, and by the action of the Fire are rather changed in their diſpoſition, than ſeparated into their proper conſtituent parts? The Chemiſts, certainly, eſpecially after *Franciſcus Travaginus* of *Venice*, and the famous *Otto Tachenius*, had publiſhed their Writings of Alcali's and Acids, have been of Opinion, that all theſe Salts were in reality originally compounded of an Alcali and an Acid that were before in being, and that they then firſt appeared in the Univerſe. After a good deal of conſideration of this matter, however, it appears very probable to me, that the Salt in the Sea did actually exiſt before there was any the leaſt ſign of the acid Spirit of this Salt, or any fixed Alcali from burnt Vegetables to be found in the World. Nay, from Sea-Salt, no Mortal has been ever able by any Experiment whatever, to procure one Grain of a fixed Alcali. This, I myſelf, have ſufficiently experienced. Take any quantity of the pureſt, drieſt Sea-Salt, and by long rubbing, mix it intimately with three times as much very dry common Bole: Urge it then in a very ſtrong Fire in what manner you pleaſe, and it will yield but a certain proportion of acid Spirit of Salt; nor can you procure any more from it, tho' you increaſe your Fire to ever ſo great a degree. At the bottom of the Veſſel, then, there will always remain the Bole, which will ſtill continue Salt. Take this, and with Water waſh out all the Salt, then filter it carefully, and form it into Chryſtals; and what will you by this means be able to procure? For my own part, I can ſay, I never found any thing of an Alcali in it, but that it always ſtill remained Sea-Salt. Beſides, as far as I have been able to inform myſelf, no Perſon living has ever diſcovered any ſuch thing as an acid Spirit of Nitre, or Sea-Salt, but what was produced by Art or Fire, from theſe pre-exiſtent Salts: And when this is the caſe, it ſeems much rather to ariſe from a real change, than a proper ſeparation of the concurrent parts. I confeſs, indeed, that theſe Acids, when they are poured upon alcalious Salts according to art, do produce regenerated Salts, which ſeem to come as near as poſſible to thoſe Salts from which the Acids were drawn: But yet, ſtill there is always ſome difference betwixt theſe regenerated Salts, and the native ones. Theſe things, then, being rightly conſidered, make it plain, that we can't be ſo certain about the compoſition, and reſolution of theſe Salts, as thoſe Gentlemen wou'd perſuade us. In the mean time, you obſerve, how cautiouſly we ſhould look about us, when we make uſe of Alcali's in the ſolution of Bodies: For by the acceſſion of ſomething elſe to them, theſe Alcali's may be immediately changed into another Salt, and act no longer by that ſimple alcaline vertue, which it had when it was applied, but according to the diſpoſition of the new Salt that is thus produced. But enough of this: Let us therefore proceed to ſomething elſe.

In the ſeventh place, then, there is this very conſiderable in fix'd Alcali's, that when they are apply'd to certain Bodies that we wou'd have perfectly diſſolved, they ſeem, indeed, at firſt to effect this, but are preſently converted into Maſſes that are ſcarcely to be diſſolved by any *Menſtruums*, and which are in their — A fixed Alcali produces Glaſs.

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nature as far different from *Menstruums* as any thing can be. If, for instance, a hundred parts of pure Sand, or calcined Flints are reduced to a fine Powder like Flower, and then intimately mixed with a hundred and fifteen parts of a pure fixed alcaline Salt powdered likewise very fine; and this Mixture is then exposed to a moderate Fire in a Glass-house arch for the space of an hour, and kept constantly stirring, and afterwards, keeping it still continually stirring, to a stronger Fire for five hours more; you will by this means prepare a matter, which will have the dispositions necessary for making the choicest Glass. But if this, however, is then put up into a good dry Cask, and set in a dry warm place for four or more months, the combination of the Alcali and the Flints will be still farther perfected: If this Matter, then, thus prepared, is put into the Glass-house Pots, and exposed to the intense Heat of the Furnace, it will melt into a thick, tenacious, pinguious kind of a Liquid; and whilst it is boiling there, it will cast up a Scum to the Surface, which continually increasing more and more, rises often to a fourth part of the whole Mass. When this Scum now is carefully removed, till there appears no more of it, and the pure despumated Matter has been kept two or three days in fusion, what then remains in the Pot, the Workmen call the Metal, which when it comes to harden in the cold, produces the finest Glass. If this now was not evident from common Experience, what mortal living cou'd ever have imagined, that a solvent Alcali, spontaneously dissolving in the Air, cou'd, when it was rendered vastly active by the intenseness of the Fire, be converted with the Solvend into a metalline Mass perhaps, setting aside its want of malleability? This property, therefore, of Alcali's, must by all means be inserted in this account of the power of alcaline *Menstruums*. For here, when the Alcali, by the action of Fire is made to flow like Water, it hence becomes capable of dissolving the Powder of the Flints in the same manner, and by this very means becomes immediately so altered itself, that it retains nothing of its former disposition, but intirely acquires a new one. Hence, then, you see how *Menstruums*, and those very powerful ones too, may be joined in an indissoluble union with those Bodies which they have most intimately dissolved; which concretion is always so much the solider, as the Solution is more perfect. We learn, therefore, from this Experiment, that Alcali's, whilst they perfectly dissolve other Bodies, are hence sometimes so altered themselves, that they absolutely lose the nature of a Salt; for if there is any substance in Nature, that is intirely different from Salt, Glass, certainly, must by every-body be judged to be such a one; notwithstanding it is near a third part Alcali. And in this Operation, is it not very remarkable, that this alcaline Salt, shou'd, in the very act of Solution, so immediately put off its alcaline Nature, as soon as ever it is converted into Glass? For of all the proper characteristics of an Alcali, there is not so much as one left. It has lost all its Taste: It does not cause an Effervescence with any Acid: It makes no alterations in Colours: It becomes exceeding soft, and perfectly free from any caustic Acrimony: Nay, it is much more fix'd in the Fire when it is turned into Glass, than it was before, when it existed in form of an alcaline Salt. But how very difficult is it now to be put into fusion, as it requires so strong a Fire applied to it for so long a time to make it melt? And which is still more surprizing, as soon as ever it begins to flow, and is converted into Glass, it becomes a tenacious Mass cohering together like

Pitch, and is ſo ductile, and pliable, that you may form it into whatever ſhapes you pleaſe: Nay, and if you thruſt an Iron into it, it will ſo adhere to it, as to come out of the Melting-pot with it, and be retained upon it. But we ſtill farther obſerve here with admiration, that from two Bodies exceedingly opake, concreted into one ſolid ſubſtance, ſhould be formed one ſo pellucid, that in the beſt ſort of it we find the tranſparency of pure Water. And laſtly, to detain you no longer, we ſee here a Body produced by ſolution, and that from a fixed alcaline Salt, which of all Salts is the moſt ſoluble, which itſelf cannot be diſſolved by any known *Menſtruum* whatſoever. Upon this, neither Water, Spirits, Oils, acid, alcalious, ſimple, or compound Salts, nay, nor the very *Spiritus Vini Philoſophicus*, the *Sales Circulati Philoſophorum*, nor even the *Mercurius Philoſophorum* has any influence: For the Adepts *bona fide* aſſure us, that all theſe *Menſtruums* are produced within glaſs Veſſels: Nay, and they unanimouſly agree, likewiſe, that all their digeſtions, diſtillations, circulations, fixations and ſolutions of all Bodies whatſoever, they perform with their *Menſtruums* in Glaſs alone. And, which is ſtill more, even the ſecret Operations of the Alcaheſt itſelf, by which they tell us, all Bodies are converted into Water, are brought to perfection in glaſs Veſſels, without their ſuffering from it any manner of alteration. Do not we, then, hence evidently learn, how difficult it is for a Philoſopher to explain the origin of a given natural Body? How vaſtly hard to aſſign the Principles of which it was at firſt compounded, by plainly reſolving it into thoſe Principles, in ſuch a manner, as by compounding them again certainly to produce the ſame kind of Body? If a man was perfectly acquainted with every other part of Natural Philoſophy, but know nothing at all of the Art of Glaſs, what judgment, with all his ſkill and application, could he make of a piece of Glaſs that ſhould be given him to examine? Certainly, as far as I am able to judge, he would not find the leaſt indication by which he could poſſibly ſuſpect that this Subſtance was concreted in an intenſe Fire, from an alcalious Salt, and calcin'd Flints? What a taſk then do the Philoſophers undertake, when poorly furniſhed with Experiments, they diſpute about the origin, nature, and principles of natural Chryſtals, and even Gems themſelves? We had better, certainly, in theſe caſes, confeſs we are in the dark, than to hope ſuch mighty things from our narrow capacities. For the difficulty of coming rightly at the knowledge of theſe things does not depend only upon the nature of the concurrent Principles, but alſo upon that ſurprizing effect of Fire, by which thoſe very Principles are altered at the time they are coaleſcing into one Maſs.

Difference of Alcali's with regard to their purity.

Having thus, then, examined into the origin and nature of alcalious *Menſtruums*, and explained their effects upon various, and, indeed, the principal kinds of Bodies, we muſt obſerve, before we proceed, that from what has been ſaid it appears, that more or leſs of the acid Salt contained in the Vegetables, by burning which the Alcali was produced, may ſtill adhere to it; and, conſequently, that this alcaline Salt will be of a different nature from what it would have been, had it been perfectly free from this Acid. And the ſame muſt likewiſe be conceived of the adhering Oil and Earth. Hence, therefore, according to the various proportion of theſe Principles, the common Alcali's will be very different. Nor for this reaſon is it at all a wonder, that ſome writers ſhould give us an account of Experiments performed by Alcali's, which, upon being afterwards tried by others, would not ſucceed; for it is not unlikely, but that the alcaline Salt they made uſe of was of a different nature.

From other Bodies added to them.

But there is likewiſe a very ſurprizing cauſtic, and conſuming quality communicated to Alcali's, by mixing them according to art with Quick-Lime, made of burnt Oyſter-ſhells, or ſtony Sea-plants, but, particularly, of alcalious calcin'd Flints. For by this means ſuch a fiery, acrid, Alcali is produced, as being boiled with them, will ſoften and diſſolve almoſt all the Solids, both of Animals and Vegetables; ſo that here you have the moſt acrid, alcaline Solvent procured from the ſame matter, which, we obſerved before, produced mild, unactive Glaſs, *viz.* this *Calx* and an Alcali. Nay, and this Alcali, when it is thus rendered more acrid with Quick-Lime, and is dried with a pretty ſtrong Fire, will eaſily melt almoſt the Wax; and hence, if any Bodies are thrown into it, it acts upon, and diſſolves them in a very particular manner. Was this the ſecret which ſome of the ancient Alchemiſts made uſe of, when they tell us they performed ſome very ſingular Operations, by means of an Alcali that melted with a gentle Fire? Might not this poſſibly be their *Sal Tartari inceratus*, ſo called, becauſe, like Wax, it diſſolv'd ſo eaſily in the Fire?

Limits of an Alcali.

We have now, I think, treated ſufficiently of Alcali's. In the mean time, however, it is neceſſary I ſhould juſt obſerve to you, that Alcali's act with no diſſolving power upon pure Mercury; for compound theſe two Bodies together in whatſoever manner you pleaſe, the Mercury is not found to ſuffer any alteration. And hence, therefore, upon thoſe Metals, which the Adepts tell us are made up of the pureſt Mercury, and an igneous, metallic, ſulphureous, fixed Spirit, with regard to the mercurial part, they are able to effect nothing by way of ſolution. Gold, therefore, and Silver, to the beſt of my knowledge at leaſt, ſuffer no alterations from Alcali's. Upon the other Metals, indeed, an Alcali is found to act with more efficacy; perhaps, becauſe theſe have ſome other Matter united with their mercurial part, which coming near to the nature of an Oil, or a Sulphur, is more expoſed to the action of an alcaline Salt. And as theſe external Sulphurs do not ſuffer themſelves very eaſily to be ſeparated from the metalline Glebe, with which they are concreted, hence it often happens, that whilſt alcaline Salts are acting upon the Sulphur, they ſeem to induce a change, likewiſe, upon the mercurial part which is cloſely united with it, though, in reality, they don't at all affect the nature of the Mercury. This I learnt evidently in melting common Antimony with Salt of Tartar; for the whole Subſtance, as well the mercurial part of the Antimony, as the ſulphureous, was diſſolved into one brown Maſs, without any *Regulus* ſubſiding. But if you take *Regulus* of Antimony, from which the external Sulphur is firſt ſeparated, and melt it with a fixed Alcali, then the Alcali, when it is in fuſion, ſwimming at top, will extract ſtill ſomething of Sulphur, and by this means tinge the alcaline Salt with a golden colour; and at the ſame time, the reguline, mercurial part of the Antimony which lies under it, will become purer, and of a finer Silver colour. Hence then the power of Alcali's, conſidered as *Menſtruums*, upon Metals, ſeems to be limited; for though you apply them even to calcin'd Metals,

Metals, they don't appear to be able, by the action of Fire, to penetrate into that Sulphur which fixes their Mercury into the form of particular Metals. Certainly, after all the contrivances that have been made use of, the production of a metallic Mercury, by the assistance of fixed Alcali's has not succeeded. Nay, the very greatest Masters of the Art, after so many Experiments made for this purpose, have declared, that they believe these Mercuries have been seen rather in idea, than in fact. For my own part, after taking a great deal of pains in this matter, I confess, the event has not answered, as has been promised. If, therefore, those things are true, which *Boyle*, *Tachenius*, *Homberg*, and others have wrote concerning the resuscitation of the Mercuries of Metals, there must be some secret method of making the resuscitating Alcali's penetrate even into their fixing Sulphur.

Passing these things by, therefore, the first and principal vertue of Alcali's seems to be this; that if they can but be applied, and determined in their action upon animal, vegetable, or fossil concretions, whether fixed or volatile, so far as they are of an oily, balsamic, gummy, resinous, or gummy-resinous nature, and therefore howsoever concreted from oily substances, they intimately open, attenuate, and resolve them all, and dispose them to be perfectly miscible with Water, Alcohol, and Oils; the same effect, likewise, they have upon pure, proper Sulphurs, or these compounded and mixed with other substances. Hence Alcali's come to be the principal instrument in extracting what the Chemists call Tinctures. By the help of these are prepared, according to the opinion of these Gentlemen, at least, the most noble Medicines. Gum-Ivy, Juniper, Lac, Myrrh, and others, are not dissolved by Water, or Alcohol, without a great deal of difficulty; but if they are first properly prepared by these Alcali's diluted and heated, they dissolve in them very easily, and if they are then dried with a gentle Fire, they will excellently give out their vertues in solution. In the second place, when the elements of any Bodies are concreted together by means of a *Gluten*, or an Acid, interposed between them, then these Alcali's often bring about the Solution desired, by attracting into them the coagulating Acid, and by this means removing the *Vinculum*, and setting the Elements again at liberty. We are sensible, indeed, that these Acids are often so intimately united with some Bodies, that they won't be very readily, nor so perfectly fetched out the first time by these Alcali's; but still at last they generally yield to them: Mercury, when it is once accurately corroded by Spirit of Nitre, and then by the action of Fire converted into *Mercurius præcipitatus Ruber* does not, upon pouring on of Oil of Tartar *per Deliquium*, immediately return to fluid Mercury, but is changed into another Powder; but yet if this is put into a retort, and forced off from this alcaline Salt, with a strong Fire, the Mercury will leave its Acid united with the Alcali, aud will recover again its pristine form. In the third place, if to some Bodies, when they are dissolved into their smallest Particles by an acid *Menstruum*, you apply pure Alcali's, these Alcali's often acquire a new vertue, by which being more intimately admitted to these Elements, they dissolve them much more efficaciously than if they had acted upon the same Bodies without this previous corrosion by the Acid. And hence we see, that in most of the methods by which the Alchemists have endeavour- Its Action.

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ed to procure fluid Mercury from Metals, they first order you to calcine them with Acids, and then mix and agitate them with Alcali's.

A volatile Alcali. In the last place, now, it is necessary we should say something of volatile, alcalious *Menstruums*. Whether any volatile Alcali, then, ever naturally existed, as such, before the putrefaction or distillation of Animals or Vegetables, I won't pretend absolutely to determine. Some persons, perhaps, may be of opinion, that that singular Salt, which is found in chalybeate Waters, should be referred hither; but this I think must not be done without proper deliberation, as this cannot by any Art whatever be made to resemble the other volatile Alcali's, in all its characters; though it may be more properly, indeed, referr'd to these, than to Acids, as the famous *Hoffman* has elegantly proved in his writings upon this subject. The Bodies, however, of all Animals whatsoever, and those of Vegetables, that will putrify, are constantly so altered and disposed by putrefaction, as to have their saline Principle become a perfect volatile Alcali. The acrid Vegetables that we formerly mentioned will yield these Salts, by simple distillation; as do all Animals, likewise, that have been hitherto examined. And lastly, if the juices of Animals, not yet alcalious, are mixed with a fixed Alcali, they are so changed, that the other part being attracted into the fixed Alcali, they instanly send forth an alcaline Vapour, and by the action of the Fire yield immediately a volatile Alcali. This Salt, now, though produced after so many different manners, if it is perfectly purified according to art, will have exactly the very same appearance, and the same vertues: And these vertues are pretty nearly the same as those of fixed Alcali's, though in some measure, however, they differ from them in their effect, as plainly appears upon comparing them together. Volatile Alcali's, spontaneously, or in a very small degree of Heat, are always themselves in motion and action: Fixed Alcali's require a much greater assistance from the Fire, to make them efficacious. Volatile Alcali's soon fly off by Heat, and consequently from the Substance to be dissolved, if heated, and therefore do not continue applied to it in such a manner as to be able to exert its power upon it; whereas fixed ones, on the other hand, by means of the Fire that keeps them in agitation, persists to act constantly upon the Body exposed to them, if that is itself of a fixed nature, and does not quit them. When volatile Alcali's, however, are made to adhere to the solvend Body, they then, in a moderate Heat, become vastly efficacious, and that too very quickly. This appears evidently in the pure Alcali of Urine, which, if you apply it to the human Body, and cover it over with an adhesive Plaister, there instantly arises in the part, Heat, Pain, and an Inflammation, succeeded by a black, gangrenous Eschar, and an Erosion to the very Bones. These differences, then, being thus taken notice of, the other properties of volatile Alcali's may be learned from the History of the fixed ones. Let us, therefore, briefly take a view of,

Acid Menstruums.

Native, vegetable Acids. The physical character of an Acid has been given already; and upon examination it has appeared, that Acids rarely exist in a solid form, except in the essential Salt of acid and austere Plants, and in Tartar. But whatever Acids have been found in Vegetables, and Fossils, I have never yet known any proper to Animals. Vegetable Acids are either native, or produced by the help of Fermentation. Native vegetable Acids, ſeem to owe their origin intirely to the Juices that the Plants draw out of their mother Earth; and hence, perhaps, all theſe may, in this reſpect, be look'd upon as of the nature of Foſſils, eſpecially as the Plants, that grow in the Sea, and have not their Roots inſerted into the Earth at its bottom, conſiſt purely of alcaleſcent parts, and in diſtillation yield an oily, volatile Alcali, as the illuſtrious Count *Marſilli*, in his Writings upon this head, informs us, he long ago obſerved. In ſome Vegetables the native Acids diſcover themſelves evidently; as in Sorrel, the *Trifolium Acetoſum*, and the Juice of all Fruits, whether the Pulpous, or Summer Fruits, eſpecially before they are ripe, for afterwards, being concocted by the warmth of the Sun, they in ſome meaſure loſe their acidity, and grow more mild. In the ſpring time, too, when Vegetables begin to put forth, and ſhow again new ſigns of Life, the Juices often contain a perfect Acid, nearly like that of Vinegar. In other Vegetables there is likewiſe a true Acid, but it lies more concealed, as in Woods, and Aromatics. In Guaiacum, Saſſafras, Cinnamon, and a vaſt many more, who would ever have expected an Acid, if it had not appeared ſo evidently by diſtillation? In the nobleſt Balſams, who would have thought of any ſuch Acid as Turpentine, when it is diſtilled, yields ſo eaſily, and in ſuch great abundance? Theſe Acids, indeed, can ſcarcely be obtained pure, but are blended with other Bodies, and hence it is exceeding difficult to treat clearly of their proper action: The vertue of ſome of them, however, upon certain Bodies, is evident, as we ſee the freſh Juice of Oranges, Citrons, and Lemons, diſſolves Lead, Tin, Copper, and Iron, and pretty ſtrongly calcines them, as well as foſſil Acids. Theſe acid Salts, however, are formed into ſolid Glebules, in a different manner from the other. *viz.* by taking the very thin, expreſſed, acid Juices, filtering them, inſpiſſating them, and then letting them ſtand quiet, till they ſhoot into ſaline Chryſtals; of theſe I have ſhewn you ſome every year procured from Sorrel, which are exceeding like Tartar, and have the true native vegetable acidity.

But fermentation ſeems more and more to exalt the latent Acid of Vegetables. For the Juices of Vegetables that are exceeding ripe, and ſweet, appear to have hardly any thing of acidity in them, as we ſee evidently in the expreſſed Juice of Grapes, Caſſia, Manna, Honey, and Sugar; and yet when theſe are rightly fermented, and ſet a working, an Acid may be preſently drawn from them, but eſpecially when the Wine begins to grow finer and more ſubtil. In ripe, mealy Corn, is there the leaſt indication of an Acid? And yet when this has fermented but a very little while, it diſcovers an acidity. As theſe Acids, now, thus produced, are of a ſomething different, and more ſubtil nature than the native ones; hence, to diſtinguiſh them, we may be allowed, for the future, to call them vinous Acids. Theſe vinous Acids then are of two ſorts; for either they are diſperſed through the Wine, in form of liquid Acids; or elſe in time collect themſelves together in the Wine, and fix themſelves to the ſurface of the Veſſel, in the ſolid form of Tartar. And theſe fermented vinous Acids have pretty nearly the ſame vertues as the preceding native ones.

Acids, liquid and ſolid, call'd vinous.

But

Acetose Acids.

But the Acids of Vegetables, now, produced by a second fermentation, with your leave, I will call by the name of acetose ones. For if any known Wines are with acid, rough, crude ones, made to undergo again a proper acetose fermentation, they will be converted into *(Aceta)* Vinegars, will consume their proper Tartar, become much more acid, and will acquire a stronger and more durable Acid, which will remain even in distillation: Hence in Vinegars there is obtained a pure, active Acid, and then they are called pure, distilled, acetose Acids. These last, now, are of such incredible service and efficacy in the chemical art, that hence all other *Menstruums*, likewise, have been called *Aceta* too, as appears evident in the *Aceta Philosophorum*.

Fermenting Acids.

But among these Acids, we must take notice, likewise, of fermenting Acids; by which we mean, vegetable Juices, that are in the very act of fermentation, and thus in a kind of middle state between their natural one, and that which they pass into when the fermentation is perfectly compleated; for during this time, the most elastic part of the fermenting Liquid acquires such a power as is not to be equalled by any thing I know of in all nature. For if this (*Sylvestris*) Sylvestrian, incoercible, explosive, acid Spirit, rising from a vast quantity of fermenting Vegetables, should pass through a very small venthole into the nostrils of the strongest man, it would strike him dead in an instant. If it does not act with all its force, it causes a sudden Apoplexy; if less powerfully still, a Childishness, with a *Paraplegia*; if very lightly, only a Giddiness. The truth of all this has been too certainly evinced by melancholy instances. Hence we come to have a more perfect idea of the more immediate cause of drunkenness, and the *tremors* upon the Nerves, that are a consequence of it. And hence we see the occasion of that surprizing *Phenomenon* mentioned by the illustrious *Cornaro*, in his noble treatise wrote in the praise of Sobriety, where he tell us, as he grew in years, he was annually, just before the time of vintage, troubled with a *Languor*, and lowness of spirits, which would not give way to any Medicine, or Regimen, but increased so as to become extreme, till, upon drinking new Must, he recruited his exhausted Spirits, and returned again to his former Vigour: This, then, he continued to enjoy till the Wine of that year began to grow old, and then relapsed into his usual debility, and was forced to wait for a fresh recruit of new Wine to set him to rights again. From all this then we evidently learn, what an incredible effect this fermenting Acid has upon the Bodies of Animals, either for their detriment, or their advantage. Whence does it happen, that the *Cholera Morbus*, in so short a time becomes so fatal? Certainly from Must, and ripe Summer Fruits, actually fermenting in the Stomach, and smaller Guts, and by the explosion of their Spirits, contracting the Muscles of these parts into spasms, that often prove mortal. Of this there is a remarkable instance in the *British Philosophical Transactions*, where that excellent Anatomist, St. *Andrew*, gives a very accurate account of the Body of a Man that fell into a *Cholera*, upon drinking a large quantity of bottled Ale, of which he died, in the manner there described. As by these accounts, now, the singular efficacy of such an Acid does evidently appear, so likewise it seems exceeding probable, that those Spirits, considered as a *Menstruum*, produce often upon other Bodies very surprizing effects. And I have sometimes doubted, whether this wonderful Spirit is not fixed in Tartar, and afterwards, when by the action of the Fire, in the distillation

diſtillation of this Salt, it is ſet at liberty, does not produce that elaſtic Vapour which the Chemiſts have always obſerved to be ſo vaſtly powerful, as to be able to burſt to pieces all their Glaſſes, let them be ever ſo large. In the mean time, however, this is certain, that if Bodies that we want to be diſſolved, are put into fermentable ſubſtances, in the very act of fermentation, they will be diſſolved by them in a very different manner from what they would have been, had they been mixed with them, when they were not aſſiſted by this fermentative power. This is evident in throwing green Herbs into Wine, or Ale, when they are working; for hence you have a Liquor in which all their vertues ſeem to be moſt equably united into one and the ſame Liquid, and afterwards to act with a joint efficacy. And thus the different ingredients in *Theriaca*, when they are mixed together with Honey, are reduced into one homogeneous Maſs, and conſpire together in the ſame operation.

But pure, thin, acetoſe Acids, are procured pretty much in their natural form, from Vegetables expoſed to the Fire: For if you take a ſtick of Wood, a green one in particular, and lay it upon a clear Fire, in ſuch a manner, that both the ends ſhall lie out, then the Fire acting upon the middle part of the Wood will fuſe the humours that are contained there, and in form of Water drive them out of the extremities with a hiſſing and froth: And this Liquor, when it is examin'd, appears to be a pure Acid, has all the properties of Acids, and the diſſolving qualities common to them. Hence, then, we learn, how the Smoke of Wood, that which is green in particular, makes the Eyes ſmart ſo violently, *viz.* by the acrid Acid which it diſperſes all about. This, likewiſe, when it penetrates into Fleſh or Fiſh, that are hung in Smoke, tinges them with a red colour, and by its acidity prevents their growing putrid, or rancid. And this Acid is exceedingly like thoſe that exiſt naturally in moſt Trees. Acid vegetable by burning.

But again, there are diſcovered other very ſingular Acids, that are in ſome meaſure of a balſamic, and oily nature, which are drawn from Vegetables by Fire in a cloſe Veſſel, both *per adſcenſum* and *deſcenſum*. Thus the Wood of Guaiacum, Juniper, Oak, and a vaſt many others, if you reduce them to dry Shavings, and carefully diſtill them in a Retort, yield a limpid, reddiſh Liquor, which is very acid, ſomewhat oily, and has a good deal the ſmell of a Herring dried in Smoke. And the Liquid thus prepared is ſtrongly acid, eſpecially if it is depurated by Filtration, and letting it ſtand quiet, called rectification; and the acid ſolvent vertue of this *Menſtruum* is perfectly ſingular. In the human Body it produces wonderful effects, by attenuating, preſerving, ſtimulating, and reſiſting putrefaction, and carrying off the noxious Matter by Sweat and Urine. If in theſe *Menſtruums*, therefore, the medicated vertues of Plants are diſſolved, the ſolutions become exceedingly efficacious; as they act by their very ſubtil, penetrating, ſingular Acid, and exalt the qualities of the Bodies diſſolved in them. Of all theſe vegetable Acids, therefore, it is true, that they are capable of intimately diſſolving many animal, vegetable, foſſil and metalline Subſtances: By digeſtion and coction they diſſolve the Horns, Hoofs, Bones, and Fleſh of Animals: The Shells of Fiſh, and other Animals, they perfectly corrode into a pellucid Liquor: And Metals they diſſolve, as I hinted before, except Mercury, Silver, and Gold. The ſame diſtilled.

Art, therefore, has ſought out and diſcovered other Acids, which are able to diſſolve Mercury, Gold, Silver, and other Foſſils, which were unaffected by vegetable Acids, and hence were not eaſily managed by the power of human Bodies. For vegetable Acids may, by the action of a ſtrong healthy Body, eſpecially if aſſiſted by a conſiderable motion, be ſo changed, as to loſe their Acid nature, and be converted into another kind of Salt: But thoſe Acids that we are at preſent acquainted with, which are capable of diſſolving Mercury, Gold, and Silver, are not ſo eaſily ſubdued by the concoctive, animal powers, but being ſuperiour to them, for the moſt part deſtroy them. And hence theſe become almoſt Poiſon to Animals, except in a very few caſes, where a putrid Alcaleſcence prevails, as when alcalious Poiſons are taken in by them, or in a putrid ſtate of the Humours, as where the virulence of a Plague, or the ſudden putrefaction of the Small Pox are to be dealt with.

Native, very rare. Foſſil, native Acids, now, are found to be very few, ſince it has been diſcovered, that the medicinal Waters once looked upon as acid, approach, in every character, nearer to an Alcali. There is often, indeed, a Vapour obſerved in Mines, which reſembles a ſuffocating, ſulphureous Acid, and by other marks demonſtrates its acidity: But it is exceeding ſeldom that it is found alone, and very pure, in form of a Fluid.

Fixed ones, frequent. But whenever it happens, which is very often the caſe, that it meets with a ſolid Body, that is capable of attracting that Acid, it then unites with it, and becomes fixed, and capable of examination: And when it is afterwards drawn out of that fixed Body, it then falls under the notice of our ſenſes, and then, as far as one is able to judge of it, appears to be always one and the ſame.

In Sulphur. For, as I formerly took notice to you, if it lays hold of a pinguious Foſſil, it produces the various kinds of Sulphurs, which if they are burnt, emit Fumes, which being collected, refrigerated, and mixed with the humid Air, yield the Spirit, or Oil of Sulphur *per Campanam*. If you take this, now, and put it into a clean glaſs Veſſel, and expoſe it a good while to the heat of boiling Water, you will diſtill from it a conſiderable quantity of pure Water, which, whilſt the Sulphur was burning, had inſinuated itſelf out of Air into the Acid; and there will then remain at the bottom a ponderous, thick, cauſtic Acid, which in every character reſembles the pureſt Oil of Vitriol, except in this alone, that it contains nothing of a volatile Metal, which is always more or leſs in Oil of Vitriol.

In Alum. But if this acid happens to get among Lime-ſtones, and corrodes them, it then produces Alums, which are of different kinds, according to the diverſity of the matter that is mixed with them. All theſe, now, if they are firſt lightly calcined, and then with an intenſe Fire urged into Vapours, will by the condenſation of theſe yield a Liquor, which, when it is purified according to art, is the very ſame with the former procured from burning Sulphur, without any difference at all.

In Vitriol of Iron. Again, if you take native green Vitriol, and by the help of a moderate Heat reduce it to a dry, white Powder, and then by gentle degrees expoſe it to the Fire, till you come to the greateſt, it will emit white, cloudy Vapours, which collected into a Liquor, and accurately depurated, is the very ſame again as was obtained from the Sulphur, and Alum.

The

The blue vitriol, likewise, if it is treated in the same manner, gives a liquid, which is the same with the former, nor can be distinguished from them, when it is rectified according to Art. All these acid Liquors, now, if they are urged with a heat of 560 degrees, boil, emit white cloudy Fumes, which disperse themselves about, and float to great distances, and destroy all Animals we are acquainted with, even Insects themselves. If they happen to be drawn into the human Lungs, in their full force, they presently excite an acute Cough, not to be removed, and then a suffocating, fatal *Dyspnœa*, with sudden death: Or if from some concurring circumstances they don't act so violently, they bring on a most troublesome Asthma, that continues during life. And the very same effect has Oil of Sulphur, Alum, Vitriol of Copper, and Copperas, as soon as ever, by the action of the Fire, they are raised into Vapours, by combustion, distillation, or ebullition. Nay, and take any of these Acids, which you please, unite it with a pinguious Oil, and it produces a Sulphur; with Lime-Earth, an Alum; with Iron, Vitriol of Iron; and with Copper, Calcanthum: From all these considerations, then, we are induced to believe, that the native acid, so ponderous, and difficult to boil, which is found in the fossil Kingdom, is always one and the same, that is to say, if you consider it as existing in form of a pure Acid. The properties of this Acid, now, are, first, that it is naturally the heaviest of all Acids. To Spirit of Nitre its specific gravity is as 11 to 9: To Spirit of Salt, as 11 to 8: To *Aqua Fortis*, as 11 to 9: And to distilled Vinegar, as 11 to 7, nearly, *Mem. de l'Ac. Roy. des. Sc.* 1699. p. 47. Secondly, it is of all Acids the most fixed; for in the heat of boiling Water it never emits any Fumes, except by means of the Water that adheres to it, not of the Acid itself: If you urge these Acids, however, with something more than 560 degrees of heat, they will then boil; and at the same time will send forth noxious Vapours. In the third place, these Acids, being perfectly freed from all their Water, by a strong Fire, and hence being rendered very pure, heavy, and acrid, very greedily attract into them Water out of the Air, and by this means dilute themselves, and increase their weight. Fourthly, the same thus rendered very pure, grow very hot immediately, upon the effusion of cold Water. In the fifth place, this Acid induces such an alteration on Sea Salt, Fountain Salt, and *Sal-Gem*, by the assistance of Fire, that in distillation they yield a Spirit of Salt; mixed with Nitre, it causes a Spirit of Nitre to rise from it; and if it is mixed with many other Bodies, dissolved by acid Spirits, it sets them free from their solvent Acids, by dislodging them, and rendering them volatile, whilst it often takes possession of their place itself. Upon this principle it is that Alum, and Vitriol, if they are first calcined, and then mixed with Nitre, yield *Aqua Fortis*; if with Sea Salt, Spirit of Sea Salt: For in the Colcothar there still remains a latent Acid of Vitriol, exceeding strong, and so fixed, that the Fire was not able to expell it, which being mixed with the Nitre, makes the acid Spirit of the Nitre rise into *Aqua Fortis*, which is the pure Spirit of Nitre, without any mixture of Oil of Vitriol; but at the same time, that part of the vitriolic Acid which remained in the *Calx* of the Colcothar, is left at the bottom with part of the Nitre, and produces there an exceeding fixed Salt, like *Nitrum Vitriolatum*. And the case is the same in the Sea Salt. In the sixth place, it readily dissolves Iron, Copper, somewhat slower, Silver with a good deal of difficulty, and Mercury not in less than

In Calcanthum.

than 560 degrees of Heat: Lead and Tin it don't diſſolve at all. In other reſpects, this Acid agrees with the reſt. It has this too in common with ſome, that it will perfectly diſſolve Camphire into a liquid Oil, which by the effuſion of a good deal of Water, may be recovered again into true Camphire.

Acid of Nitre.

But there is another ſort of foſſil Acid, likewiſe, that is procured from Nitre, nor ever was diſcovered any where, even in the ſmalleſt quantity, 'till it had been firſt drawn from that Salt. For if you take Nitre, and intimately mix with it three times as much Bole, Clay, Brick-duſt, or any thing of the like nature, and urge it with a very ſtrong Fire, a great part of it will be converted into red Fumes, which being collected into a Liquid, are called Spirit of Nitre. Or if you diſtill dry Nitre, with an equal quantity of Oil of Vitriol in the ſtrongeſt Sand-heat, but gradually increaſed, you will then likewiſe from red Fumes have the ſame Spirit of Nitre. Or laſtly, if you rub Nitre with an equal quantity of the *Calx* of red Vitriol, or Alum, and then urge it with a very great degree of Heat, it will then again emit the ſame Fumes, and from them yield a ſpirit of Nitre, which is as good, and as pure, as the former, but is then called by the Artiſts *Aqua Fortis*, *Aqua Stygia*, and *Aqua Docimaſtica*. This Spirit, now, howſoever prepared, is the ſame in every mark, and every property; for if there is any difference, it ſcarcely diſcovers itſelf by any Experiment. And it has this peculiar in it, that when it grows very hot in the Fire, it always ſends forth very red Fumes, and diſſolves Silver into very bitter cauſtic Chryſtals; which Solution is proper to this Spirit, and can ſcarcely be effected by any other Acid, even pure Oil of Vitriol not doing it without difficulty. It diſſolves Mercury, likewiſe, Lead, and Copper. Gold it does not affect; and ſcarcely diſſolves Tin. This Acid, when it has diſſolved its Metals, and intimately mixed itſelf with them, adheres to them with a conſiderable force, ſo as to remain united with them, in a pretty ſtrong Fire. This appears evidently in Silver diſſolved in this manner, which ſuffers itſelf to be melted into the *Lapis Infernalis*, without letting go its corroding Acid. *Mercurius præcipitatus Ruber*, too, when it is rightly fixed, how long will it reſiſt an intenſe Fire, before it parts with the Acid that adheres to it?

Acid of Sea-Salt.

Sea-Salt, as Nitre, when it is pure, diſcovers no ſign of an Acid, but if it is treated in the ſame manner we juſt now mentioned of Nitre, it is changed into a volatile acid Liquor. For if to prevent its melting, you mix it with three times its weight of Earth, and then urge it gradually till you come to the greateſt degree of Fire, it will be diſſipated into denſe, white Fumes, that float about, are very volatile, and being collected form a Liquid of a golden or green Colour. If you diſtill it with Oil of Vitriol, you have the ſame Liquor, but more volatile. And if you mix it with the *Fæces* of diſtilled Alum, or Vitriol, and afterwards expoſe it to a very ſtrong Fire, it will then likewiſe give out the ſame Spirit of Sea-Salt. And theſe Spirits, prepared in theſe three different ways, are intirely one and the ſame. Nay, and they will be the ſame, if you make them with *Sal-Gem*, Fountain, or Sea-Salt. This Spirit, now, has this peculiar in it, that if it is drawn from the pureſt Salt, and you repeat the diſtillation upon freſh pure Salt, when it begins through the violence of the Fire to grow exceeding hot, it emits white Fumes, and diſſolves Gold, which

which no other Acid in nature is able to penetrate. It likewiſe diſſolves Tin, Mercury with a flatulent noiſe, Iron, and Copper. Silver it does in no manner affect; nor perfectly diſſolves Lead: So that this again is an Acid perfectly ſingular in its kind.

Hence, therefore, it appears, that Spirit of Nitre, and Spirit of Salt, are two perfectly diſtinct things, tho' at the ſame time they ſurprizingly approach to one another, and are converted into one another with wonderful eaſe. This certainly, then, in the Hiſtory of *Menſtruums*, ought well to be conſidered, and is as follows. If Spirit of Nitre is cohobated in a glaſs Retort upon Nitre that is exceeding dry, and purified with the utmoſt ſkill, ſo that there is not the leaſt grain of Sea-Salt in it, you will then have the very choiceſt Spirit of Nitre, growing better and better upon every cohobation, and fitter for the Operations proper to this Spirit. But if this cohobation is performed upon common Nitre, which is not purified by chryſtallization, then the cohobated Spirit of Nitre will loſe the nature of Spirit of Nitre, and will acquire the diſpoſition of Spirit of Sea-Salt, or *Aqua Regia*, and will diſſolve Gold. If we carefully examine, now, this extraordinary *Phænomenon* we ſhall eaſily perceive, that to this natural Nitre there muſt adhere ſomewhat of Sea-Salt, which intermixes itſelf with the nitrous Spirit in diſtillation, and thus from Spirit of Nitre produces *Aqua Regia*. And this again appears evident from the following Experiment. Take one part of pure decrepitated dry Salt, reduced to Powder, put it into a clean Retort, and pour upon it four parts of good Spirit of Nitre, or *Aqua Fortis*. Diſtill it then according to Art, to the utmoſt dryneſs, keeping your Sand-heat very ſtrong to the laſt; and the acid Spirit which is thus procured, will be no longer *Aqua Fortis*, but *Aqua Regia*, which will diſſolve Gold, but will not touch Silver. If you examine, then, the Salt, that remains at the bottom of the Retort after this Operation, by Solution, Filtration, and Chryſtallization, you will have a true, pure, inflammable Nitre. *Du Hamel. Hiſt. de l' Ac. Roy. des Sc.* p. 158. *Boyl. Or. Forms.* p. 215. Again, if you take one part of the pureſt Nitre, and two of the beſt Spirit of Sea-Salt, and diſtill them in a proper manner in a Retort, there will come off a Spirit which will diſſolve Gold much eaſier and ſooner, than Spirit of Sea-Salt. And the Salt now again that remains at the bottom after the ſtrongeſt diſtillation, if you diſſolve it in Water, filter, and chryſtallize it, appears to be a good inflammable Nitre. *Boyle. Ib.* from p. 215. to 224. *Bohn. Chem.* 35, 36, 163. *Hoffm. Diſert. Chem. Phyſ.* L. iii. Obſ. 20. Hence, therefore, it appears that *Aqua Fortis* becomes *Aqua Regia*, as ſoon as ever Spirit of Nitre and Spirit of Salt come to be mix'd together, in whatever manner, and almoſt in what proportion ſoever: Nay, and if to *Aqua Fortis* you add *Sal-Ammoniac*, *Sal-Gem*, Sea-Salt, Fountain-Salt, the *Sal Febrifugus Sylvianus*, or true Spirit of Salt, in all theſe ways there is conſtantly produced *Aqua Regia*. Acid *Aquæ Regiæ*.

Thus then we have given you the Hiſtory of Acids as it ſtands at preſent. And in this, it is particularly remarkable in the firſt place, that Acids are ſo eaſily generated from Non-acids; as appeared above in the Acids of Vegetables. Wine too, not at all acid, has, by being cloſe ſtopped up in a clean Bottle, and tied to the Sail of a Wind-mill, been converted in three days into good Vinegar, according to the Obſervation of Monſieur *Homberg. Mem. de l' Ac. Roy. des Sc.* T. II. p. 11. But in the ſecond place, it deſerves well to be taken notice of, likewiſe, Corollaries.

likewise, that Acids, when they are once produced, will bear the Fire for a long time and be scarcely altered: For *Aqua Fortis*, *Aqua Regia*, Spirit of Nitre, Spirit of Salt, and Oil of Vitriol, being included in Glasses hermetically sealed, and exposed for four years to the equable Heat of an Athanòr, retained the same dissolving power: Vinegar only was grown insipid, and had acquired an aromatic Smell; and the Spirit of Salt had begun to corrode the Glass. In the third place, however, these same Acids lose their acid nature, whilst they act as *Menstruums* upon solvend Bodies. This Monsieur *Homberg* very ingeniously inferred from a tedious Experiment performed with Mercury and Spirit of Nitre. *Du Hamel. Hist. de l' Ac. Roy. des Sc.* p. 442, 443. Hence, therefore, it appears, that the strongest acid *Menstruum*, is, by dissolving its object, converted into an insipid, unactive Fluid, not unlike Water, and deprived of the proper solvent Power which it had before: And hence, perhaps, it is not improbable, that these Acids are generated, and perish. For what Person living has ever discovered any Spirit of Nitre in the World, which was not first procured from pre-existing Nitre? And yet Nitre is produced from Earth, filled with animal Excrements Lime and an Alcali, and Air; or from pure Spirit of Nitre attracted into a pure Alcali, particularly a fixed one. Rich and fruitful Lands too, defended from the Rain, and perfectly prevented from consuming their strength by nourishing of Vegetables, are all found by length of time to be impregnated with a fruitful Nitre, if you take care that no Sea-Salt shall come at them. *Boyl Scept. Chem.* p. 177. Hence, then, it is evident, that the acid Spirit of Nitre is, by the sole action of the Fire, produced from pure Nitre, altered; whereas native Nitre is produced without any such Spirit first existing. In the fourth place, therefore, these Acids, whilst they dissolve Bodies, become concreted with them, are changed, and converted into new ones, and thus from one, give rise to a great variety: For Spirit of Nitre dissolves Silver, Lead, wonderfully changes Tin, Copper, Mercury, Nitre, Antimony, Zincq, and Emmery, and with them forms new Bodies, that are different in Taste, Smell, Colour, Density, and all their effects. *Boyl. Mec. Qual.* 118, 119. In the fifth place, all these Acids agree in some particulars, but differ in others.

The agreement of Acids.

They agree, with regard to the Effervescences they excite by being mixed with Alcali's, and the production of new Salts that arise from this combination. As likewise, in their composition with Chalk, Corals, Crabs-eyes, Pearls, Mother of Pearl, the Shells of Cockles, Limpins, and Oysters, Stones, Bones, Hoofs, quick and slaked Lime, Iron, and Copper: For all these are generally dissolved by all sorts of Acids sooner or later, whether it is effected quietly, or with a great *impetus*. These Bodies, now, when they are thus dissolved, always attract into them the acid of the Solvent out of the Water, in which that Acid was before diluted: And the dissolved Matter being by this means united with its solvent acid Salt, may afterwards be diluted in Water like a Salt, so long as its Acid adheres to it; tho' these Bodies before this Mixture were no ways dissoluble in Water. But when this Acid is again by any method removed from the dissolved Matter, then this constantly appears again in form of an Earth, which most strongly resists a Solution in Water. Hence, then, it appears, how very much we may be imposed upon by Water, whilst judging of it by its appearance, we make use of it in our Operations for pure ele-

mentary

mentary Water; whereas, in reality, it may contain in it various kinds of diſſolved Bodies, together with their Solvents. And hence it comes to paſs, that Effects are frequently ſuppoſed to be produced by ſimple Water, which in fact, are owing to theſe latent Solvends and *Menſtruums*. And this, indeed, happens the more eaſily, becauſe, Metals excepted, Acids in general, when they are accurately united with the Bodies abovementioned to a perfect Saturation, they loſe all their Acrimony, and for the moſt part all their Taſte, and thus lie perfectly concealed. * With of Spirit of Nitre, diſſolve 4 drachms and 9 grains of Crabs-eyes, as it generally will, and let the Solution be carried accurately to the point of Saturation, and you will have a limpid, and almoſt inſipid Liquor; let this then be diluted with very pure Water, and filtered, and let it ſtand for ſome time in a moderate Heat, and it will appear like clear Water; and yet, if you drop into it a ſtrong fixed Alcali, the diſſolved Body will all precipitate to the bottom, which a Perſon not apprized of the contrary, might ſuſpect to be produced from the Water itſelf. Theſe Acids farther agree in this, that by diſſolving Bodies, they not only become united and concreted with their Solvends, but are likewiſe at the ſame time changed in their own nature: For it is demonſtrated by undeniable Experiments, that the moſt acid Acids, whilſt they corrode their Objects, are truly changed by them, and put off the diſpoſition, not only of an Acid, but a Solvent likewiſe. Thus Spirit of Nitre, for inſtance, when it has corroded Mercury, and is ſeparated from it again, preſently loſes the power of diſſolving it any more. Another property of Acids in common, is their turning vegetable Juices of a red Colour, as appears in the Turnſole, Roſes, and Violets. And again, they all agree in this, that they do not ſo much alter the Bodies they diſſolve, as they are altered by them themſelves. This is found to hold true in almoſt every caſe. Vinegar in diſſolved Lead, does not continue Vinegar there, nor is ſeparated Vinegar again; but the Lead is recovered perfect Lead. Spirit of Nitre diſſolves Mercury, and the Mercury is procured from it again exactly the ſame; but the Spirit of Nitre, when it is ſeparated, is nothing like what it was before. Hence, therefore, laſtly, this likewiſe is common to all Acids, that many of them are continually deſtroyed.

But theſe Acids, now, on the other hand, differ very widely firſt of all, in the proportion between their true Acid, and the Water it is mix'd with. Difference of Acids. Thus in an ounce of the beſt Vinegar, there are 18 grains of pure Acid, and all the reſt Water: In an ounce of Spirit of Salt, 73 grains of true Acid, the reſidue pure Water: An ounce of Spirit of Nitre, gives 2 drachms and 23 grains of Acid, the reſt Water: The ſame quantity of *Aqua Fortis*, 2 drachms 26 grains: And, laſtly, an ounce of Oil of Vitriol yields 4 drachms and 65 grains of Acid, according to the Obſervations of Monſieur *Homberg*. *Hiſt. de l' Ac. Roy. des Sc.* T. L. p. 52. In the ſecond place, this ſame Acid, when it is pure in every particular ſort, differs ſurprizingly in its diſſolving power: For the Acid of Nitre boiled with Gold, has ſcarce any effect upon it, except changing it black; whereas it diſſolves Silver preſently: And the contrary is true of *Aqua Regia*. Hence then it appears, that the Acid does not act there as

* The quantity of Spirit of Nitre is not added, and our Author ſays it is not neceſſary; nor indeed is it abſolutely ſo, as it will be determined by the Saturation: But then why he ſhould mention ſuch an odd quantity of Crabs-eyes, as 4 drachms 9 grains of Crabs-eyes, and add *ut ſolet facere*, I can't imagine.

an Acid in general, but as a Body endued with a peculiar vertue. In the third place, Acids differ likewise in this respect, that whilst they dissolve their Objects, some of them are changed a great deal more than others. Spirit of Vinegar, for instance, in dissolved Lead, becomes an oily pinguious Spirit: But Spirit of Nitre, whilst it corrodes Tin, is not altered in this manner. Fourthly, the same Acid is very much changed by acting upon some particular Bodies, but very little or nothing if it acts upon others. Thus distilled Vinegar, in the Solution of Lead, is altered in the manner I just now observed; if it corrodes Iron, it loses all its former nature, nor can be ever recovered from it again; but if Copper is corroded by it into a Mould, and then dissolved into a green Liquor, and from this you procure Chrystals, these Chrystals will contain an exceeding strong Vinegar, and if you distill them in a Retort with a great degree of Fire, you will have a very strong acid Spirit of Vinegar, scarcely at all altered, tho' it adhered so tenaciously to the Copper. Hence, therefore, it appears, what different changes are induced upon Acids by being united with different Metals; which is true in other Bodies likewise. All Acids in general, now, may be diluted in Water. They may be mixed with Spirits, as Spirit of Nitre with Alcohol, with a prodigious Heat, very red Fumes, and an Effervescence which almost bursts out into Flames. They may be combined likewise with Oils; Spirit of Nitre, sometimes, with such an agitation as excites Fire; for the most part with an intense Heat. Oil of Vitriol likewise, mixed with Alcohol, and Oils, makes the Compound vastly hot. But whenever Acids are intimately united with Oils, they almost always produce somewhat of a bituminous, pitchy, or sulphureous Substance; whence often arise very extraordinary changes. Thus, then, I think I have laid before you such an account of acid *Menstruums*, as is sufficient to enable you to judge of their action. We must now, therefore, briefly take under consideration those called the *Neutri*, *Hermaphroditi*, *Compositi*, and *Enixi*.

Of neutral Salts, as Menstruums.

Sal-Ammoniac a Menstruum.

And here let us first examine *Sal-Ammoniac*. This is very easily diluted in Water, nay and in a moist Air dissolves into a very acrid, and surprizingly penetrating Brine, which most happily attenuates, incides, opens, and resolves the thick, viscid, pituitous, and pitchy concretions formed in animal Bodies, and then expells them by Perspiration, Sweat, Urine, and *Saliva*, and excellently too resists putrefaction. And for the same reason, if this Brine is boiled, or digested, with the Gums, Resins, or Gum-Resins of Vegetables, it intimately resolves them, and disposes them to be conveniently dissolved in aqueous, and fermented spirituous *Menstruums*. Upon Metals, likewise, it has beautiful effects. If you boil Filings of Iron in it, they are surprizingly dissolved, and converted into an excellent restorative aperient Medicine. If you boil or digest it with Filings of Copper, it gives a Liquor of a beautiful Colour, a few drops of which taken in a morning fasting, has often done great things in the Epilepsy, and Worms. On these accounts, this Brine affords a noble *Menstruum* in the Animal, Vegetable, and Fossil Kingdom. But when the exceeding pure dry flowers of this Salt are rubb'd for a long time, and accurately mixed with Fossils, and they are afterwards sublimed together in a Sand-heat, and in a close Vessel, they then, as a *Menstruum*, acquire inimitable vertues. Hence the Chemiſts have called it the *Aquila Alba*, and the *Piſtillum Sapientum*. Sulphurs, ſulphureous Subſtances, Semi-metals, and Metals, treated in this manner, are vaſtly attenuated, opened, rendered volatile, and perfectly altered: And hence are prepared ſuch excellent Medicines, as can ſcarcely be equalled by any other Art; witneſs the flowers of the *Lapis Hæmatitis*, the *Ens Veneris*, and *Ens Martis*, not to mention many more. What is more ſurprizing, than the various changeable Colours of Antimony thus produced from a black one? Let it ſuffice to take notice only, that many of the Philoſophers have called this Salt, the Key, that is to admit us into the more profound parts of chemical knowledge. It has certainly this excellent quality, that it is ſcarcely altered at all by ſublimation, except by means of ſome other Bodies joined with it. If it is mixed with *Aqua Fortis*, or Spirit of Nitre, it immediately converts theſe Liquors into *Aqua Regia*. If with fixed alcalious Salts, it is inſtantly changed into a very pure volatile Alcali, acting afterwards in that character, and into a new Salt pretty much reſembling Sea-ſalt. From Spirit of Sea-ſalt perfectly ſaturated with a pure volatile alcaline Spirit, *Sal-Ammoniac* is produced; as it is likewiſe from Sea-ſalt, Urine, and Soot mixed together. Hence then it appears to be a true ſemi-volatile Sea-ſalt; and on his account its whole power, as a *Menſtruum*, may be reduced chiefly to that of Sea-ſalt. Hence too it can never be made better than by ſubliming it ſome number of times in a Veſſel accurately cloſed, from the pureſt, drieſt, decrepitated Sea-ſalt; for by this method are prepared the choiceſt flowers of *Sal-Ammoniac*.

Sea-ſalt comes next in order, which, as I have often taken notice of already, is not only found in the Sea, but is dug likewiſe out of Pits, and procured too from Fountains: Theſe three ſorts, therefore, being perfectly the ſame, I ſhall deſcribe them altogether under the name of Sea-ſalt. This Salt being, either by means of the Sea, Fountains, or Pits, diſtributed all the World over, proves a univerſal preſervative againſt putrefaction. It readily diſſolves in Water, and in a moiſtiſh Air ſpontaneouſly runs into a very ſtrong Brine, which gives us the moſt beautiful, and defecated *Menſtruum* of Sea-ſalt, the Effect of which, with regard to chemical purpoſes, is almoſt the ſame as has been aſcribed to the Brine of *Sal-Ammoniac*, and which therefore may be applied to the ſame uſes. This Sea-ſalt being ſet upon the Fire, will decrepitate, and then, in a dry, hot Veſſel, may be readily reduced to a Powder, and melted in the Fire, at which time it will eaſily inſinuate itſelf through the Pores of the Veſſel it is fuſed in, and ſo diſappear in the Fire. But when with this Salt thus in fuſion, you mix Foſſils, Metals, and Semi-metals, there are very ſtrange alterations produced, peculiar, and different from all others. I took myſelf 8 ounces of moiſtiſh Sea-ſalt not decrepitated, and 2 ounces of common Antimony reduced to a Powder; and after they had been accurately mixed by rubbing them a long time together, I put them into a Crucible, which I covered with another inverted, and cloſed them together with a ſtrong Lute. Theſe being thus prepared, I put them in the Fire for four and twenty hours, and then urged them with ſuch a Heat as to melt the Salt, after which the Crucible being opened, I found a blackiſh-brown Maſs, at the top of which there ſtood up ſome white *Spicula*. I reduced the whole again to Powder, and luted the Crucible as before, and then obtained a reddiſh-brown Maſs at the

Sea-Salt a *Menſtruum*.

bottom of which there was ſomewhat of a more metalline nature. I repeated the ſame again a third time, and when it came to melt, almoſt all the Salt ran through the Crucible, and at the bottom I found a Maſs of Antimony, which was of a reddiſh-yellow, and ſurprizingly changed. By this inſtance, then, it appears, how this Salt, as a dry *Menſtruum*, acts with the aſſiſtance of Fire. There are an infinite number of other Operations, to which it may be applied with a very different effect, than what wou'd be produced by any other Salt. Hence in Cementations, this Salt mixed with Brick-duſt in a dry form, is made uſe of to many beautiful purpoſes in the exaltation, ſeparation, and maturation of Metals, concerning which *Paracelſus* wrote ſo largely in his Works, what other Perſons ſince have found to be true. Among other things, we may take notice, that if dry Sea-ſalt is mixed with Brick-duſt, and expoſed to the Fire, it will be converted into a volatile acid Spirit reſembling *Aqua Regia*, which will then act upon metalline Glebes like *Aqua Regia*, and hence perform very ſingular Operations. *Vid. Paracelſ. de Cœmentis, & Gradationibus.* But when by the method above-mentioned in the deſcription of the acid ſpirit of Sea-ſalt, this Sea-ſalt is converted into a Spirit, and this Spirit again, by diſtillation, is drawn off from ſome of the ſame pure, decrepitated, dry Salt, and cohobated a good many times, you then obtain a ſingular and wonderful ſolvent of Sea-ſalt. Theſe are tedious Labours, I confeſs, but they are uſefull ones; and therefore, if you have a mind to repeat them after me, you may do it in the following manner. In two pounds of ſpirit of Sea-ſalt, by adding a little and little at a time, I diſſolved as much fine dry powdered Sea-ſalt, as it wou'd poſſibly take up. This Liquor, by letting it ſtand quiet, and filtering it, I made exceeding pure, and then put it into a tall Bolthead, and fitting another ſmaller one into it, luted them well together, and expoſed them to the Heat of the Sun, from the tenth of *May* to the tenth of *July*. I then diſtill'd this Liquor in a Retort with a gentle Fire, till there remained at the bottom a thick pinguious Liquid, that appeared like a thinner kind of an Oil, in which there were hard Chryſtals of Sea-ſalt. When this was done, I poured the diſtilled Liquor back again, and repeated this three times, conſtantly drawing off the ſame quantity I put on; and at laſt there was left a ſpongy, oily, pinguious Salt at the bottom. This Operation I afterwards repeated with all poſſible care and accuracy for five and twenty times more, and then took what came off upon the laſt diſtillation, and poured it back again upon the *reſiduum*, and let them ſtand thus mixed together for five months. I then, with a very gentle Fire, drew off a Phlegm that was almoſt inſipid, and when I perceived a very acid Spirit begin to riſe, I fixed on another Receiver, and urging it with a little ſtronger Fire, there came over a very acrid, acid, heavy Oil of Salt. This I ſet aſide by itſelf; and after all theſe diſtillations, the Salt that remained at the botton of the Retort, was ſtill very acid, and conſiderably fixed. This I then put into a glaſs Plate, and expoſed it to the Air in a ſubterraneous place, where it run *per deliquium*. * When this

* It's pretty remarkable here, that our Author does not ſay that he actually did depurate this Liquor, *&c.* and then procure from it this noble Solvent; but ſays, when it is depurated, *&c.* ſuch a one may be procured, and refers us to *Paracelſus*. Nor in the next ſentence, tho' he ſays he took all this pains to learn whether what *Paracelſus* ſaid was true, does he tell us whether it is ſo or no.

Liquor

Liquor is afterwards depurated by filtration, and mixed again with the Phlegm, Spirit, and Oil of Salt, that came off first, there is produced, upon a new distillation, a Liquor of those solvent vertues, that fully answer all our trouble. *Vide Paracels.* x. *Archidox.* C. 4. I was willing, Gentlemen, to take all this pains, to learn, if I could, what truth there was in what *Paracelsus* had asserted. Mr. *Boyle*, after a proper and long protracted digestion, by a moderate sand heat, procured from Sea-Salt, without any thing mixed with it, a Spirit, without any Phlegm, and before any Phlegm arose. Nine parts of Sea-Salt being dissolved, filtered, depurated, and chrystallized, yield one part not to be formed into little Glebes, which is rough, austere, and saline: This being separated, the Salt becomes purer. *Du Hamel. Hist. de l'Ac. Roy. des Sc.* p. 16, 17. If a person then considers all these things, he won't wonder, that the greatest Masters have ascribed such extraordinary vertues to Sea Salt chemically prepared, both in *Menstruums*, and Medicines: Every one will see what method it ought to be prepared by.

Our Nitre, procured from animal substances, an Alcali, and Lime-Earth, and afterwards purified, hence easily becoming alcalescent, and fixed, and being as readily again convertible into a volatile Acid, is of a pretty singular nature, considered as it acts upon Bodies, as a *Menstruum:* And its operations, indeed, are often so intricate, that it is scarcely possible rightly to comprehend them; which happens chiefly from its being so mutable in the Fire itself, when it is mixed with other substances. If it is exposed to the Fire, pure and dry, as it so soon runs with other Bodies like Water itself, hence, though they otherwise would not melt without a great deal of difficulty, it wonderfully promotes the fluxing them, and attenuates, divides, and mixes them together, even though you suppose it to act here with no other vertue. For this reason, persons who are employed in fusing of Metals, make use of Nitre for forwarding their work. But in the second place, if there is any thing in the substances mixed with it of an oily, pinguious, sulphureous nature, this immediately, in a melting Fire, detonates with the Nitre, with a great *impetus*, takes fire, instantly excites a prodigious Heat, greatly raises the strength of the Fire, applies it more violently, and hence vastly changes, divides, melts, and separates Bodies, and in a very different manner from what can be effected by any other contrivance. But at the same time, the Nitre itself likewise loses the nature of Nitre, and acquires that of *Sal-Polychrest*, which has quite another dissolving power from what the Nitre had from which it was produced. Hence, therefore, there are three various actions of Nitre upon Bodies in the Fire; one before it deflagrates with them; a second during the time of deflagration; and a third when it is perfectly over. In the third place, when Nitre is melted with Vegetables that turn to a Coal, it then, likewise, is put into a very great motion, violently agitates and dissolves the solvend Bodies, and at the same time sends forth wonderful active Fumes, which being assisted by the Fire, penetrate, and dissolve every thing. And lastly, when it is thus converted into a fixed Alcali, it won't then melt without the strongest Fire, and has then acquired the quality of an acrid, penetrating Alcali, though always of a particular nature; and hence again it begins to act as a fixed, alcaline *Menstruum*, and thus obtains and exerts a new dissolving power: But this was treated of before in our History of alcalious *Menstruums.* In the fourth place, if the same Nitre fus'd

Salt of Nitre a *Menstruum.*

with its ſolvend Bodies, happens to meet with any Earth, Stones, Alum, Vitriol, Brickduſt, or the like, it is immediately converted into a very acid, volatile, ſharp Salt, which being agitated with ſo great a Heat, penetrates, diſſolves, and induces prodigious changes upon the Bodies it is mixed with, acting in this caſe like *Aqua Fortis*, with one part, whilſt the other part that remains at the bottom acquires a new, and very different ſolvent power. Hence, therefore, we ſee how wonderfully efficacious this Salt muſt be, when it is uſed like a Cement with metalline Glebes; for then it is converted into ſuch corroſive Spirits, which at the ſame time make great alterations in the Metals. But this I have ſufficiently explained in our account of Acids, to which, therefore, give me leave to refer you. Again, in the fifth place, if pure Nitre is fuſed in an intenſe Fire, and is kept in the Fire with the reguline part of Antimony, it becomes a perfect cauſtic Stone, which acts in a manner that cannot, as I know of, be imitated by any other Salt: For this Salt is exceeding fixed, vaſtly difficult of fuſion, and of an uncommon, igneous acrimony. Hence, therefore, it appears what a wonderful diſſolving efficacy this Salt muſt have, when, together with *Regulus* of Antimony, it is applied to Bodies in the Fire. Sixthly, if upon Nitre, when it is in fuſion in a clean Crucible in the Fire, you throw powder of *Sal-Ammoniac*, it will take fire in the ſame manner as if a live Coal was thrown into it, but ſomewhat ſofter; and it is by this means altered every moment, and becomes of another nature, 'till at laſt, being perfectly ſaturated, it will not take fire any longer upon throwing in of the *Sal-Ammoniac*, but is converted into a new kind of Salt, which at laſt grows reddiſh, is of a ſingular nature, though but little regarded or known amongſt the Chemiſts. When Nitre and *Sal-Ammoniac*, therefore, are thus mixed together with other Bodies in the Fire, a different kind of ſolution will happen every moment, and conſequently new effects will be continually produced, whilſt theſe thus remain in the Fire together. To theſe things the Operators very ſeldom ſufficiently attend, and hence it comes to paſs, that they frequently meet with *Phænomena* they were not aware of, which diſturb their Operations, and render the ſucceſs of their Experiments uncertain. In the ſeventh place, if to the Solvend you add one ounce of Sea-Salt, and two ounces of Spirit of Nitre, or *Aqua Fortis*, the Liquor that is expell'd with a moderate heat will be an *Aqua Regia*, and act only with the power that that does; whilſt the Salt that remains at the bottom will be Nitre. Hence, therefore, it appears, that in the latter part of the Operation, when it comes to be dry, it will act like true Nitre; whereas, at the beginning, the Liquor that was ſeparated had the efficacy of *Aqua Regia*; and it is likewiſe as evident, how various the effects may be in different parts of the time that any given *Menſtruum* continues in action. In the ſame manner if upon one part of very pure Nitre, you pour two of Spirit of Sea-Salt, they will yield in diſtillation a pure *Aqua Regia*, perfectly ſo in every property and very ſtrong; but if you then increaſe your Fire, and proceed to diſtill to a perfect dryneſs, you will find again at the bottom of the Retort a true Nitre in all reſpects. Hence, therefore, we ſee how cautious we ought to be, that we are not deceived in our *Menſtruums*. And again, if Spirit of Nitre, and a proper quantity of any Alcali are mixed together, with the ſolvend Bodies, they ſoon return into a Nitre, and therefore act like a Nitre in the laſt part of their Operation. And if what *Glauber* ſays is true, that Sea-Salt, a fixed Alcali,

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and Quick-Lime, mixed together, and ustulated till they are red hot, and then exposed to the Air, and thence moisten'd, will produce a true Nitre, then certainly if these materials are made use of together in cements, they would have a very different effect from what one would at first imagine. These things, then, if a person rightly considers, and at the same time adds what we have already said of the conversion of Nitre into an Alcali, in our History of alcalious *Menstruums*, and into an Acid, in our account of acid ones, he will sufficiently understand its efficacious and various dissolving power.

Native Borax, the produce of the *East-Indies*, *Persia*, and *Transylvania*, being dissolved in Water, filtered, and chrystallized, is of a bitter sweetish taste, and neither acid, nor alcalious. In distillation it yields a mere Water, and a Glass; which Glass may be afterwards dissolved in Water. If it is mixed with Sand, and urged with the strongest heat, it affords no acid Spirit. It exceedingly promotes the fluxing of Metals, and by thus fusing them, unites them thoroughly together, and by this means produces many effects which could not be accomplished in another way, without a great deal of difficulty. Borax as a *Menstruum*.

Whoever, now, is properly acquainted with what we have delivered concerning saline *Menstruums*, will readily conceive, how, by the various combinations of these Salts with one another, may be produced a vast number of new saline *Menstruums*, every one of which will presently acquire new and different dissolving vertues. This composition, now, is sometimes effected by art, and with design; at others, it happens accidentally, and without being foreseen, and so comes to be reduced among other chemical observations. And from these two fountains have there risen a vast quantity of *Menstruums* which have been described by the Chemists. Thus, for instance, if volatile Alcali's are united with fixed ones, then the volatile, by the action of the Fire, are always rendered stronger, harder, and more volatile; whilst, on the other hand, the fixed attracting the Acid, perhaps, from the volatile, as likewise the Oil, and Earth, become always differently compounded, and have not the same efficacy they had before. Fixed Alcali's, mixed with native, vegetable Acids, produce a wonderful compound Salt, which is soft, aperient, and diuretic: This we see in *Omphacium*, or Juice of Lemons, or the like, mixed with a proper proportion of Salt of Wormwood; for the Salt arising hence has very different solvent powers from what the Principles have from which it is made, or than any other Salts have. If you mix volatile Alcali's with these Acids, you have then another compound Salt, as different as possible from the former with the fixed ones. If you rightly combine fixed Alcali's with pure, fermented, vegetable Acids, you procure, after many surprizing *Phænomena*, a saturated Salt, which is volatile, soft, penetrating, saponacious, melts easily in the Fire, and possesses very extraordinary vertues. Here the Vinegar returns into its proper *Matrix*, Salt of Tartar, and impregnates it with its own peculiar Acid, which was acetose; for the Chemists call Vinegar fluid Tartar; and hence they have given to this Salt the name of regenerated Tartar. Others have called the Mixture prepared in this manner (*Acetum radicatum*) radicated Vinegar; as it appeared to return into its proper (*Radix*) Root. And having myself often experienced the beautiful effect of this Salt, both in the animal, vegetable, and fossil Kingdom, I have been in doubt, whether this is not in reality the *Sal Tartari Volatilis* of *Helmont*, which the author so highly extoll'd for its vertues. Be this as it will, Compound, saline *Menstruums*.

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this I can ſafely affirm, that in the whole claſs of *Menſtruums* there is ſcarcely one that deſerves examination, and application, better than this does. This I could make appear by an infinite number of examples; but let one ſuffice. That noble Gum, Myrrh, cannot, without a vaſt deal of difficulty, be ſo diſſolved by Alcali's, or Acids, as to be rendered ſubtil enough to penetrate into our Veins, if it is taken into the ſtomach; but if you digeſt it according to art with this Salt, it melts, and in an inimitable manner diſſolves into a thick, homogeneous, medicinal Maſs. This Salt, if it is made very accurately, will very intimately unite with Alcohol of Wine, and thus yield a *Menſtruum*, which no perſon will repent making, though it coſts him a great deal of pains. Hence, therefore, we ſee how much ſome of the more modern Chemiſts are in the wrong, who, making Alcali's and Acids the grand principles of Bodies, aſſert, that theſe can't be mixed together with any propriety, nor without acting contrary to true chemical knowledge, intimating, that by this means the noble vertues of the Alcali's are deſtroyed by the Acid, and what remains is of no efficacy, as *Zwelfer* in his works ſo often inculcates. But theſe Gentlemen may know, that if the pureſt Alcali of Tartar is united, according to art, with the volatile Acid of Tartar converted into Vinegar by a double fermentation, then the Alcali, and its proper vertue, being deſtroyed, as well as the Acid of the Vinegar, and its proper vertue, there ariſes a new neutral Salt, the efficacy of which is much more excellent than that of either the Alcali, or the Acid. And when a pure volatile Alcali is accurately combin'd with a very pure, ſtrong Spirit of Wine Vinegar, ſo that you nicely obtain the very point of ſaturation, you have then a limpid Liquor, very little Salt, without any remarkable acrimony or ſmell, conſiderably volatile, and compounded of the lighteſt Alcali and Acid. And this poſſeſſes a very peculiar, diſſolving power, which in vain you will ſeek any where elſe; for it is capable of penetrating into almoſt all kinds of Bodies, and reſolving them without any great apparent agitation. Hence the Phyſicians have valued this Water exceedingly for removing diſeaſes of the eyes and ears, ariſing from any preternatural concretions. And for the ſame reaſon, among all the ſecrets for diſcuſſing, and reſolving glandular tumours, nothing hardly is found more efficacious than fomentations with putrified Urine and Vinegar, if the part is firſt well rubb'd, and they are then applied hot. From theſe obſervations, now, we may likewiſe underſtand, what will be the conſequence of combining fixed or volatile Alcali's with fermenting Acids; for at firſt they will cauſe a ſudden effervescence, then put a ſtop to the fermentation that was begun, and produce Salts, very much reſembling thoſe that have been deſcribed. And the ſame kind of Salts are produced, likewiſe, by mixing Alcali's with thoſe Acids that are ſeparated from Vegetables, whilſt they are burning, or with thoſe that are drawn from them by diſtillation. But if you combine fixed Alcali's with the native Acid of Foſſils, there then again ariſe new Salts, but thoſe vaſtly different too from one another. If, for inſtance, you diſſolve the pureſt Alum in clean Water, and heat it, and drop into it hot Oil of Tartar *per Deliquium*, 'till it is perfectly ſaturated, they will precipitate a chalky *Calx*, and the limpid Liquor ſwimming at top, and conſiſting of the native Acid of the Alum attracted into the Alcali, being defæcated, and filtred, will yield a Salt like *Tartarus Vitriolatus*, but free from any ſuſpicion of a metalline taint, whoſe vertues are excellent in Chemiſtry as a *Menſtruum*, and are very efficacious in medicine. In the ſame manner, if you take either the white, blue, or green Vitriol, and diſſolve it in four times its weight of Water, filter it, and drop into it hot, a fixed, hot Alcali, till you come to the point of ſaturation, you will thus again have a compound Salt ariſing from the Alcali, attracting into it the Acid which had corroded the Copper, or Iron, in the Mines: So that here again you have a natural, vitriolated Tartar, which differs from the common, in this particular, that its Acid has not been expoſed to ſo ſtrong a Fire, and hence has more beautifully retained its natural vertues: And beſides, it will more perfectly depoſit its metalline parts, except it be the true *Calcanthum* of Copper, for then, indeed, part of the Metal remaining in the ſolution, will diſcover itſelf in the Salt, by a blue colour. But farther, whenever you intimately mix a fixed Alcali with any true Sulphur, then the foſſil Acid is attracted into the fixed Alcali, and if nothing elſe prevented it, there would be produced a Salt like the former: But we find, however, that it is in ſome meaſure of another nature, as appears from the ſaline *Spicula* that are formed from it. And this ſeems to happen, becauſe the pinguious, oily Matter, which is mixed with the Sulphur, unites itſelf with the fixed Alcali, as well as the acid does, and thus prevents the pure ſaline parts concreting together, and by its interpoſition forms a decompound Salt, of a very different ſmell, taſte, and efficacy. From what has been ſaid, then, it appears what will be the conſequence of mixing Vitriolic, or Alum Waters, or their inſpiſſated, pinguious *Reſiduums*, by what name ſoever diſtinguiſhed, with theſe fixed Alcali's; for by this means the metalline and terreſtrial part, which theſe contained in them, will be ſeparated, and the ſolvent Acid will unite with the Alcali into a vitriolated Tartar, whoſe diſſolving Power will be ſingular, and different from that of all other Salts: This the application of it to Metals, Semi-metals, Sulphurs, and other foſſil Glebes generally evinces. And it commonly too retains its vertues longer without alteration, than any other compound Salt; for it has its Acid more ſtrongly combined with a very fixed Alcali, into an exceeding fixed Salt: Nor is there any known Acid in Nature, which, if poured upon vitriolated Tartar, is able to diſlodge the Acid that is united with it, though the native Acid of Vitriol expels the Acids from all other compound Salts, as has already appeared. But on the other Hand, if with native, foſſil Acids you mix pure, volatile, alcaline Salts, there then ariſe particular kinds of *Sal-Ammoniac*; and as theſe are compounded of a foſſil Acid, and a volatile Alcali, perhaps, for diſtinction ſake, they may be, not improperly, called Semi-volatile, vitriolated Tartars. And theſe, likewiſe, deſerve to be well conſidered by the Chemiſts among their *Menſtruums*, on account of their remarkable diſſolving power; and by the Phyſicians for their noble efficacy in opening, attenuating, reſolving, and ſtimulating. What then will be the effect of mixing common *Sal-Ammoniac* with Vitriols, and then expoſing them to the Fire? Why, the Acid of the Vitriol being attracted into the alcaline part of the *Sal-Ammoniac* will expell thence the acid Spirit of the other part of the *Sal-Ammoniac*, render it volatile, and ſeparate it, and then from the conjunction of the Acid of the Vitriol, and the Alcali of the *Sal-Ammoniac*, there will be produced a ſemi-volatile, vitriolated Tartar, ſuch as was juſt now deſcribed, and the remainder will be a metalline Maſs, which exiſting before in the Vitriol,

Vitriol, is now precipitated from it, and ſeparated in the Form of *Fæces*, or, being again corroded by the Spirit of the Salt, produces a new kind of diſſolved Metal. Hence, then, you have a true method of judging what will be the conſequence of combining fixed or volatile Alcali's, with all native, foſſil Acids, though theſe often lie very cloſely concealed in Metals, Earths, Oils, and other Salts; for the effect will be always the ſame, and for this reaſon may be foretold. And, indeed, theſe Experiments are ſo certain, and hence ſo entertaining, that they cannot be recommended too much; eſpecially if we conſider at the ſame time, that they are of excellent ſervice both to Chemiſtry and Phyſic.

But before we quit this doctrine of *Menſtruums*, it is neceſſary we ſhould take likewiſe into conſideration thoſe *Menſtruums* which are produced by the combination of fixed Alcali's with the foſſil Acid procured by Fire. A pure, fixed Alcali, therefore, when it is perfectly ſaturated with the Acid of Sea-Salt, Fountain Salt, or *Sal-Gem*, gives a regenerated Salt, which reſembles true Sea-Salt in almoſt every quality. If it is ſaturated with Spirit of Nitre, it forms a Salt that in almoſt every character reſembles Nitre. If it is properly united with the Acid of Alum, burning Sulphur, or Vitriol, it makes the *Tartarus Vitriolatus* before deſcribed. On the other Hand, when a pure volatile Alcali is in the ſame manner combin'd with Spirit of Sea-Salt, *Sal-Gem*, or Fountain Salt, there then ariſes the genuine common *Sal-Ammoniac*. If it is united with Spirit of Nitre, or *Aqua Fortis*, it produces a ſemi-volatile Nitre. If with the acid Spirit of Alum, burning Sulphur, or Vitriol, it gives a ſemi-volatile, vitriolated Tartar, the ſame which we above deſcribed. Theſe things then evidently inform the Chemiſt, how many, and what ſurprizing actions may be often excited in *Menſtruums*, purely from mixing and uniting certain Bodies together, and then expoſing them to the Fire, as a common moving cauſe; for it's incredible, what a prodigious alteration often ariſes from the accidental or deſigned addition, but of one ſingle Body. And yet without an accurate knowledge of all theſe things, the chemical Doctrine of *Menſtruums* will never be compleat. The Experiments I have made to inform myſelf in this matter have given me a great deal of Pleaſure, as it does now to communicate the ſucceſs of them to you. But there ſtill remain to be conſidered the actions of thoſe *Menſtruums* where pure ſimple Salts are united with others. But this, from what has been already laid down, is almoſt evident of itſelf. If a pure Alcali is united with Sea-Salt diſſolved in Water, the Brine grows turbid, an Earth is precipitated, and the Salt then properly procured by chryſtallization, is a pure Sea-Salt. A fixed Alcali put into a *Lixivium* of Nitre, makes it turbid and whitiſh, precipitates an Earth, and produces the moſt pure Nitre we know of. The ſame mixed with the Brine of *Sal-Ammoniac* attracts its Acid, by this means ſets free its Alcali, expells it, and at the bottom produces a pure, fixed Sea-Salt, the volatile Alcali being diſſipated into the Air. A pure, volatile Alcali put into a Brine of Sea-Salt, makes it turbid, depurates the Salt, and then flies off. If it is mixed with diſſolved Nitre, it does the ſame, and purifies the Nitre. If you put it into *Sal-Ammoniac* well diluted with Water, it effects the ſame depuration there likewiſe, but it does not at all alter the nature of the *Sal-Ammoniac*, which continues exactly of the ſame vertue it was before. Vegetable Acids mixed with

with Sea Salt, Nitre, and *Sal-Ammoniac*, make but little alteration in them. And the ſame Acids, fermented, or rendered purer by diſtillation, mixed with the ſame Salts, don't change them a great deal. What alterations are produced in *Menſtruums* by the artificial mixture of foſſil Acids, with the Salts juſt mentioned, I gave you before, when I treated of thoſe Acids and theſe native Salts. In a very few Words, therefore, I juſt repeat, that in Alum and Vitriol calcined to a dryneſs, there remains a good deal of a fixed Acid, which is exceeding ſtrong, and has this peculiar property, that when it is rendered active by the Fire, it will expell all other Acids from any Bodies that were diſſolved by thoſe Acids, provided thoſe Bodies are of ſuch a nature, that they may be diſſolved by this Acid of Alum, Vitriol, and Sulphur; and by this means it produces very particular effects, as a Solvent. Give me leave to illuſtrate this by an Example. Take Vitriol calcined to a dryneſs, rub it with Sea Salt, and put them together into a Retort, and with a Fire gradually increaſed to the greateſt degree, diſtill them, and there will riſe a pure Spirit of Sea Salt: For the Acid of the Colcothar being ſuperiour, expells the volatile Acid of the Sea Salt, takes poſſeſſion of the other fixed part of this Salt, and from theſe two concreted together, produces a kind of *Sal Mirabilis Glauberi*, but which, at the ſame time, contains the metalline *Fæces* that were in the Vitriol. But this, indeed, I explained to you before. Again, if you take Mercury, and rub it with calcined Vitriol, 'till it is thoroughly divided, and then to this Mixture add decrepitated Sea Salt, and put this Compound into a Glaſs Cucurbit, and very gradually urge it with a ſand heat, then the Acid of the Vitriol converts the Acid of the Sea Salt into a Spirit, which being agitated and heated, diſſolves the Mercury, as uſual, and then carries it up in form of a pure *Mercurius Sublimatus*; which is nothing elſe but the very pure Spirit of the Sea Salt, attracted into the Mercury, and united with it into a homogeneous, vitriolic, mercurial Maſs. But there are an infinite number of effects, and thoſe very ſurprizing ones too, that may be underſtood from theſe principles in the Hiſtory of *Menſtruums*. Hence, from Alum, or Vitriol, calcined, and mixed with Nitre, is diſtilled *Aqua Fortis*, in which there is nothing of the Acid of the Vitriol, but which is pure Spirit of Nitre. If they are treated in the ſame manner with Sea Salt, you have a Spirit of Salt. If with Nitre and Sea Salt together, in diſtillation there ariſes an *Aqua Regia*. Hence, if Nitre and Colcothar are expoſed to an open Fire in a Crucible, the Acid of the Nitre is diſſipated, and there remains a kind of *Nitrum Vitriolatum*. And Sea Salt calcined in this manner, leaves a kind of *Sal Mirabilis Glauberi*. But it will be more entertaining to you, from the principles I have laid down, to carry theſe Experiments farther yourſelves, than if I ſhould lay them before you too particularly. I have but one thing more, therefore, to add, and that is, that by combining Salts with Salts in any manner whatſoever, there always ariſe new Salts, and new *Menſtruums*. By this means, therefore, the Chemical Science is continually advanced; and hence now, appearances perpetually offer themſelves to our obſervation, which are very agreeable, promote the knowledge of natural Philoſophy, and often furniſh us with new and very uſeful diſcoveries.

But in the laſt place, there ariſe new *Menſtruums*, likewiſe, and thoſe of different vertues, from the combination of various *Menſtruums* with one another: And here there is room for infinite application; as there is alſo in reducing of any ſort of *Menſtruum* to its greateſt purity; and the attenuating any one into the leaſt Particles, which it is poſſible either for art or nature to reduce it to: For in theſe three particulars ſeem to have conſiſted the peculiar and excellent knowledge of the top Maſters of the Art. But it's impoſſible to deliver here what might be ſaid upon this Head: Let one Example ſuffice. I want, for inſtance, the pureſt, ſtrongeſt, and moſt ſubtil, vegetable Acid. Take, then, the beſt Verdegreaſe, which is Copper finely corroded by a fermenting, exhaling Acid, and pour upon it twenty times as much of the ſtrongeſt Spirit of Vinegar that can be procured by diſtillation: Digeſt theſe, that the Verdegreaſe may be diſſolved into a very green Liquor, which depurate accurately by letting it ſtand quiet, and filtering it, and then with a gentle Fire inſpiſſate it till a pellicle is formed on the ſurface: Then let it be ſet by in a quiet place, and it will ſhoot into Chryſtals, like Emeralds, conſiſting of the Acid of the Vinegar, and the corroded ſubſtance of the Copper. Decant the Liquor, collect the Copper Glebules, and inſpiſſate the Liquor again to a pellicle. Take out again the new-formed Chryſtals, and proceed in this manner, 'till no more Chryſtals appear. If you then dry this Copper Mould, thus ſaturated with the Acid, very gently with a moderate warmth of the Air, and then very gradually urge it in a glaſs Retort, you will have an incorruptible, vegetable Acid, exceeding ſtrong, nor affected with any metalline taint from the Copper. If you attempt this with Lead, Tin, or Iron, it will never ſucceed: Copper only anſwers the end, by attracting the Acid, ſeparating it from its Water, and returning it back again, without any alteration; whereas the others attract it indeed, and ſeparate it, but never part with it again pure. As from malt Liquor, now, fermented Manna, Honey, Sugar, Cyder, and Perry, ſuch Vinegar may be prepared, from theſe, likewiſe, by the help of Copper, may be procured ſuch a ſtrong Acid. Hence *Zwelfer* falſely imagined, that he was in poſſeſſion of the famous Alcaheſt, for which he was ſharply handled by the ſhrewd *Tachenius*, who ſtrenuouſly inſiſted upon it, that it was nothing but ſtrong Vinegar. But there are infinite numbers of *Menſtruums* that may be ſtill found out: And hence almoſt every Artiſt boaſts of ſome particular *Arcanum*; nay, and indeed is able generally by the aſſiſtance of it, to do ſomething more than any body elſe can poſſibly do, who is not acquainted with it. But here, it's true, the uſefulneſs of the diſcovery is often not ſo much to be extoll'd, as the vanity of the poſſeſſor of the ſecret is to be blamed; as no body who is expert in the art will ever be at a loſs to find out new *Menſtruums*, if after that he has by his art prepared Bodies, he will but apply them to others. And hence, perhaps, the Solvents proper to every kind of Body, and therefore to the human *Calculus*, might by this time have been diſcovered, if the Chemiſts had but applied all their Liquors to this Stone, as there are often effects produced in this manner, which could not poſſibly be foreſeen: Thus, if a perſon was acquainted with all *Menſtruums* whatever but Spirit of Bread, the efficacy of that in diſſolving many Bodies would appear to him quite incredible. But by mixing one *Menſtruum* with another, there often ariſe new ones, and thoſe too very beautiful. Thus, for inſtance, *Tartarus regeneratus*, if it is rightly prepared, may be intimately united with the pureſt Alcohol of Wine; and then you have a vegetable *Menſtruum* compoſed of a vegetable Alcali, Acid, and Sulphur, exceeding ſubtil, and very cloſely combined together; and hence it is of mighty efficacy, made uſe of either as a *Menſtruum*, or a Medicine. Again, if the pureſt, moſt ſaturated, alcaline Spirit is united with the pureſt Alcohol, it becomes the *Offa Helmontiana*, and makes a noble *Menſtruum*. This very nicely diſſolves diſtilled, vegetable Oils, and hence ariſes a *Menſtruum* conſiſting of a genuine Sulphur and Alcali, concerning which one may doubt, whether there is any thing more excellent, either in Medicine or Chemiſtry. In the ſame manner, if the beſt Spirit of Nitre is perfectly ſaturated with an alcaline Spirit of *Sal-Ammoniac*, we obtain an almoſt volatile Salt of Nitre; and hence may be prepared that ſo much wiſhed for volatile Nitre, which whether or no it anſwers the great Expectations formed of it, may then be eaſily tried by Experiments. In the cultivating and improving of theſe ſtudies ſome Chemiſts have employed an Age, and have thought the pleaſures that aroſe upon their new diſcoveries a ſufficient recompenſe for all their labour. And let me adviſe you, Gentlemen, to apply yourſelves to theſe inquiries, noting down whatever new you meet with, that thus, from a ſufficient number of Obſervations collected together, you may, at laſt, with caution, be able to draw ſome Rules that ſhall be of a more general nature.

The doctrine of *Menſtruums*, then, being thus diſpatched, let us proceed to deduce ſome Corollaries from what has been delivered. Firſt, then, it is not yet certain, whether any *Menſtruum* has ſuch an innate power, that it is able to act upon its ſolvend object without the leaſt aſſiſtance of Fire. Nor, indeed, is it poſſible to make any Experiment that ſhall be able to determine this, as in every place there is Fire, and that a pretty deal too, from which it cannot poſſibly be freed. Nay, in fact, almoſt all the *Menſtruums* that we are at preſent acquainted with, if they are quickned with a certain degree of Heat, perform their Solution ſo much the better. 2. *Menſtruums* ſcarcely become efficacious, 'till they are reduced to a fluid form, or one very near it. And this, Fire, Air, Water, and Attrition, in particular, bring about; which four cauſes likewiſe generally excite *Menſtruums* into action, though before they lay quiet. 3. Some *Menſtruums* ſeem to have a power implanted in them, by the efficacy of which they produce a motion, depending only upon the nearneſs of the Bodies to which this motion relates. If a very good Loadſtone, ſuſpended by a Thread and at reſt with reſpect to its poles and thoſe of the World, ſhould be abſolutely without motion, one would be led to think, that it had no active power: But if in the very greateſt degree of cold, a piece of Iron, or another Loadſtone ſhould be brought within the ſphere of its activity, there would immediately be generated a motion in them both, which would laſt till they came into contact, and then being joined together, they would both be at reſt. This power, therefore, ſpontaneouſly, and without the aſſiſtance of any ſenſible Fire, generates motion, not ſeeming to be excited by motion, itſelf. In the ſame manner, the beſt Spirit of Nitre, though it's kept cloſe ſtopp'd up, will for years continue to emit a red Fume, which hanging over the ſurface, keeps in continual motion, and riſes out of the mouth of the Veſſel as ſoon as ever you take out the Stopper. The ſame thing is true, likewiſe, in an alcaline Spirit of *Sal-Ammoniac*, which, as far as I have been able to obſerve, is never at reſt. And as for that Spirit which is diſtilled from *Sal-* Corollaries.

Ammoniac, with Quick-Lime, that is ſtill much more agile. Such Bodies, therefore, both excite and preſerve motion in a wonderful manner. That ſuch Vapours, now, may be perpetually floating about in the ſubterraneous parts of the Earth, 'till they light on ſome certain Bodies, in which being afterwards fixed, and united, they form variety of compound Bodies there, who will deny? In all theſe caſes, however, this muſt be conſidered, that even in the greateſt degree of Cold, the Air is in a conſtant oſcillatory motion, which is often the cauſe by which thoſe motions are likewiſe excited. By this motion, now, proper to *Menſtruums*, and ariſing from them, ſolutions are often brought about immediately, which could not be effected by the greateſt degree of motion excited by any other cauſe. If you have a mind to ſee an inſtance of this, take only a piece of *Engliſh* Chalk; let it be calcin'd in the intenſeſt Fire, nay, even *Tſchernhauſen*'s *Focus*, and it will ſcarcely be altered in this vaſt motion; expoſe it to the hotteſt, coldeſt, calmeſt, or moſt ſtormy Air, and it will remain juſt the ſame; keep it ever ſo long in boiling Water, it will not be diſſolved; boil it in a *lixivium* of Salt of Tartar, and it will ſtill be chalk: And yet put it only into cold Vinegar, and it will diſſolve and diſappear. Hence, therefore, it is evident, what a prodigious difference there is between that motion which is excited by the reciprocal action of the *Menſtruum*, and Solvend, and that which is produced by Fire, Air, Water, and Impulſe. 4. That which we call acrimony, therefore, in a *Menſtruum*, becauſe it corrodes our Body, and gives us pain, does not render ſuch a *Menſtruum* fit to diſſolve other Bodies: This we ſee evidently in Oil of Vitriol, Spirit of Nitre, Spirit of Salt, and *Aqua Regia*, which though they inſtantly conſume any part of us, are not capable of diſſolving Wax, and Sulphur, which are ſo eaſily diſſolved by our Humours. 5. Many *Menſtruums* cannot naturally diſſolve certain Bodies; and yet if theſe Bodies are firſt diſſolved in ſome other *Menſtruum*, they will then be diſpoſed to be diſſolved in thoſe very *Menſtruums*, which before they abſolutely reſiſted. Boil, for inſtance, common Sulphur in Alcohol, as long as you pleaſe, and it will no more diſſolve in it, than a Stone will in Water; but melt this Sulphur with Salt of Tartar, and it becomes a rediſh brown Maſs, and then pour Water upon this, even in the cold, and the Sulphur will be very readily and intimately diſſolved: Boil Powder of Antimony in Alcohol, and it has no effect upon it; but boil the ſame in an alcaline Salt diſſolved *per Deliquium*, till it becomes a dry Maſs, and then pour Alcohol upon it, and you will ſoon have a golden Tincture.. And, indeed, ſuch a well-managed, ſucceſſive application of different *Menſtruums* to Bodies, the greateſt Maſters in the Art have laid ſo much ſtreſs upon, that *Boyle*, *Homberg*, and *Tachenius* have told us, that even Metals themſelves may by this means be intimately reſolved into their two conſtituent Principles, a fixing Sulphur, and a regenerated Mercury. For they aſſert, that if Silver is diſſolved in Spirit of Nitre, and then digeſted for a long time in a pure, fixed Alcali, and afterwards ſublimed a good many times with *Sal-Ammoniac*, it will at laſt yield a fluid Mercury; and at the ſame time they call theſe, reſuſcitating Salts. Thus Acids procure an entrance for fixed Alcali's into the inmoſt parts of Metals; and then the fixed Alcali's aſſiſt the volatile, alcaline Salts to penetrate them, which otherwiſe they had not been able to effect. This is what theſe Gentlemen aſſure us. If you aſk me whether

I believe

I believe that Metals may thus, by the aſſiſtance of Salts, be reduced to Mercury? I can't tell what to ſay to it. For my own part, I frankly confeſs, I have taken a great deal of pains upon this head, but have never yet been able to effect any ſuch thing: Conſcious, however, of my own inferiour abilities, I would by no means go about to detract from the capacity or credit of others. 6. Some *Menſtruums* diſſolve certain Bodies, which before the Experiment was made, ſeem'd the leaſt in the World fitted for ſuch a ſolution, whether you regard either the *Menſtruums*, or the ſolvend Bodies. Thus, for inſtance, the tenacious, viſcid, native Turpentine becomes ſo penetrating in the human Body, that in a very ſhort time it gives a violet ſmell to the Urine, changes its colour, and heats the whole Body; if it is mixed with Oils, it diſſolves them; as it does perfectly Reſins in a ſmall degree of Heat, tho' they diſſolve with ſo much difficulty: And it has the ſame effect, likewiſe, upon Gum-Reſins, which can ſcarcely be diſſolved by any other method; as Gum-Copal, and others. But what muſt we think, again, of the Yolk of an Egg? If one may be allowed to ſpeak by analogy, it is the *Placenta* of the Chicken, an organical Machine, whoſe infinitely ſubtil ſtructure eludes the moſt acute, microſcopical obſervation, and the moſt curious anatomical inquiry. Is it not a viſcid, tenacious, unactive Subſtance, without Smell, taſte, or any the leaſt degree of Acrimony? And yet if this is rubbed in a gentle Heat, according to art, with any gummy, oily, reſinous, or balſamic Subſtances whatever, it does more than can be effected by any other *Menſtruum*; for it deſtroys their viſcidity, and renders them diſſoluble in Water, and Spirits, and very eaſily miſcible with the animal juices. Here then we muſt allow, that Nature furniſhes us with a *Menſtruum*, that can ſcarcely be equall'd by any production of the profoundeſt Art. The very bitter, yellow Bile too of any ſound Animal, Fiſhes in particular, that have no Lungs, and are voracious, have almoſt the ſame effect upon balſamic, gummy, reſinous, tenacious, teribinthenaceous, viſcid Subſtances, which they happily diſſolve by being gently mixed with them. Manna, Honey, and Sugar, with warmth and rubbing do the ſame. I might here take notice, likewiſe, of the White of an Egg: When this is hardened by boiling, well ſeparated from the Yolk, and diſtilled in a *Balneo Mariæ*, it yields a clear Water, that has no conſiderable Smell, or Taſte, is neither ſaline, acid, or alcalious, and yet whoſe efficacy is ſo great and peculiar upon Metals, that both *Paracelſus* and *Van Helmont* agreed, that this alone was proper for the preparation of their medicated Mercury, of ſuch excellent vertues. And if you take the hard White of an Egg, put it in a clean Veſſel, and in a Cellar expoſe it to the Air, you will have from it a very inſipid Liquor, which, if it was offered one, one would take to be pure Water; and yet this Water will penetrate Myrrh, which is ſo hard to be diſſolved, in ſuch a manner, that it will be better reſolved by this, than by any other *Menſtruum* whatſoever. To perſons, now, not acquainted with theſe things, there is nothing ſeems more ſurprizing, than that Bodies ſhould be diſſolved by the very ſofteſt *Menſtruums*, which are affected by ſcarcely any other. 7. I aſſert, therefore, that neither acidity, a lixivious acrimony, or ſaline diſpoſition appearing phyſically to be preſent in any *Menſtruums*, does ever demonſtrate, *a priori*, that ſuch a *Menſtruum* will diſſolve any given Body; but this certainty muſt always depend upon ſome Experiment, by which it has appeared that this Solution will happen, if this *Menstruum* and that Body are mixed together. For if simple Sulphur is put into any known Acid whatever, from the mildest to the strongest, even tho' it is assisted by Fire, the Sulphur will remain unaltered as Sand in Water. So Spirit of Nitre, howsoever it acts upon other Metals, has no effect upon Gold. It is idle, therefore, to say in general, that Acids dissolve Metals; for this or that Acid only, dissolve such and such particular Metals. If a Person, after he had in many instances experienced the corroding quality of the strongest caustic Alcali, should hence begin to believe that this power would extend itself to all other Bodies; how much would he be deceived, when he saw plainly that Mercury, Gold, and Silver, suffered nothing from this Solvent. And the same thing we observe holds good in Salts: For if Silver is boiled with Salt of Tartar it grows white, tho' it does not do so at all if it is boiled with Sea-salt. We must not therefore, pretend to say, that Alcali's, Acids, or saline Bodies, are solvents in general, but only in a limited sense, with respect to their particular objects: If we offer to proceed any farther, the nature of the thing is against us. 8. On the other hand, a prudent Chemist would not presently conclude, from seeing any Body dissolved, that the cause of this Solution, was an acid, alcalious, or saline Body, if there were not some other circumstances, that might more certainly determine it. And yet this error, the modern Chemists have often fallen into, who, being too prone to run into generals, have from any observed Solution presently imagined, that they knew the Solvent. But suppose, now, that in a given case, a Person was sure that Gold was there dissolved into its smallest Particles, and at the same time knew perfectly well that Gold is not dissoluble by any known Salt except Sea-salt, and what is produced from it: Yet even here, one cou'd not certainly conclude, that because Gold was here dissolved, therefore Sea-salt was the Solvent; for if the purest Mercury is rubbed upon the cleanest Gold, it will penetrate, corrupt, and dissolve it. In all nature, now, we don't know any Body, that is less acid, alcalious, or saline than Mercury; no Body in which there is less Acrimony than in this, as it gives no pain, tho' it is applied to the Eye, or the bare Nerves: And yet this we see dissolves Gold, which Sea-salt excepted, resists every acid, alcalious, saline, acrid Body that we are acquainted with. 9. But I assert farther, which is still a greater paradox, that all that physical Power, which we generally call corrosion, or corroding Acrimony, is, absolutely considered, nothing at all, but relative only between particular corrodents and corrodends, and not between every corrodent and all other Bodies: Hence, if a Person, after he had, in an infinite number of instances, experienced the corrosive Acrimony of *Aqua Fortis* upon Animals, Vegetables, and Fossils, shou'd thence hastily conclude, that therefore this very corrosive Liquid wou'd much easier corrode any Bodies that were softer, he wou'd soon find himself mistaken by putting into it the softest Wax, or the brittlest Sulphur. 10. Nor, on the contrary, will it at all follow, that because any particular Body is very soft, with regard to our senses, nor corrodes and resolves the Animal Fibres, it has not, therefore, a dissolving Power: For a Person, without any inconvenience, might take a considerable quantity of sweet Oil of Olives; and yet Sulphur, which resists every corroding Acid, may soon be entirely dissolved in it; as may Wax likewise, which corrosive Acids do not affect. Even melted Wax, which is so soft and unactive, is said to extract a

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Colour from Coral, gently indeed, but very efficaciously; and yet the same Coral would bear the extreme violence of the Fire for a long time, without being altered; nor be affected by any Alcali's. This no-body could easily have believed *a priori*, but must first be convinced of the truth of it by particular Experiments. Those Bodies, therefore, which appear to us to be exceeding hard, and are found to be so in the Fire, do not hence, in order to their Solution, require Solvents which have given any proofs of their being very acrid. And hence, upon these principles, it won't seem impossible to be found out in Art or Nature, a Solvent that shall be suited to any given Body scarcely dissoluble by any thing else, which *Menstruum* at the same time shall not be able to corrode other Bodies, that are much weaker and softer. And the only way here, if one would do any good, is successively to apply all the *Menstruums* we know of, to the Body whose Solvent we want to discover: For very often that which seems most unfit for the purpose, answers it better than any other whatsoever. Consider, for instance, the Stone in the Bladder, and Cancers. These we have not hitherto been able to cure; but yet we ought by no means to despair of finding out a Remedy, which may be able to dissolve the Stone without hurting the Bladder, which from what has been said, we see wou'd not necessarily follow. Spirit of Rye-bread, has a wonderful power of dissolving almost any Stones, and yet does not by any corrosive quality hurt the human Body. The Water drawn from the hard Whites of Eggs, may be dropp'd into the Eye without any pain; and yet with regard to many things, has a dissolving vertue. 11. Most *Menstruums*, at the very same time that they dissolve, and change their objects, are perfectly likewise changed by them, so that the action between them is reciprocal. This appears to be true in almost all *Menstruums*. Water, Alcohol, and Mercury, indeed, are less altered than others, but those likewise are changed by degrees. For tho' the Alchemists say that the purest Mercury never suffers any alteration; yet this by the admixture of other Bodies is altered by concretion: And as that itself is often rendered impure by other Bodies, it must then be in some measure altered by them; even when by transmutation it is converted into Metals. 12. It is a very great mistake to imagine, that all *Menstruums* will constantly perform their Solutions so much the more efficaciously, as they are more depurated, and reduced to their greatest degree of strength; for very often their vertue decreases in proportion to their strength and simplicity. If you want, for instance, a Vitriol of Lead, and for this purpose dissolve it in *Aqua Fortis*, you will always find the Solution more difficult in very strong Spirit of Nitre, than if it is diluted with a sufficient quantity of Water. The same is true in Iron, which dissolves in Oil of Vitriol mixed with four times its weight of Water, whereas if it is thrown into the purest Oil of Vitriol, the Mass in an instant becomes almost immoveable. Hence the purest Alcohol coagulates a great many things which common Spirit of Wine dilutes and dissolves: This appears evident in human Blood, which is coagulated by the former, but diluted by the latter. Hence the greatest simplicity of a *Menstruum*, or its utmost perfection in its kind, does not always increase its dissolving power upon particular Bodies. But on the other hand, it is true likewise, that if the same *Menstruum* is applied to other Bodies, it often requires the exactest purity to be able to act upon them as a Solvent. If we want, for instance, to dissolve distilled Oils accurately in Spirit of Wine, it

must

must first be reduced to the purest Alcohol, or it will have no effect at all. In the same manner, if you wou'd dissolve Amber in Spirit of Wine, you must make use of the most rectify'd Alcohol possible. So that here again we can't pretend to pronounce absolutely of *Menstruums*, whether they are required pure, or diluted, to induce such and such changes upon Bodies, unless it has been first precisely determined by Experiment. 13. But in this Doctrine of *Menstruums*, there is nothing more remarkable, than that in Solutions performed by them upon their object, there often arises a new power in Nature, which neither existed in the *Menstruum*, or Solvend, before the Solution, but depends intirely upon this union of them together. A Child, for instance, may without any inconvenience, take 3 grains of Crude Mercury, and so it may 7 or 8 grains of Spirit of Sea-salt; and yet when from these prepared together, you have 4 grains of *Mercurius sublimatus corrosivus*, if the Child should take this, it would prove a most violent Poison. So one may safely give a Child 30 grains of Crude Antimony powdered, and as many of Nitre properly diluted; but if these are reduced to a Powder, mixed together, and then set on fire, you have in an instant a *Crocus Metallorum*, of which no-body wou'd give a Child 6 grains, that did not design to destroy it. I wish, therefore, the Chemists wou'd hence be cautioned for the future, not to believe that the productions of their Solutions are always good Medicines, or at least not hurtful to the human Body, because the Simples which produced the Compound had medicinal vertues, or else were innocent. Certainly, the greatest miscarriages that have happened in the Art, and have often brought it under such disgrace, have risen from this precipitancy of the Artists. And, indeed, nothing has ever more surprized me, than to see the unlimited liberty that both the Chemists and Physicians have taken in determining the medicinal vertues of every Body which they have by their Art prepared. Examine *Basil Valentine* only, in his *Currus Triumphalis Antimonii*, and you will see a flagrant instance of it. For my own part, I have often thought with myself, that a Carpenter, Mason, or any other handicraft, might as well cry up every thing in their way, as these Persons do in theirs. But you, Gentlemen, who will make truth, and the good of mankind your study, will always remember, that this itch of commending every thing must be prudently restrained; and that if you shou'd meet with any new thing that you have a mind to make trial of, it is proper to begin with a very gentle dose, and proceed gradually, carefully attending to every effect it produces: And if it is made use of with this caution, the Doctrine of *Menstruums* will open a way to the understanding the most excellent things that belong to the Art. For if you examine the *Classes* we have described, and the Objects that properly belong to every one of them, and consider carefully the true marks assigned, you may then at length make use of this Doctrine in such a manner, as to be able, as much as possible, to determine *a priori*, what will happen upon the application of one Body to another: But here, however, you will continually meet with new appearances which you were not acquainted with before. As far as I have been able to let you into the Knowledge of these things, I have done it with pleasure, and must now pass on to something else, *viz.* the consideration of

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The universal Menstruum or Alcahest.

Whoever, therefore, carefully considers what has been hitherto delivered, will easily believe, that all chemical solutions of Bodies, except a few purely mechanical ones, are the effect only of attraction, and repulsion, between the Particles of the *Menstruum* and those of the Body dissolved; hence, therefore, that all the action here depends upon the relation betwixt these two; and of consequence, that according to the known rules of art there cannot be assigned any Body, either natural, or artificial, which, without any distinction, would dissolve all Bodies whatsoever: Nay, and farther, that it is impossible to deliver any physical method, by which the resolution of all Bodies promiscuously may be obtained. Nevertheless, after *Van Helmont* the Father had published his Writings, there was a report went about in the Chemical World, of a secret, universal *Menstruum*, which *Paracelsus* was said to have possessed, and which he, according to his manner of writing, called the *Alcahest*. If any such thing, now, as *Helmont* solemnly swears, was ever known to any mortal, it certainly ought to be looked upon as the most excellent favour, that the Divine Being ever indulged Mankind with, either in the Chemical, or any other Art. This, without dispute, would be vastly more valuable than any Philosopher's Stone, and much more to be wished for, as by the help of it might easily be obtained the most certain means both of Health and Riches. This, with a great deal of reason, was the opinion of Mr. *Boyle*, who yet, after an infinite deal of Pains, and with all the skill that he by this means acquired, was never able to come at the discovery of it, nay, upon the best foundation, scarcely believed, that there ever, in reality, was any such thing. Designing Men, however, have made a handle of it to satisfy their avarice, by imposing upon such persons as they found fond of such kind of *Arcana:* Prudent Men have always remained in suspence, not daring absolutely to pronounce any thing in it. For these reasons, therefore, I was willing to give you an historical account of this Affair, just as it is, that is to say, as it may be collected from the Writings of those Authors who alone have wrote of this *Menstruum*; that thus at least we may know the opinion of those Persons, who tell us, they have possessed, and made use of this *Arcanum*. Every thing, however, that has been said upon this head, by other People, has been borrowed from *Helmont* alone; for from what *Paracelsus* himself wrote of the *Alcahest*, no mortal would ever have thought of any such thing, had not *Helmont* given the hint, that such great mysteries were couched under this uncommon Word. As for my part, I confess freely, I am not master of this secret of the Fire; and therefore I can do no more than by carefully examining, and faithfully comparing one thing with another, lay before you what is to be found in these Authors. And if these persons were really acquainted with any such thing, and were willing that one who studied their Writings attentively should find it out; I know no better way of coming at it than what I have proposed. By this means a person who is disposed to set about this grand work, may know what Matter he must make use of, by what Instruments he must operate, and in what method he must proceed, that so he may not lose both his labour and his money. And it will farther, too, have this great advantage, that it will secure us from being impoſed upon by the tricks of Impoſtures, whoſe boldneſs and knavery make them formidable, but who don't know themſelves what they pretend to; for theſe Fellows may be eaſily detected by any perſon who is acquainted with the doctrine of *Paracelſus*, and *Van Helmont*. This I myſelf have ſometimes found excellent uſe in, when I have happened to have to do with theſe vain pretenders. Let us, therefore, with a great deal of caution, proceed.

First, the Name. And in the firſt place, let us conſider the name, which is *Alcaheſt*. This word, before *Paracelſus*, no body ever made uſe of, no not even among the Chemiſts. And even he himſelf, as far as I have been able to diſcover, never uſed it, but in one paſſage, which you have in his Treatiſe *de Viribus Membrorum*, Lib. II. C. 6. where there are theſe words. *And the Liquor of the Alcaheſt is exceeding efficacious in the Liver, to comfort and ſtrengthen it, and to preſerve it from a Dropſy, and all the Diſeaſes that have their riſe in it. And its proceſs is, to be reſolved after Coagulation, and coagulated into a tranſmuted form. This appears in its proceſs of Coagulation and Reſolution. And then if it overcomes* (ſui ſimile) *that which is like it, it is a Medicine for the Liver above all Medicines. Nay, though it were conſumed, it would ſupply the place of an intire Liver, as though it were not conſumed. All you, therefore, that make Phyſic your Study, ought to know how to prepare the Alcaheſt, in order to remove a great many Diſeaſes that have their ſeat in the Liver.* So that *Paracelſus* never made uſe of this word but twice, and that only in this place; nor is there the leaſt Mention of any ſuch thing, either before or after, as I informed myſelf by a careful examination of all his works. No mortal, therefore, from what he ſaid upon this head, would ever have thought of this grand ſecret, had not *Helmont* afterwards added his interpretation.

Secondly, its Etymology. The derivation, therefore, of this new word, thus coined by *Paracelſus*, was examined into. And upon conſidering, that it was uſual with him to conceal common words by the tranſpoſition of their letters, it was imagined that was the caſe here; though ſometimes too he formed ſtrange words by joining the beginnings of different words together. Thus when he would have you make uſe of *(Tartarus)* Tartar to reſolve the *Saburra* in the Spleen, he ſays, take *Sutratar*. L. II. *de Vir. Membr*. C. 7. And again when for diſeaſes proper to the Kidneys he preſcribes Saffron, which from its golden Colour the Chemiſts called *Aroma Philoſophorum*, he ſays, theſe Diſtempers are cured by *Aroph* L. II. *de Viribus Membr*. C. 10. Hence, therefore, ſome perſons have thought, that *Alcaheſt* ſignified *alcali eſt*. *Rolfinc. Eph. Germ*. D. 12. Ann. VI. VII. p. 193; *Rulandus* in his Lexicon; and hence ſuppoſed that it has always an Alcali for its baſis, which is then ſaturated with a proper Acid. Others have been of opinion, that it was called ſo *quaſi Staltzgeiſt* becauſe if the *Alcaheſt* is the ſame with the *Circulatum*, they imagined it was made from Sea Salt, coagulated, reſolved, and coagulated into a tranſmuted form. But again, others ſuſpected, that it was called *Alcaheſt*, *quaſi Algeiſt*, or a perfectly pure ſimple Spirit: This they thought its proceſs of coagulation, reſolution, and coagulation, ſeem'd to teach us. And laſtly, there is *Faber*'s opinion, who ſays, it is a pure, mercurial, metalline Spirit, which is ſo united with its own proper Body, that hence two become one Body, that is inſeparable, and indeſtructible. *Eph. Germ*. D. 11. Ann. 8. App. III. This, then, being

being all we can learn from the etymology, let us paſs on to the ſynonomous terms, and ſee if by comparing them together we can get any farther light into it. *Paracelſus* himſelf has left us no ſynonomous name, but *Helmont* has a great many, and therefore theſe we will now examine. And in ſhort we have no other aſſiſtance beſides the authority of *Van Helmont* alone, who declares that the very ſame bottle was given likewiſe to him.

Thirdly, the *Synonoma's.*

In the firſt place, then, he calls it ſimply, *Water*; telling us, p. 88. § 27. that he knew a *Water* which he muſt not diſcover, by the mediation of which all Vegetables might be tranſmuted into a diſtillable Liquor, without the leaſt *Fæces* remaining at the bottom of the Veſſel. And in the ſame place § 29. he ſays he mixed together a certain *Water*, and Coals made from Oak, in an equal quantity, and digeſted them with a bath heat in a Glaſs hermetically ſealed. And there he calls the ſame a *thick Water*, whilſt he writes § 28, that in the ſecond Book only of the *Maccabees*, Chapter the firſt, there is mention made of a *thick Water*, which was a perpetual Fire, and perhaps not unlike his *Water*. And in another place he calls it a *ſolvent Water*, as p. 628, where he ſays, the Liquor *Alcaheſt* is an immutable, *ſolvent Water*. But he came ſtill nearer the matter, when with one word he called it *(Ignis-Aqua) Fire-Water*, for whilſt p. 337. § 3. he is giving an allegorical account how he came by his knowledge, he pretends he received a bottle in which there was *Ignis-Aqua*, of one word only, a name perfectly ſimple, ſingular, indeclinable, inſeparable, and immortal. And again he calls it a *Latex* reduced to its leaſt Atoms poſſible in nature. p. 94. § 28. But he very frequently calls it a *Liquor*, p. 85. § 6. By the addition of the *Liquor Alcaheſt* of *Paracelſus*, he aſſerts, that all Bodies may be converted into Water, p. 119. § 89. And that by the *infernal Fire*, which is the *Liquor Alcaheſt* of *Paracelſus*, may be known how much any Vegetable contains of either Luminary. p. 265. § 11. p. 384. §. 43. p. 419, 628, 700. § 23, 700, § 2. p. 706. § 10. 714. § 27. 776. § 11. 60. And he calls it, likewiſe, the *ſolvent Liquor* p. 88. § 29. All theſe things, therefore, ſeem to intimate, that this *Arcanum* was of a moiſt, liquid form, like a kind of a Water. In another place, as a ſynonomous term, he makes uſe of *the Fire of Hell*; for he ſays expreſly, § 28. p. 119. by the *Fire of Hell*, which is the Liquor *Alcaheſt* of *Paracelſus*. And again, p. 45, 15. Original Sand reſiſts both Art and Nature, nor can by any means be made to recede from its conſtancy, except by an artificial, *infernal Fire* alone, in which artificial Fire Sand becomes Salt. If *Helmont*, therefore, in this appellation has followed *Paracelſus*, by this we may know what the *Alcaheſt* was, becauſe *Paracelſus* himſelf has wrote of this *infernal Fire*: But of this by and by, when we come to ſpeak of the *Alcaheſt* itſelf. Afterwards, *Helmont* ſays, this is a moſt happy and perfect Salt, which has arrived to the utmoſt degree of purity and ſubtlety that Nature is capable of. § 24. p. 384. And for this reaſon, he ſeems to call it, the *Ens primum Salium*, p. 419; the *Sal Circulatus*, and the *Sal Circulatus Paracelſi*, § 11. p. 43. § 49. p. 374; the *Circulatum majus. Ibid. Sal Circulatum*, p. 576. *Sal Circulatus*, p. 628; *Sal Circulatus Paracelſi*. § 23. p. 700; of which he made mention in his Book *de Renovatione & Reſtauratione*. If, therefore, *Van Helmont* has acted candidly and honeſtly in this

 affair,

affair, we may from theſe ſynonomous terms, and the writings of *Paracelſus*, make an attempt towards a diſcovery of this wonderful *Menſtruum.*

Its origin. But before we proceed to this, we muſt in the fourth place conſider its origin. Firſt then it is never found ſpontaneouſly in Nature; for here Nature is deficient, § 12. p. 56. where he expreſly aſſerts, that part of Earth may be homogeneouſly reduced into Water by Art; but ſtrenuouſly denies, at the ſame time, that this can ever be effected by Nature alone, becauſe in Nature the agent is wanting by which true Earth may be reduced into Salt and Water. Nor is this produced except by the chemical art, which alone diſcovers a *Latex*, which cannot be tranſmuted, being reduced to the ſmalleſt Atoms that are poſſible in Nature. § 27, 28. p. 94. Nor is this to be effected by vulgar Chemiſtry, but by the labour of Wiſdom. *Ibid.* § 23. p. 700; and that, as he expreſly aſſerts, as its ultimate and moſt perfect production. And laſtly, he ſays, Chemiſtry, as its moſt excellent effect, prepares a *univerſal Solvent.* § 65. p. 387. Nay, and in the whole Art there is not any operation more difficult than the preparation of the *Alcaheſt*; nor is there in the whole Art any thing more laborious. Nor can the knowledge of this Operation be acquired either by reading, or meditation, but by a fulneſs of ſcience, and that too doubly confirmed; and hence very few are acquainted with it. § 23. p. 700. And for this reaſon this *Liquor*, whoſe Operation is vaſtly tedious, cannot be obtained by human underſtanding; For though a perſon ſhould have ſo much skill in the Art as to be properly qualified to come to the knowledge of it; yet unleſs the Moſt High, by a ſpecial favour, leads him to it, he will never arrive at it; for he muſt be choſen by a particular privilege, whoever becomes Maſter of it, § 27. p. 714. For God alone is the diſpenſer of it, for reaſons which are known to the Adepts, § 2. p. 704. From this origin of it, therefore, thus delivered by *Helmont*, we may ſee how much they are miſtaken, who idelly imagine, they ſhall be able to prepare it with a little trouble. Theſe vain boaſters certainly thus diſcover both their ignorance and their diſhoneſty. Nor let them impoſe upon you, by pretending to more things of the ſame nature; for *Helmont* abſolutely refutes every thing of this kind, by plainly aſſerting, that as in the whole compaſs of nature there is but one Fire (*Vulcanus Ardens*) a burning Fire, ſo there cannot be but one Liquor, which will diſſolve all Bodies into their firſt Matter, without any alteration in itſelf, or diminution of its ſtrength; as the Adepts know and teſtify, § 6. p. 677, 678. Being ſecured, therefore, by this doctrine, I have been able to ſilence many illiterate perſons, rich in promiſe and expectation, and ſometimes crafty Foxes too, by only asking them one or two queſtions, by their anſwers to which I ſoon perceived how little they underſtood of what they boaſted of.

Fifthly, its Vertues. Firſt, with regard to its Object. But let us now proceed to examine into the ſtupendous vertues that are aſcribed to this wonderful, and almoſt tremendous *Arcanum.* This *Menſtruum* then can efficaciouſly exert its diſſolving power upon all ſenſible Bodies whatever, whether Simple or Compound, Volatile or Fixed, Solid or Liquid, Animal, Vegetable, or Foſſil; nay, upon Gold and Mercury themſelves, upon which nothing elſe can act to their intimate parts. Thus hear him ſpeaking himſelf. (*Noſtra Mechanica*) Our Mechanics have diſcovered to me, that all Bodies, whether rocky, ſtoney Subſtances, or Gems, Flints, Sand, Mercaſites,

Clay,

Clay, Earth, Bricks, Glaſs, Lime, Sulphur, *&c.* may be tranſmuted into an actual Salt, æquiponderant to the Body from whence it is procured: And Vegetables, Fleſh, Bones, Fiſh, and every thing like them, I have known to be reduced by it into their three mere Principles: Metals, however, on account of Anatic Commixture of their Seed, and Sand, are reduced to a Salt with a great deal of difficulty, § 11. p. 43. For Sand, or original Earth, reſiſts both Art and Nature, nor will by any helps of Art or Nature be made to recede from its primitive conſtancy: But under the power of the Artificial *Infernal Fire* alone, Sand becomes Salt, and at laſt Water, §. 45. p. 15. Again, The *Alcaheſt* of *Paracelſus*, by ſubtilizing them, tranſmutes all natural Bodies, §. 7. p. 57. And in another place, all Bodies are eaſily reduced to Water by the application of the *Liquor Alcaheſt* of *Paracelſus*, §. 6. p. 85. Even thoſe that otherwiſe refuſe to be reſolved into their three Elements, *Ibid.* By the help of this likewiſe, all Vegetables are commutable into a Liquor, which may be diſtilled without any *Fæces* remaining at the bottom of the Glaſs, §. 27. p. 88; even oaken Coal itſelf, *ibid.* §. 29. For one and the ſame Liquor, *Alcaheſt*, perfectly reduces all tangible Bodies in the Univerſe to their firſt Life, §. 11. p. 266; even all Poiſons themſelves, §. 49. p. 374. And which diſſolves every thing beſides itſelf, as warm Water diſſolves Snow, §. 24. p. 380. §. 65. p. 387; Oil itſelf, and Spirit of Wine, p. 576; Cedar Wood, p. 634; All kinds of *Elixir Proprietatis*, 635; The *Ludus* likewiſe of *Paracelſus*, p. 700; Mercury, §. 10, 11. p. 776; Gold itſelf, §. 10. p. 706, which cannot by any other Solvent whatever be radically deſtroyed into its conſtituent Principles, as it is much eaſier to make Gold out of what was not Gold before, than to produce any thing from Gold which ſhall not be Gold. To this agree all the whole Tribe of Adepts, who unanimouſly aſſert the truth of it.

In the ſixth place, let us conſider the manner in which the *Alcaheſt* exerts its power upon theſe its Objects. And here we find its efficacy is always excited by Fire, and this applied only in a gentle degree, whether it acts in digeſtion, diſtillation, or cohobation. For he mixed the *Alcaheſt* with Coal made from Oak in equal parts, and digeſted them for three days in a Bath-heat, in a Glaſs hermetically ſealed, and the Solution was then compleated, §. 29. p. 88. The *Sal-Circulatum*, by digeſtion only, reduces every ſort of Oil, and Spirit of Wine, into a prodigious different form, from what they were in before, p. 567. If the *Alcaheſt* is mixed with an equal weight of Cedar-wood reduced to ſmall pieces, and is expoſed to a kindly warmth in a ſealed Glaſs, the whole Wood will, in a week's time, be reduced to a milky Liquor, p. 634. Sometimes too, the work is done by one ſimple diſtillation: For if the Liquor *Alcaheſt* is diſtilled once only from common Mercury, it leaves it at the bottom coagulated, and pulverizable, and neither increaſed nor diminiſhed in its weight, p. 628; which is effected in a quarter of an hour, p. 776. But ſometimes a cohobation is neceſſary, in order to accompliſh your deſign. For frequently, when Bodies are converted into a Salt of the ſame weight they were of before, they muſt be cohobated ſome number of times with the *Sal-Circulatus* of *Paracelſus*, before they will intirely loſe their fixity, §. 11. p. 43; which happens chiefly in Metals, Gold in particular, on account of the perfectly equable commixture of its Seed, *ibid.* On the other hand, if by one diſtillation only it is drawn off from the *Ludus*, or *Cevilla* of *Paracelſus*, this

Sixthly, with regard to its method of acting.

diſtillation,

distillation, in so small a space as that of two hours, it converts the whole Stone into a Salt of the same weight. As for any other manner of applying this universal Solvent, I can find none, nor does it appear by any argument, that a greater degree of Fire is necessary for the operation. By a gentle agitation of its parts therefore, excited by the Fire, it is capable of dissolving all Bodies. For the *Alcahest* itself rises in distillation with the second degree of a Sand-heat, §. 29. p. 88. But it does not ascend with a Bath-heat, §. 29. p. 88. 634.

Seventhly, its effects. But farther, there was nothing ever observed in all Nature, or even related, that is more surprizing than the physical effects which these Authors ascribe to the action of this *Menstruum*: For it intirely converts the whole Body of its Object, into a Matter which has neither gained nor lost the least weight during the Operation; and this transmuted Matter seems always to be liquid or saline. In this affair, however, there is some variety: For Mercury, by the action of the *Alcahest*, is reduced to a fixed Powder, which is pulverizable, resists a Wind-Fire, and remains fixed if mixed with Lead. §. 10, 11. p. 776. Almost all other Bodies are converted into a Salt æquiponderant to their former Mass, § 11, 15. p. 43. § 12. p. 56. An oaken Coal is soon changed into two diaphanous Liquors, which differ in situation and colour, § 29. p. 88. Cedar-wood is converted into a milky Liquor of equal weight with it, and then farther into a twofold Oil, which afterwards, by simple digestion, are changed into a pure Salt, so that it may be mixed with Water, p. 634. But the *Ludus*, or *Cevilla* of *Paracelsus*, which is a Stone found at the bottom of the *Scheld*, near *Antwerp*, is within the space of two hours only, converted by a gentle distillation into a Salt æquiponderant with the concrete, which being exposed to the Air, dissolves, and runs into a Liquid, without leaving any *Fæces* at all, § 23. p. 700. From this whole account, then, it is evident, that this Solution at the beginning is performed after different manners, but that at last, however, it reduces all Bodies into a kind of Salt that may be dissolved in Water, Mercury alone excepted, which on account of its perfect simplicity, which renders it more pure than Gold, and exceeding like pure Water, refuses to be converted into a Salt; and hence it radically resists all division possible to be effected, either by Art or Nature, and for this reason is perfectly indestructible, § 8. p. 55. § 10. p. 705. These Bodies, however, after they are by the help of the *Alcahest* reduced to an æquiponderating Salt, still retain their proper vertues, which depend upon the seminal property of them, and which therefore are peculiar to them, and not common to others. This very remarkable circumstance is described, § 7. p. 55. where he says, the *Alcahest* of *Paracelsus*, by subtilizing them, transmutes all Bodies in Nature; for Bodies, when they are reduced to their utmost possible subtility, at last pass into another substance, with a retention of their seminal Properties. And § 65. p. 387. By the universal Solvent, all things return back to their *Ens primum*, and exhibit their native qualities, whence they have an opportunity of acquiring great and unlimited powers. But more plainly still, § 6. p. 677, 678. while he asserts that this Liquor alone dissolves all Solids into their first Matter, without any diminution, or alteration of itself. And therefore, he cries out, get but acquainted with this homogeneous, immutable Solvent, which resolves all its Objects into their first liquid Matter,

 and

and then you will be able to look into the intimate essences of things, and examine their qualities, § 25. p. 780. By this means, therefore, all these Bodies are converted into a saline volatile Matter, which still retains their particular *Spiritus Rector*. Hence it may be intimately mixed with any Humour of the human Body, with that circulate through all its Vessels, and in its whole passage every where exert those powers which are proper to it, with regard to our Body. These, therefore, they called Potables. Hence, then, we see, what the Adepts meant by potable Gold, and how vain and deceitful the boast of those Persons is, who pretend to be Masters of it. Gold, when it is corroded by Acids, will still give you again its actual Particles of Gold, tho' they then lie concealed in the Acid: But the philosophical potable Gold, is a saline Liquor æquiponderant to the Gold, without any *Menstruum* whatever united with it, being only the pure simple first Matter of the Gold, or its *Ens primum*. See in particular § 23. p. 700. Here, therefore, above all, it is particularly remarkable, that the *Alcahest*, whilst it thus dissolves, never mixes itself at all with its Solvend, but remains perfectly separate from it. Hence, therefore, it neither increases nor diminishes the substance of the Body dissolved, but leaves it exactly the same as it found it. This you evidently see, § 28. p. 88. where he says, that the two Liquors of the dissolved oaken Coal, which were different in Situation and Colour, rose with the Warmth of the Bath, whilst the solvent Liquor remained at bottom, of the same weight it was before. For it finds no Body with which it can be joined, itself being too pure and subtil, and reduced to its least Atoms, and hence disdaining all ferments, and always remaining single, § 27, 28. p. 94. Hence it acts only by an external action, not concreting with its transmuted Object, as the purest Fire uses to act upon its Object, as warm Water melts Snow, § 24. p, 380. § 6. p. 677, 678. For this Liquor leaves nothing of itself mixed with its Solvend, § 10, 11. p. 776. Hence, therefore, besides others, this *Menstruum* seems to have two excellent advantages above all others: In the first place, that it does not act by attraction, or repulsion, but only by a mechanical dissolving Power, contrary to all others that we are acquainted with, Fire, perhaps, alone excepted: And then, secondly, that it always preserves intire the native Powers of its Solvends, and yet whilst it resolves Poisons, it deprives them of their violent and deadly quality, and gives them the most excellent medicinal vertues, by reducing them to their *Ens primum*, § 49. p. 374. which, however, it must be allowed, is very difficult to comprehend. When Bodies, now, are by the help of the *Alcahest* reduced into their saline volatile *Ens primum*, retaining at the same time all their seminal qualities, if they are then urged any farther by the action of this Solvent, they are perfectly deprived of their proper seminal vertue, and from every one, how different soever, there is produced the same unactive, inodorous, insipid, simple, elementary Water; so that by too great an application of the very same *Menstruum*, whatever excellence was produced before, is now destroy'd. It appears, therefore, that the ultimate matter of all tangible Substances is Water, upon which the *Alcahest* itself can act no farther, but which being again impregnated with the seminal fæcundity of any Seed, may be converted again into any new Bodies whatever. Hear what he says himself! Every Body is transmuted into an actual

actual Salt æquiponderant to the Body from whence it is made; and this Salt being cohobated some number of times with the *Sal-Circulatum* of *Paracelsus*, loses intirely all its fixity, and is transmuted into a Liquor, which itself likewise at last becomes an insipid Water, of the same weight with the Salt from which it proceeded, § 11. p. 43. Original Sand, by the artificial *Infernal Fire* alone, is changed into a Salt, and then a Water, § 15. p. 45. And I know a *Water* by the mediation of which, all Vegetables are converted into a distillable Juice, which rises without leaving any *fæces* at the bottom of the Glass; and which Juice being distilled with Alcali's, is totally reduced into an insipid elementary Water, § 27. p. 88. An oaken Coal turned into two Liquors by the *Alcahest*, and then mixed with a little Chalk and distilled, rises with almost its former weight, and has all the qualities of Rain Water, § 29. p. 88. And then they all become so volatile, that they rise with a Bath-heat, and fly off from the *Alcahest* which remains at the bottom, § 29. p. 88. § 24. p. 380. p. 634.

Eighthly, its proper immutability.

But what is much more surprizing than all the rest, is in the eighth place, that this *Menstruum*, whilst it operates so wonderfully upon all other Bodies, is not in the least lessened, altered, or weakened in its efficacy by any of them: So that in this respect again it resembles Fire, and is with a great deal of reason compared to it. By a very expressive Phrase, therefore, it is said to act, by its power of acting upon all sublunary Bodies, without reaction, § 15. p. 45. And that after it had dissolved the oaken Coal in so extraordinary a manner, the solvent Liquor remained at the bottom of its former weight and strength, § 29. p. 88. For its transmutation is despaired of, as it cannot find any Body worthy enough to be wedded to, and is single with regard to every commiscible ferment, to which it might be in subjection: And hence it cannot die, § 27, 28. p. 54. In its most perfect action, therefore, it reduces every tangible Substance to its middle life, without any change in itself, or diminution of its strength, § 11. p. 265. It is immutable, therefore, and immortal, § 3. p. 377. This alone, by operating, is not altered, § 24. p. 380. § 6. p. 628. 634. 677, 678. It acts, therefore, without any re-action of the Patient, or depauperation of the Agent, § 27. p. 704. § 10, 11. p. 776. For this Dissolvent is homogeneous and immutable, § 25. p. 78. and being the same both in number, weight and activity, it is as efficacious, the thousandth Operation, as it was at first.

Ninthly, its Volatility.

But among other things remarkable in this *Menstruum*, is, in the ninth place, its degree of Fixity or Volatility in the Fire: And this again is exceedingly surprizing. For after it has rendered all Bodies, the most fixed not excepted, so volatile that they will rise with the gentle heat of a Bath, yet itself remains fixed at the bottom, nor ascends with them, § 14. p. 56. § 27. 29. p. 88. § 10. p. 634. 700. 776. In the mean time, however, the *Alcahest* itself is so volatile, that it rises in distillation together with the Bodies it has dissolved in the second degree of a Sand-heat, § 29. p. 88. And hence it may, by distillation, be drawn off from common Mercury, which it fixes, and coagulates, p. 776. 628. Hence, therefore, the compass within which the whole power of this *Alcahest* exerts itself, is accurately determined.

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In the tenth and last place, before we quit this subject, we must observe to you, that this *Solvent*, that thus remains intire in all its Operations, nor is ever overcome, or fatigued by the resistance it meets with from any thing, does yet acknowledge one Body in Nature with which it may be so united, as to be brought into Wedlock with it. This appears evident, by considering the Text of the Author. § 27, 28. p. 94. Chemistry was solicitous about finding out a Body, which should have so great a sympathy of purity, that it should not be dissipated by any corrumpent. And at last Religion was astonished to see a *Latex* discovered, which being reduced to the least possible Atoms in Nature, remained single, and disdained to be wedded to any Ferment. Its transmutation therefore was despaired of, as it could not find any worthier Body with which it might be united. But the labour of Wisdom found out an anomalous Body in Nature, which rose without any commiscible ferment different from itself. This Serpent bit itself, revived from its Poison, and afterwards knew no Death. So that we see here the conjunction of two things which were in some measure different. But he intimates this still more plainly and distinctly, § 11. p. 265. where he says, that one and the same Liquor, *Alcahest*, reduces all the tangible Bodies in the Universe to their first Life, without any alteration in itself, or diminution of its strength, but is brought under the yoke, and altered by its equal alone. And in another place he comes still nearer the matter, § 14, 17. p. 56, 57. telling us, that when Mercury is perfectly freed from the original Sulphur, which intimately adheres to it, it is not afterwards mutable by any Fire, but immediately destroys all other Seeds, except its equal.

Tenthly, its submission to one certain thing.

Thus, Gentlemen, I have faithfully laid this affair before you. Concerning any thing of this nature, I have not, to my knowledge, read a Word any where but in these Authors. Neither the ancient Philosophers, nor any other Chemists or Physicians ever mentioned, or heard of any such thing; and yet, of every thing we want in Physics, it is vastly the most to be wished for. You will, no doubt, therefore, be mighty solicitous to know in what kind of Matter it ought to be sought; for which reason I will add a few words upon this head, having tried a vast variety of things myself, which I have sometimes repented of with indignation. *Paracelsus* then had a Liquor which he prepared by an infinitely tedious circulation from Sea Salt, in which Nature has placed the greatest perfection. This by an indefatigable application he still advanced to a perpetual Oil; and then he called it the *Ens Primum salium*; *Oleum Salis*; *Liquor Salis*; *Aqua Salis*; *Circulatus Salminor*; *Circulatum minus*; L. IX. *Achid.* under the remedy *ad Maculas.* In his Treatise *de Sale*, C. IV. *in correctione & additione*. Lib. *de Renovatione* Arch. IV. Cap. 4. *Essentia de Salibus*, Archid. L. VIII. Cap. *de Elixire Salis Quintæ Essentiæ extractio de salibus*, *Archid.* X. Cap. 2. And the preparation of this *Sal Circulatus*, which is vastly troublesome, is there described, nor is there any thing obscure in it, except that we don't know what the Spirit of Wine is, that is there required to separate the impure from the pure. This now agrees exactly with the Opinion of *Van Helmont*; for he says, that the Salt of Bodies being some number of times cohobated with the *Sal Circulatus* of *Paracelsus*, is converted into Water, § 11. p. 43. And hence to the *Primum Ens Salium* he ascribes the vertues of the *Alcahest* itself, p. 419. And says,

Of the Matter of the *Alcahest.* Sea Salt for the *Circulatum minus.*

ſays, that by the *Sal Circulatus* all poiſons die, § 9. p. 374. And hence he calls it the moſt happy, perfect Salt, which is reduced to the ultimate degree both of purity and ſubtilty, and hence pervades every thing, that alone remaining immutable during its operation, by which it readily diſſolves every thing elſe, § 24. p. 380. This *Sal Circulatum* acts wonderfully upon Oil, and Spirit of Wine, p. 576. This *Sal Circulatus* reduces Bodies into the Liquor of their concrete, p. 628. And with that may be prepared the *Ludus*, § 23. p. 700.

And Mercury to be united with the *Circulatum minus*.

But *Paracelſus* had another Solvent, much more powerful than the former *Circulatum minus*, and much more difficult to be come at, which, therefore, he called his *Circulatum majus*, *Archidox*. x. C. 4. And hence in the ſame place he calls it, likewiſe, the *Materies Mercurii Salis*; and afterwards, *Living Fire*, *Archid*. x. C. 5, 6. In common Mercury he ſuppoſes there is a moſt perfect Fire, and a latent, celeſtial life, and that the quinteſſence of Mercury is celeſtial Fire, if it is diſſolved with its Mother, *viz.* an *Arcanum* of Salt, *Archidox*. x. C. 6. When theſe two, therefore, by a true adunation, are intimately united together, and together rendered pure, ſubtil, and volatile, then ſeems to ariſe that wonderful mercurial Water, which he deſcribes in the Chapter *de Corrodente ſpecifico*, where he ſays, that Gold ſo dies there, that it continues to be Gold no longer; whereas in all other corroſions of Gold, the Gold is only divided into very ſmall Particles, but ſtill remains the ſame true Gold, and by an artificial reduction may be always recovered again. By this art, therefore, there is a perfect union of Water with Water: For there is a two-fold Water, *viz.* a common one, which is in Salt, and a metalline one, which is in Mercury, both which, however, have the ſame Root. All this now ſeems to have been underſtood by *Van Helmont* exactly in the ſame manner, and therefore in a few words I ſhall juſt add what he has ſaid upon it. Pleaſe therefore to hear him ſpeaking, § 8. p. 55. The internal Mercury of Metals, perfectly freed from every taint of a metalline Sulphur coheres together with an indiſſoluble union, ſo that it radically reſiſts all poſſible diviſion either by Nature or Art. Nor could I learn the nature of Water, except under the Rod prepared from Mercury's Wand. And I found the nature of Mercury adequate to Water: For it does not contain the leaſt Earth in it, but is always the Son of Water alone, § 10. p. 56. 705. And he ſays with all the ancient Alchemiſts, if I had not ſeen that Mercury eludes all the labour of the Artiſts ſo, that it either flies all off from the Fire ſtill intire, or elſe all remains in it, and both ways retains its immutable identity, and the anatic homogeneity of its identity, I ſhould ſay that that art was not true, which is true without any falſity, and by far the trueſt of all. So that what is above is like that which is beneath; and the contrary. And hence it is abſolutely impoſſible either for Art or Nature to find any different parts in the homogeneity of Mercury, not even by the *Alcaheſt* itſelf, as Mercury is more ſimple than even Gold itſelf, and formed with a greater anatic identity. And hence, therefore, there is in Mercury the *Ratio proxima* of indeſtructibility, as in the Elements themſelves. Hence all ſublunary things are too weak to ſubdue pure Mercury, or to penetrate, alter, or defile it. It remains ſecure in Air, Fire, and the acrid Liquor. It is not affected by any Solvent, much leſs penetrated through by Air. And, therefore,

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fore, there is nothing in Nature like this pure Mercury, no not at a distance, § 17. p. 670. It resembles, therefore, the *Ens Metallicum*, and comes very near it, § 4. p. 705. And at length, actually existing simple, and not as a constitutive part of things, § 17. p. 670. From these principles, then, we know, that it is brought under the yoke, and changed by its equal alone, § 11. p. 265. For this anomalous Body in Nature, rose without any commiscible ferment different from itself; but it bit itself, revived from the Poison, and afterwards knows no death. Thus, then, Gentlemen, you have the History of the *Alcahest* of *Paracelsus*, and *Van Helmont*, which I have extracted from their own Writings, and laid before you with the utmost fidelity. Here, therefore, you see at once, that it is in vain to seek for this *Menstruum* in human Urine, or any of its productions. Nor can it ever be found in Tartar, or any of its Preparations, tho' this may be substituted as Regent to the Prince, § 25, 26. p. 780. Nor can Phosphorus ever be reduced to it: The properties that have been proposed won't admit of it. *Glauber* too is mistaken, when he seeks it in the fixed Alcali of Nitre: As *Zwelfer* is in hoping to find it in the most acid Spirit of Vinegar distilled from Verdegrease. Nor does the famous *Guernerus Rolfincius* seem to have had a right notion of it, when he supposed it to be threefold from a fixed Alcali as the *Basis*, *viz.* in Fossils from an Alcali of Tartar, and Vinegar of Antimony; for it is a mere vitriolated Tartar that is thus produced: In Vegetables from an Alcali of Tartar saturated with Vinegar; for this gives a mere tartarizated Tartar: In Animals from the same Alcali saturated with the acid Whey of Milk; for hence arises a tartarizated Tartar, but a more valuable one: Nor does the addition of *Sal-Ammoniac* much alter the case, *Eph. Germ.* D. I. Ann. 6, 7. p. 193—196. App. And indeed, no-body in the description of the *Alcahest* has come nearer to the Sentiments of *Paracelsus* and *Van Helmont*, than *Peter John Faber*, in his Manuscript concerning Alchemy, to the most serene *Duke* of *Holsace*, which is printed in *Eph. Germ.* D. II. Ann. 8. App. p. 111. 117. out of which these remarkable words confirm my opinion. The Liquor *Alcahest* is a pure mercurial metalline Spirit, so converted to its proper natural Body, that these two become one inseparable indestructible being, destroying every thing else, and converting them into their first Matter. It is the true *Mercurius Philosophorum*, prepared from the Mineral Kingdom, joined to its own Body, inseparable from it, being a milky, buttery Liquor, penetrating and dissolving every thing. This, now, is of two kinds, Simple and Compound: The Simple is made from a pure metalline Acid, and a pure metalline Salt, rendered volatile with its Spirit; and the Preparation of this is exceeding difficult: That, however, of the Compound, is still far more so; for this is prepared from a mineral Acid, and a pure animal and vegetable Salt. The Liquor *Alcahest*, or the perfect pure *Mercurius Philosophorum*, is like Fire of an incorruptible unalterable nature, reducing every thing to its first Matter. And the very sagacious *Joachim Becherus*, in his *Subterranea*, is almost of the same Opinion: For he asserts, that he has discovered in Sea-Salt, a certain arsenical and mercurificating Power, which was it but separated and pure, would be the *Alcahest* itself, which, however, would be perfectly distinct from the *Mercurius Philosophorum*. Hence Mercury itself, he looks upon as a sulphuro-metalline Substance, which of itself would be solid, and receive all its Fluidity from an arsenical Sulphur of common Salt. This very subtil conjecture, I wish he had more clearly demonstrated. The sum of this Gentleman's Argument is this: The purest Silver, corroded by Spirit of Nitre, and precipitated by Spirit of Sea-Salt, becomes volatile, and then easily disposed to part with its Mercury; and therefore Sea-Salt can transmute the purest Metals from their fixed Nature into true Mercury. Perhaps, now, at last you may be willing to know my Opinion of this matter, and whether I believe that any of the Chemists were ever Masters of this grand *Arcanum.* To this I freely answer: *Van Helmont* complains, that the Bottle was once given him, but that it was taken away again, and therefore he could not make many Experiments with that Liquor: And *Paracelsus* does not say so many, and so great things of his Solvent, and therefore, I really don't know what to say of it. This, however, I'll venture to say, and would advise you to try it, that if you will but examine Sea-salt, and Mercury, in every chemical Method you are acquainted with, you will never repent of your Labour.

Of Chemical Vessels, and the Furniture of an Elaboratory.

As the business of Chemistry is concerned in producing and observing the changes of Bodies, and as these changes are particularly effected by the application of Fire, hence the Operators necessarily stand in need of Instruments and Vessels, without which it is impossible for them to exercise their Art. By a Vessel, now, I mean every hollow Body, in which the Matter to be chemically changed, or actually changed, is contained, as likewise the changing Body or Solvent. An Instrument, I shall call every body that has that strength, size and figure, as to make it fit to apply the changing causes to the Bodies to be changed in such a manner, as by means thereof, to excite such a motion as the rules of Art determine, and by the assistance of which, the Operator shall be able to manage both those causes, and those Objects. In general, then, your chemical Furniture must consist of Bodies to be changed by Art, of causes capable of effecting such changes, of Vessels, Instruments, and Bodies actually prepared by the chemical Art, if you would have your Elaboratory compleat.

Chemical Vessels. Chemical Vessels, to which the Objects to be changed are committed, must be able to contain such Bodies, and their solvent causes, and at the same time to bear the Fire that acts upon, that they may not prove defective in the middle of their Operation. It is necessary, therefore, that these should be very strong, and of such a nature, as not to taint their Contents: And these one may call containing Vessels. And those on the other hand, that receive the Substances after they are changed by their causes, which are almost always separated by the force of Fire from the Body, which in the containing Vessel either does then bear, or has born that force, we may call Receivers: And in these Vessels we have particularly to consider, the Matter, and the Figure.

The Matter of the Vessels. The Matter of the Vessels, is either Wood; Clay; Stone; Metal, or Glass.

Wooden Vessels, made of dry Wood, not oily, or painted, are reckoned best for keeping Salts, saline Bodies, Limes, and calcined Substances, if they are put in them, when they are both very dry, and the Vessels are then stopped very close: For in this manner those Bodies use to keep, which in almost all others

others melt from the Moisture of the Air. Mortars and Bowls too, turned out of Wood, are used to advantage, particularly for rubbing Metals with Water that are dissolved in Mercury, for which purpose they are better than any thing else. These too are of service in reducing melted Lead and Tin to Powder, if they are first rubbed over with Chalk: And these are the chief Uses they are put to.

Vessels made of Glass are of excellent service, because they neither change, add, or take away from the Bodies they contain; and whilst they are exposed to the action of the Fire, they suffer nothing to transude through them from within, nor admit any thing from without, except Fire, and Magnetism, containing and bearing even the *Alcahest* itself in the Fire. In every Experiment, therefore, we want to make, and in every chemical Operation, these, and these only ought to be made use of, when there is not required a greater degree of Fire than Glass is able to bear without melting. And as the *German* green Glass which least of all affects the contained Bodies, is the most incorruptible, and bears the Fire a long time without being fused; hence that is preferable to every other sort for these purposes. As for the white, which is almost like Chrystal, and easily flaws, and sweats out its Alcali, that must be rejected here, because it melts too easily, and communicates its Alcali to Bodies, as appears too evidently. The green Glass, I mention, will bear more than 600 degrees of Heat before it is put in fusion, but how much more exactly, I don't yet know: In the greatest Sand-heat, however, I have brought it to melt. It is evident, therefore, that this can bear a considerable compass of Fire, without any inconvenience, tho' beyond certain limits, it can sustain it no longer. It were much to be wished, therefore, that *Van Helmont* had acquainted us with that secret Lute, with which a glass Vessel being coated, it would bear the strongest open Fire of a Wind-furnace, without melting, so that he cou'd with Glass distill the igneous Oil of Vitriol. This Crust is said neither to split, crack, fall off, nor vitrify. And thus in the greatest intensity of the Fire, this Coat is said to incrustate the Glass internally, *Helm.* § 19. p. 707. If this was true, then all Operations might be performed in Glass; but, I confess, I know of no such coating, nor have ever met with any body that did. Glass Vessels.

The third sort of Matter made use of for chemical Vessels is Metal. Of Metals, now, Iron melts with the most difficulty; and hence a great many Vessels are made of Iron. All metalline Vessels, however, have two inconveniencies, the first that they are corroded by Salts when they come to be red hot, and hence both spoil their contents, and are themselves destroy'd: The second, that they melt in the Fire. This I myself have had experience of; for I got some iron Long-necks made of cast Iron, in order to distill Phosphorus from Urine, but they melted long before the Operation was finished. Metal Vessels.

In the fourth place, therefore, the Chemists make use of Vessels likewise, made of Potters Clay. But these too, when they are made of a fat clayey Earth, vitrify when they come to be exposed to the greatest degree of Fire, and thus prove deficient. The best, therefore, are those made of a poorer Earth, such as the *Hessian*, and the like, which are made of crucible Earth; for these bear the most intense Fire. But these, too, as they are porous, transmit some saline Particles, especially when you make use of them in the distillation of acid Spirits. Of this variety of Vessels, now, it is evident what sort are the most Potters Vessels.

proper for any particular Operations: Pure aqueous Liquors, for instance, and perfect fermentative Spirits, may be distilled in Metal: Acetose, distilled, fermented vegetable Spirits conveniently enough too in Tin: Other saline Substances require Glass. The spiral Tubes made use of in the distillation of acetose Liquors, are made of Tin; but it's best always to make the Head of Glass, for the reasons just mentioned. Earthen Vessels are never made use of, but where there is required a very great degree of Fire, and then, that they may transpire less, and be not so apt to crack, they should be always coated with a proper Lute. When you are perfect Masters then of this affair, before you begin any chemical Operation, you must consider the nature of the Matter to be operated upon, and the degree of Heat it will require, and hence you will easily see what kind of Vessels are fit for your purpose. And here, where one is perfectly at one's liberty, one wou'd always prefer Glass, if it was for no other reason, than that one can here look into the Vessel, and observe all the *Phænomena* that happen to the Bodies within, during the Operation; which setting aside the gratifying one's curiosity, is of excellent service both in Chemistry and Philosophy, as by this means we come at the origin of a great many appearances. The *Indian* Potters Earth, of an ash colour, is like *China*, and is, perhaps, a *Species* of it. The Potters make Vessels of this Earth of all sizes, in which they put up their Pickles and Sweet-meats, to send abroad. These are neither corroded nor penetrated by Acids: And hence your Distillers of *Aqua Fortis* make use of them, to keep their acid Spirits in.

The best Figures of Vessels for keeping Bodies.

Vessels, now, let them be made of what Matter you will, may differ vastly in their Figure; of which, with regard to chemical uses, I shall just add a few words. Those glass Vessels that are designed for putting volatile Liquors, and Salts in, are best, I think, made with a plain bottom, hollowed inwards, the sides rising cylindrically, and terminating at top in a narrow cylindrical Neck. The mouth of these must be secured with a glass Stopple, ground nicely to the concavity of the Neck: And the larger that part of the concave Surface is, that the Stopple is in contact with, the more nicely it will answer the end. But those Vessels out of which Liquors are to be dropped, should be made with a spherical Belly, and the Neck of these too should be cylindrical, and the Mouth of them produced into a Rim, which on the upper part should be a little hollow. These may be stopped with a Cork, or if you keep volatile acid Spirits in them, with the Gardiners yellow Wax. The Figures of these you see in Plate IX.

For chemical Operations.

Other Vessels which the Artist wants for the separation of Bodies by Fire, which is generally done by distillation, require different Figures according to the different ends to be answered. And here it is necessary that these should be of two Sorts, one for containing the Body to be changed, and bearing the Fire necessary for the Operation; the other for receiving what is separated out of the other by the action of Fire; which are almost always colder. I shall now then consider the Figure of each of these.

Crucibles and other melting Vessels.

If the Body to be changed and separated in the Fire, is to have nothing but its fixed part preserved, then the Figure of the Vessel made use of, is almost always an obtuse Conoid with its *Base* at the top, and truncated *Vertex* at the bottom: And these are varied through all the degrees, from this conical Figure, to a concave spherical Segment. Thus the melting Pots called Crucibles

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are conical, but the ſmelting Veſſels uſed for uſtulation, and calcination are concave parts of a ſpherical Segment. In theſe Veſſels, the effect of their Figure is this, the ſhallower the Veſſels are, and the more they diverge from the bottom, the more eaſily will the volatile Matter fly off from the fixed, and the Fire will be applied to a larger Surface both of the Matter to be ſeparated, and that which remains fixed; and hence for uſtulation, the loweſt, and openeſt Veſſels are always made uſe of.

But when the volatile Matter, ſeparated from the fixed, is to be ſaved as well as the fixed, then the containing Veſſel has a three-fold Figure, *viz.* either a cylindrical one, a conical one, converging upwards, or a conical one, converging downwards. The cylindrical, by its ſides only keeps in the volatile Bodies, but neither forwards or impedes their aſcent: The whole difference, therefore, in this ſort, ariſes from the height; and hence, as is the height, ſo is the diverſity of the operation. In order to ſeparate the moſt volatile Bodies from the leſs volatile ones, theſe cylindrical Veſſels muſt be very high; and the contrary, when you want to ſeparate Bodies that are almoſt fixed, from thoſe which are perfectly ſo. But when from a narrow bottom, the Veſſels are expanded upwards, as in the Hemiſpherical Cupels, or thoſe that are only the ſegment of a Sphere, then it is plain from Hydroſtatics, that every point of the concave baſe will ſuſtain an incumbent column of Liquor, whoſe height is meaſured by a line drawn perpendicular to the horizon from that point to the ſurface of it. Hence, therefore, it is plain, that the columns will be always ſo much ſhorter, the nearer you come to the edge; for which reaſon this diverging figure wonderfully forwards elevation; and on this account exhalation is effected by it moſt expeditiouſly. Thus then we have an idea of the Veſſel called a Retort; for it is a hollow Sphere terminating in a cylindrical neck, whoſe upper horizontal line is a tangent to the upper point of the Sphere, whilſt the inferior one produced, forms a diameter to the Sphere parallel to that tangent. Such a Veſſel, therefore, eaſily determines the ſeparated Matter into the cylindrical Aperture, and thence, into the Receiver, which is here very eaſily raiſed by the Fire, and confined and repelled by the arched figure of the Veſſel. This Veſſel, therefore, is fitteſt for ſeparating by diſtillation thoſe parts which are very fixed from thoſe which are abſolutely ſo; as in the diſtillation of Oil of Vitriol, Spirit of Nitre, *Aqua Fortis*, Spirit of Salt, Spirit of Alum, and the like. But the Workmen generally bend the neck downwards, and draw it out into an open conical end, that the Vapours which are propelled into the firſt part of the neck, may afterwards ſpontaneouſly run down, and diſtill; and with this view are made all your common Retorts. But for very tedious diſtillations, where a long continued application of the Fire is requiſite to raiſe and expel Particles that very ſtrongly reſiſt ſuch an elevation, I got ſome cylindrical Veſſels made, which when they were placed in a horizontal poſition, in their upper horizontal part opened into a horizontal neck, as you ſee Plate X. with theſe are moſt conveniently diſtilled Phoſphorus, and all Liquors that riſe with a great deal of difficulty; and if you will try them, you'll be pleaſed to find ſome very difficult Operations rendered much more eaſy. When I diſtilled however yearly before you ſuch large quantities of Oil of Vitriol, and foſſil acid Spirits, in my private Lectures, you remember I always inſtead of Retorts made uſe of cylindrical, earthen Long-necks, which open with a large, circu-

Diſtilling Veſſels.

Pl. X.

lar

lar mouth. These, when they are placed horizontally in the Furnace, are the best kind of Vessels, for these distillations; for cylindrical Segments being at one end inserted into the Orifices of these Pots, and at the other, into large glass Receivers, placed horizontally, likewise, and then well luted, furnish us with the safest method of distilling these acid Spirits. These all you may examine in the figures annexed Pl. X. which will readily bring to your mind what you have so many times seen, and help you to conceive properly of those you never saw before. Thus then I think we sufficiently understand the fundamentals of the Doctrine of the figure of containing Vessels in the distillation of Bodies that rise with difficulty. And if we consider what follows from this Doctrine, we shall find this observation generally true, that with the more difficulty any thing rises in distillation, the more necessary will be the figure and disposition of these last Glasses: But on the other hand, when the Matter to be sublimed is very mobile, and in its degree of volatility differs but little from the Body from which it is to be separated, then Vessels of a contrary figure best answer the purpose. Those in the first place then are conical, which because they somewhat resemble *Hercules*'s Club, are by the *Germans* and *Dutch* called *(Kolven)* Clubs, as on account of their likeness to a *(Cucurbita)* Gourd, they have obtained the name of Cucurbits; but the ancientest Alchemists, as *Lully* and others most frequently called these Vessels Urinals. And here it is very easy to conceive, that when the Liquors in these Vessels are raised by the Fire, they must run against the converging sides of the Vessel, and being there stopp'd in their ascent, will be repelled and turned back again. If there is any thing therefore that is raised with difficulty by the degree of Fire made use of, that rarely ascends so easily in these Glasses, but is rather repelled back again, and remains at the bottom. In these Glasses, too, this is to be observed, that the greater the latitude of the bottom where it is widest, is in proportion to the aperture of the upper orifice, through which the sublimed Liquor must pass, there the impediment and repulsion of the elevated Matter will be greater, too, so that by this means the perfectly volatile part alone may be nearly separated from that which is not so much so. And lastly, the height of these Glasses must be taken into consideration, likewise, for the greater their altitude is, the more difficult will be the sublimation of those Bodies that are less volatile. A proper regard to these three circumstances has given rise to a very beautiful invention, by the assistance of which you may with a little Fire, Trouble, and Charge, distil a large quantity of simple Alcohol, or the same impregnated with the most subtil, vegetable Spirits; and it is done in the following manner. Make a conical, tin Vessel, the Base, of what size you have a mind, 6 inches, for instance, in diameter; and let the diameter of the upper orifice be one inch, and the height be 4 feet. At the top let it be bent downwards in a cylindrical form, and at the bottom let this Cylinder be turned up again, that it may be inserted into the Mouth of a cylindrical, spiral Tube, commonly called a Worm. Then if you put some Spirit of Wine in a Cucurbit, that stands in boiling Water, and fit on such a conical Vessel to it for a head, and then distill through the spiral Tube and the Refrigeratory, you will the first time have a very strong Spirit, which upon a second repetition of the operation will come off pure Alcohol. From the same Principles we understand the nature of the *(Phiala Chemica)* Chemical Vial, as it is called, which is a

spherical

ſpherical Body, from whoſe *Vertex* there ariſes a long cylindrical Neck, open at top: Theſe are generally called Matraſſes, or Boltheads. Theſe, now, are of incredible uſe in Chemiſtry, in ſome of the niceſt Operations; for as the Neck may be made of what length you pleaſe, as may likewiſe the proportion of the capacity of the Neck to that of the Belly, hence it is very evident, that you may give the Liquor contained in the Belly ſo great a degree of reſiſtance, with regard to its aſcent, that if you digeſt it with a gentle Fire, there ſhall ſcarcely any thing come out of the orifice at top. But in this kind of Veſſels I have obſerved particularly, that the column of the Atmoſphere that reſts upon the aperture of the Neck, ſurprizingly compreſſes the Liquors that are contained in the Belly, and are agitated by the Fire, and ſerves as a kind of Stopple, to cloſe up the aperture of the Neck, being at the ſame time kept in *æquilibrio* with the *impetus* of the Liquors that endeavour to riſe; for whilſt the Air being rarified by the Fire endeavours to elevate the whole ſuperincumbent column of the Atmoſphere, it meets at the ſame time with juſt the ſame reſiſtance from the renitent weight: Hence then the liquid particles that are contained in this rarified Air, are repelled to the bottom of the Veſſel, by which means it comes to paſs, that when they are agitated by the Fire, they are ſtrongly applied to thoſe Bodies that lie at the bottom of the Glaſs. This you ſee evidently with the naked Eye; for if you put ſome Alcohol of Wine into one of theſe Boltheads, that has a very long, ſmall Neck, and hold it cautiouſly over the Fire, when it begins to be ſo hot as to be ready to boil, you will perceive Vapours aſcending into the cavity of the Neck, and falling down again, like little, floating Clouds. Hence, therefore, with theſe Glaſſes, the digeſtion of *Menſtruums* with their proper Solvends, is moſt happily effected, without loſs either of the *Menſtruum*, or the Body to be diſſolved; which has been of excellent ſervice to me in performing a great many experiments, which otherwiſe I could not have made. Theſe tall Matraſſes, farther, are particularly ſerviceable in ſeparating the very volatile, pure, alcaline Spirits, and Salts, from their volatile Water, Oil, and Earth, from which it is ſo very difficult to ſeparate them by other methods. Theſe Veſſels, however, have this one inconvenience, that when the Liquor at the bottom comes to boil, as it cannot riſe up high enough, it leaves the top part of the glaſs Neck cold, and hence, if the boiling Vapour aſcends at once, by the ſudden heat it is apt to make the Glaſs fly in that place, eſpecially if it is in the Winter, and freezes. And then, again, the Drops that are collected upon the cold part of the Neck, and hence are cold themſelves, often run down among thoſe parts that are vaſtly hot in the Belly or Neck of the Glaſs, and burſt the Veſſel to pieces. This I once experienced myſelf, to my coſt, whilſt I was digeſting ſome Mercury with this *Apparatus*. From what has been ſaid, then, we conceive ſufficiently of the efficacy of the figure of Veſſels, and the neceſſity there is of ſuch and ſuch particular Forms, to anſwer different ends propoſed. The figure of Receivers, particularly if they are large ones, is two-fold; either they are made with a ſpheroidal Belly; or elſe in form of a Cucurbit. Suppoſing, however, the capacity of both to be the ſame, then that, like a Cucurbit, is preferable to the ſpherical, becauſe it being longer, the bottom is farther from the mouth of the exhaling Veſſel, and hence gives the Liquors coming very hot from the Fire, a more convenient ſpace to grow cool in: This obſervation I have found of

 ſervice.

service. It's very often necessary, however, to increase the distance betwixt the containing Vessel, and the Receiver; and this I told you before might be done by putting a cylindrical Tube between them, and then luting it to the Mouth of them both. But in the more nice distillations, of Mercury in particular from Metals, we are forced to make use of another contrivance to increase the distance to a proper length; which is done by the help of the Glasses you see here, which being made to fit into one another, form one continued Vessel of what length you please; their junctures at the same time being secured with a proper Lute. A Retort, Receiver, and these prolonging Vessels, which I have given you a Figure of Pl. XI. would be sufficient for all distillations, if we did not often want to separate Bodies that are very volatile from other volatile ones: But as this is daily the case, here again we are obliged to make use of tall, upright Vessels, which must have a Head fitted on to them, called by *Dioscorides* an ἄμβιξ, where he writes of the sublimation of Mercury, whence by an *Arabian* variation 'twas call'd an *Alambic*, or *Alembic*, under the *Rostrum* of which you place the Receiver. You will easily perceive, now, where it is proper to make use of a Cucurbit with a Head, and Receiver, and where a Retort and Receiver. This, the easiness with which any Bodies rise, and the consideration of their being mix'd with others that are very volatile, from which they are to be separated, will sufficiently point out. You perceive too at the same time, that the principal inconvenience of this last *Apparatus* is this, that as the Alembic must be luted to the Cucurbit, and its *Rostrum* to the Receiver, you must by this means have two Junctures, which, take all care you can, will transmit some of the subtil Vapours through the cracks of the Lute. But there is often necessary, likewise, a continual reaffusion of the volatile part, upon the fixed *Residuum* from which it was separated. This the Artists generally call Cohobation, *Paracelsus*, formerly, Circulation; and this operation has the most beautiful effects of any in the Chemical Art. As the Operators, therefore, saw the great necessity of it, and at the same time found, that every time they opened their Vessels, they lost some of their Liquors, by thus pouring them back, exposed to the Air, they on this account contrived a Glass Vessel, consisting of a Cucurbit and an Alembic, the two *Rostrums* of which being turned back into the Cucurbit, perpetually return into its Belly the Liquors that are collected in the Alembic; and thus, the Vessel being perfectly secured above, the loss of the Liquor is prevented, and the trouble very considerably lessen'd: This they called a Pelican, which is so much the better, as the Tubes brought from the vertex of the Alembic are longer. But as these Vessels are not very easy to be procured, the same effect may be obtained in a simpler manner, and that is, by putting the Matter you are going to work upon into a Bolthead, with a pretty long Neck, and then fitting the Neck of a less into the Mouth of it, and securing the Juncture with a proper Lute. You must observe, however, to heat the Glasses first to such a degree as will be necessary for the Operation; for then the Air, being heated, will be proportionably expell'd out of the Vessels, after which you may lute it, make your Fire, and proceed without any danger. In this *Apparatus*, however, it sometimes happens, that the Liquor which is collected at top, and grown cool, falls down upon the hot bottom, and makes it fly: Being thus cautioned, therefore, you will take care to guard against this inconvenience.

And

And thus we have sufficiently considered Vessels for any Chemical Operations.

Of Lutes.

By a Lute, the Chemists mean a ductile, tenacious Mass, growing hard when it's dry, which serves to secure the junctures of their Vessels, that no Air may pass in and out, but particularly, that the Corpuscles, when they are carried up by Fire in the distillation, may be kept in, nor suffered to escape out of the Vessels. It is evident, therefore, that the Lutes must be different, according to the nature of the Bodies to be distilled.

Use of a Lute.

If then it is an aqueous Body you are operating upon, you need only take the flower of Linseed, from which the Oil has been express'd, and with a little White of an Egg, work it well into a Paste, and it will be sufficient; for if you put this in betwixt the Cucurbit and the Alembic, and lute with it the juncture of the *Rostrum* of the Alembic, or the Retort, with the Receiver, it will grow hard with Heat, and if it cracks, may be mended by an addition of more of the same. And in the distillation of all fermented inflammable Spirits, and volatile, alcaline, and alcoholisated Salts, the same Flower will serve if it is well work'd with clean cold Water.

The Lute for aqueous and spirituous Liquors.

But in the distillation of Acids, either acetose, or other, this Lute won't do, because in this case it will be corroded, dissolved, and soften'd, and thus will suffer the Spirits to escape. For this purpose then, you may take an Ox's or Hog's Bladder that has been macerated in Water, 'till it begins to grow glutinous, and, as it were, semi-putrid, and fasten it round the juncture, and it will answer the end excellently well.

For acetose Liquids.

But again, when with a very strong Fire you distill the corrosive acid Spirits of Vitriol, or fossil Salts, you must then have a Lute, which after it is applied, will harden like a Stone; and hence this has been called the *Lutum Sapientiæ*. You make it best in the following manner. Take the Colcothar that remains after the distillation of Oil of Vitriol, and boil it in Water, which renew till the last does not appear to be at all salt; and then let it be dried, and kept carefully in a close Vessel. When you want your Lute, take some of this sweet, dry Colcothar, and rub it well with an equal quantity of the best Quick-Lime, and then with a little beaten White of an Egg, work it presently into a Paste, and apply it immediately to the juncture of the Vessels, which must be dry, and something warm. This Paste then will very soon dry, and harden like a Stone, and like Glass is capable of confining any Salts. Without all this trouble, however, I prepare a Lute of the same nature, in the following manner. With a quantity of Potter's Clay, I mix so much of the purest Sand, that the Mass, if it is work'd with Water, won't stick to the Fingers any longer; and to this I then add a fourth part of common Mason's Lime, so as to reduce it to a pretty stiff Paste. And the drier this is when it is made use of, the better, if it does but remain ductile: When this then is applied to the junctures of the Vessels, it grows hard, and excellently answers the purpose. If in a very intense Fire it should happen to split in the distillation, the crack may be soon made good again with some of the same. It has this convenience too, that it may be easily procured, whereas good Quick-Lime is sometimes difficult to come at.

For fossil Acids, and volatile Alcali's.

Coating of Vessels.

But in distillations, particularly in the hottest Furnaces, where the Vessels are red hot, it sometimes unluckily happens, that when you throw in new Fuel, either the cold Air, or the coldness of the Matter thrown in, strikes upon the Surface of the red hot Vessel, which then easily flies, and bursts asunder. Hence it is absolutely necessary, that these Vessels should be coated over with some proper Matter, in order to secure them from the ill effect of this sudden Cold. And this must sometimes be done likewise, when you distill with glass Vessels in the strongest Sand-heat, where the Glass is ready to melt; for by this means the Glass will be fixed as it were by this Crust, and be prevented being put in fusion. In order to make this in the best manner, take some Potter's Clay and Sand, reduce them to a Powder, and with some Water work them thoroughly into Paste, that is no longer tenacious, and then at last add a little Mason's Lime, and mix them well together. When you use it, warm your Vessel, hold it over the Vapour of Water, that it may be slightly moisten'd all over; then cover it intirely with this Paste, and by working it with your hands, reduce it every where to such an equal thickness, as you shall see convenient: This being done, sprinkle it over with hot dry Sand, and then set it by in a cool place, that the Coat may dry very slowly. If it should happen to get any cracks whilst it is drying, they may be stopp'd up with the same Matter. When these Vessels are prepared in this manner, they will bear a very intense Fire.

Of FURNACES.

Various Furnaces.

There is now, Gentlemen, but one thing more left to finish our Theory of Chemistry, and that is, a short consideration of Furnaces, which we shall now proceed to. And here we don't propose to describe all the Furnaces made use of in the management of Metals: Nor, indeed, is this necessary, since what the incomparable *George Agricola* has done upon this head is sufficient, who has explained this matter in the most elegant Stile, and illustrated it with very accurate Cuts. If you will consult *John Rudolphus Glauber* too, upon Furnaces, you will find some particular contrivances for rendering some of the ruder Operations of Chemistry more easy. Of these things, therefore, I need say nothing. But it's my design here to explain to you those Furnaces, which a person will have occasion for, who has a mind to exercise himself in the practical part of Chemistry, according to the method of our processes.

The end they answer.

A Furnace, then, is a Machine, by means of which, the Fire may be contained, confined, and applied to the Vessels, in which the Matter to be chang'd by the Fire is exposed to it. In a Furnace, therefore, in the first place, there is required a *Focus*, or Fire-place, in which the Fire may be lighted, kept up, and determined. And as the Fire, which must be fed with proper Fuel, requires a Chimney to carry off its Smoke, and a Draught for the Air, and a Door to throw the Fuel in at, it appears in what manner these ought to be contrived. In the second place, in building a Furnace, we ought particularly to take care, that the direction of the Fire be so managed, that it shan't spend itself to no purpose, but shall be determined towards that part where we have occasion for it. And in the third place, it must be so built, that the Vessels containing the Bodies to be operated upon, may be so conveniently dispos'd,

as

as to be equably affected with any degree of Heat necessary, till the Operation is compleated.

That Furnace, therefore, will be best in its kind, which will perform the desired effects, with the least Expence, for the longest Time, and with the greatest Equability, and be managed with the least trouble and attendance of the Operator. The first of these ends will be answered, by contriving it in such a manner, that the whole Heat of the Fire, without any loss, may be apply'd to the Body under Examination. This will be obtained by building the Furnace of solid Materials, and forming the internal Surface of such a figure, as is proper to determine the strength of the Fire to the place designed: And this contrivance will have this advantage too, that the frequent attendance of the Person that keeps up the Fire will be less necessary. The second end will be answered, by chusing out such Fuel as will consume as slow as possible, so that it will but, at the same time, keep up such a Heat as is necessary for the Operation. And this is effected in particular by observing a proper proportion between the Fire-place, the Chimney, and the Air-holes: Upon which Principles, your skillful Operators will at once lay on such a quantity of Fuel, as will last for a very considerable time. The third circumstance, however, is the most necessary of all, *viz.* That the Fire may be kept up to the same degree, without any increase or diminution of its strength. For it appears by chemical Observation, that a determined degree of Heat produces upon every Body a certain effect; and hence, when the action of it grows either stronger or weaker, the effect will be different from what it was before. For this reason, therefore, there often arises a confusion among our chemical productions, when in the same Operation, we promiscuously make use of a greater or less degree of Heat. And besides, it is particularly to be observed, that such a variation of the Fire, makes Bodies of quite another disposition, with regard to any particular degree of Heat: For if in two chemical Operations, we make use of the same Fire, but let the degrees of Heat succeed each other in a different manner, we shan't be able to produce the same things from the very same Body; which has often prov'd a very detrimental error. In building of these Furnaces, therefore, the Workman must always consider first the quantity of Fire, which the Fire-place of the Furnace must receive, contain, and keep up. Secondly, the kind of Fuel to be made use of to answer the purpose; upon which head, you may consult what has been laid down from p. 168, to 214. In the third place, he must have a regard to the strength of Fire necessary for every particular chemical Operation: For the very same quantity, of the same Fuel, in the same Fire-place, may produce such various Heats, that by means of it, every intermediate degree, from the gentlest to the most intense, may be excited and continued: In the fourth place, therefore, he must always have a particular regard to the easy access of the Air to the Fire-place; and should take into his computation too, the strength with which the Air tends to the *Focus*, either by Blast or Draught. Nay, and he ought to consider too, the various states of the Atmosphere, with regard to Heaviness, Lightness, Moisture, Dryness, Heat and Cold: For when the Barometer is highest, and it freezes hard, and the Air is dry at the same time, the same Fire will burn brightest and strongest. But in the fifth place, he ought above all to attend to the course of the Fire that is kindled in the Fire-place: For if there

The quality of the best Furnace.

there are any large paſſages, by which it can make its way out into the Air, it will be diſſipated, and loſe its ſtrength; whereas, if its united action is determined to that particular place where the Operator wants it, it will beſt of all anſwer his ends. Theſe, then, are the fundamental Principles upon which depends the juſt conſtruction of Furnaces. I ſhall, now, therefore, proceed to deſcribe thoſe Furnaces which I here make uſe of before you, and which a Perſon ought to have in his Elaboratory, if he wou'd be furniſhed with ſuch as may enable him to perform all the Operations of Chemiſtry. To begin, therefore, with the moſt ſimple, which I contrived for my own uſe above forty years ago, when I was making great numbers of Experiments in a Study not very large, and that had but a ſmall Chimney, for which I had occaſion for a good many Furnaces.

The moſt ſimple Furnace. Pl. XIII.

This then is made in the following manner. With the beſt and drieſt Oak a hollow Priſm is formed upon a ſquare Baſe, 9 inches broad, and 14 inches high. Within this there is fixed a ſquare Partition made of the ſame Wood, and an inch thick, which muſt be placed 5 inches from the bottom, and will by this means divide the Furnace into two parts, the lower of which will be 5 inches high, and is the *Focus* or Fire-place; the upper 8 inches, in which are placed the Retorts, or Cucurbits, for diſtillation. This middle Partition, which repreſents a kind of Diaphragm, has in the middle of it a round Hole of 5 inches diameter, in the hollow of which may be placed the round bottom of the Cucurbit, or Retort. And this too has four more round Holes in it, of an inch diameter each, that the Heat may riſe out of the bottom-part into the top. The Fire-place has on one ſide a Door with Hinges, which is as big as the ſide of the Fire-place, *viz.* 9 inches wide, and 5 high, that it may be opened at pleaſure, or ſhut cloſe as there is occaſion. The whole internal Surface of the Fire-place is lined with thin Plates of Iron or Braſs, that ſo the Wood may be in ſome meaſure defended from the Fire. The Door likewiſe has four round Holes in it, each an inch in diameter, for the free admiſſion of the Air into the Fire-place, to which there are fitted four cylindrical Stoppers, by the help of which you may let in more or leſs Air, as you find it neceſſary. And here the Carpenter muſt be particularly careful, that the Door be made of very dry Wood, and ſo fitted, as to ſhut the Fire-place up exceeding cloſe. As for the upper part of the Furnace, the ſide contiguous to the Door below, has a Hole cut out in the middle of it, and reaching to the top, which is $4\frac{1}{2}$ inches ſquare. On the inner edge of this Hole, the Wood is cut away all round to the breadth of half an inch, and to half the thickneſs of the Board of which the Furnace is made, and then on every ſide there is faſtened a ſlip of Wood in ſuch a manner, as to form a groove with that hollow. There is then cut out of the ſame Wood a Board an inch thick, and exactly of the ſame ſize with the Hole cut in the ſide, but that has likewiſe on its inner part a rim on all three ſides, half an inch broad and thick, in order to ſlip into the groove formed on the edge of the Hole, that thus this Board being every way ſecured, may ſhut up this Hole exactly, when you have a mind to diſtill in a Cucurbit, digeſt in a Bolthead, or exhale in an open Veſſel, and be removed again when you want to diſtill in a Retort: For which purpoſe you muſt have another piece made exactly in the ſame manner as the former, but only with a circular Hole in the middle of it, of $2\frac{1}{2}$ inches diameter, to tranſ-

 mit

mit the Neck of the Retort. The top of the Furnace consists of two folding Doors, which in their middle are cut out into an orbicular Hole of 5 inches diameter, to let through the Cucurbit, or Neck of the Bolthead: And lastly, there is a round wooden Cover made fit to this Hole to stop it close, when you distill with a Retort. When you want to set it to work, take a square earthen Pan with 3 feet, ½ an inch high, whose bottom must be plain, and its sides on the outside 5½ inches wide, and the height of the whole Pan, from the bottom of the feet to the edge of the Pan, 3 inches and a half. On the bottom of the Pan, spread lightly some sifted Ashes to the height of a quarter of an inch, and then upon this lay a Live-coal of *Dutch* Turf, perfectly red quite through, and not at all smoaky; and then this, if it is lightly sprinkled over with the same sifted Ashes, will keep up such an equable Heat for near four and twenty hours, as the human Body is capable of bearing. But here you must take notice, the thinner the Coal is covered with Ashes, the greater will be the Heat, but then it won't last so long. In this Furnace, now, you have neither Smoke nor Smell. And it maintains such a very soft equable heat, that I can't think but that Eggs might be hatched in it. But in this too we can raise as great, nay and greater degree of Heat, than that of boiling Water. In this, therefore, conveniently, safely, and with little expence, may be performed all Digestions, distillations of Waters, spirituous Liquors, volatile alcaline Salts, and all volatile aromatic and oleose Salts, as well as all Preparations of Tinctures. All exsiccations, and exhalations for the formation of Chrystals, may be affected here likewise. Nay, after *Glauber*'s manner, I have prepared in it Spirit of Nitre, and Spirit of Salt, to the great surprize of an old experienced Chemist. This therefore I call the (*Furnus Studiosorum*) Student's Furnace.

But when you want a Furnace that will yield a greater Heat for distillation in Sand, then the following seems to me the best fitted for this purpose: And as the portable ones have this convenience, that they leave the common Fire-place free, I'll describe one of that sort. With a very thin Plate of Iron, make a hollow Cylinder 17 inches in diameter, and 19 inches high. Let the bottom be closed with a Plate of the same kind, and the top be open. Let it be supported at bottom with 3 iron Legs 12 inches long, and let the inside of the bottom be covered with a copper Plate, that the Salt of the Ashes mayn't too soon eat away the Iron. Within the Cylinder, you must fix a Grate parallel to the Base, whose upper surface must be 4 inches above it. Let this Grate be surrounded with a thin Rim 3½ inches broad; and let the Bars be ½ an inch square, and stand an inch from one another; or let the diameter of the circle of the Grate be so divided as to place six such iron Bars in it. This Grate is placed within the iron Cylinder at 4 inches distance from the bottom, where it must have three pieces of Iron standing out to support it. Let your Door then to this Ash-hole be 4 inches high, and 6 wide, and made to fit nicely, that it may shut it up very close upon occasion. Three inches above the upper surface of your Grate make the opening of your Fire-place, which must be 6 inches wide, and 4 and a half high. With the *Foci* then 15 inches distant, and a perpendicular from the *Focus* to the Circumference of 5 inches, describe an ellipse; and then by this make a solid wooden Semi-ellipse, cut off at the *Foci*; by which model you must shape the internal surface of your Furnace, which must be built with Bricks, so disposed, as to form such a concave surface,

Second Furnace.

Pl. XIV.

ſurface, and ſo contrived, that the edges next the internal part may come as cloſe to one another as may be, ſo as to leave but ſmall ſpaces, which muſt be filled with Mortar made of Lime and Sand. But before the Bricklayer can do this, you muſt have a Stopper made to the Fire-place. This muſt be made of a plate of Iron, the ſame of which you make your Furnace, and with the ſame cylindrical ſurface. As for the ſize of it, it muſt be made in ſuch a manner, that when it is applied to the opening of the Fire-place, it may reach an inch beyond it on every ſide, that it may thus intirely cloſe it up. Upon this Cover, then, you muſt erect a hollow Segment, cut out of this Cylinder to the ſize of the opening of the *Focus*, the ſides of it tending towards the center of the Cylinder, and the top and bottom being parallel to the Baſe of the Furnace, that the internal ſurface of this Stopper may be made to anſwer to the concave, elliptical figure of the Furnace. Let the Bricklayer, then, fill this hollow with Brick and Mortar, and ſo form and ſmooth its internal ſurface, that when it is fixed in the hole it may make one continued, uniform figure with the ſurface of the Furnace. When this is made, build your internal Furnace with Brick and Mortar, in the manner before directed. At the upper part of the iron Cylinder, and on that part which is near to the door of the Furnace there muſt be a Segment cut out, 3 inches broad, and 2 deep, that the Neck of the Retort may be placed there in a declining poſition, when you have occaſion to diſtill in ſuch Veſſels. And laſt of all, in the upper part of the Furnace an Iron Pot muſt be ſo firmly fixed in with Mortar betwixt the Bricks, that the Fire ſhan't be able to make its way through, but at the ſame time, about the edge of the brick-work, at top, there muſt be left 4 holes, ſhap'd like a Half-Moon, an inch broad, and two inches in curvature, which may ſerve as a vent for the Smoke and Fire. A Furnace built in this manner is fit for diſtillation with a Cucurbit, Retort, and Bolthead, and as it is portable, it is convenient for a great many purpoſes.

A Third Furnace. Pl. XV. Fig. 1.

The third Furnace which an Elaboratory cannot be without is a *Balneum Mariæ*. This conſiſts of the ſame Furnace as the preceding, except that the ſurface of the Grate is only 8 inches diſtant from the bottom of the braſs cylindrical Veſſel. The braſs Veſſel which is for the Bath, and is ſet with Mortar within the upper part of the Furnace, is 12 inches deep. This is of a cylindrical form, and at the top has a horizontal Rim an inch broad, by which it reſts upon the top of the Furnace, and above that, another of the ſame breadth riſing perpendicularly. There is then another Veſſel made, in ſuch a manner, that when it is placed within the former, it may ſtand an inch diſtant both from its bottom and ſides, and may reach 5 inches above the top of the furnace. At 12 inches diſtance from its bottom, this Veſſel has a rim on its outſide, which runs a little declining, and when it is juſt broad enough to cover the aperture left between the two Veſſels, is turned perpendicularly downwards, that it may be received exactly within the erect, perpendicular Rim of the former, and thus the cavity between them may be perfectly cloſed. In the broad, lateral Rim of this Veſſel there is a hole made for pouring Water into the Bath Veſſel, that by this means it may be contained betwixt that Veſſel, and this internal one. The Neck of this ſecond Veſſel receives into it an Alembic, whoſe *Roſtrum* may be inſerted into a Tin Worm, in a Refrigeratory. To this likewiſe may be fitted that ſort of Alembic, which is produced into a tall, cylindrical Tube, and then turned down again, for the

 diſtillation

distillation of Alcohol, which we have already described. And lastly, there may be made a Cover to the Bath Vessel, to fit into the perpendicular Rim, as the former did, and close it in the same manner. And the Neck of this Cover, too, may admit an Alembic, in order to distill with a Worm. This Furnace, then, thus compleated, we may make use of first, for the common distillations of all Vegetables with Water; and of all Resins, Balsams, and Gums with Water, into their essential Oils. Secondly, for distillation of Vinegar; and very conveniently for distilling any thing whatever either in *Balneo Vaporis*, or *Maris*, in any determined degree of Heat, as far as the degree 212. And thirdly, this is of excellent service in the preparation of Alcohol at once, with a good deal of ease, and in a large quantity, which otherwise requires so much Time, Fire, Labour, and Charge. For these reasons, I have in Plate XV. given you a very exact description of it, with its whole *Apparatus*.

But there is still wanting a Furnace, in which may be raised a very intense Heat, for fusing Bodies that require a very strong Fire. And this is best built in the following manner. In the first place, let there be raised a stone Base, arched at top, and 3 feet high; for this Furnace must have the Door of the Fire-place at such a height, that the Operator may look into it as he stands upright. Upon this Base let there be raised an Ash-hole 5 inches high, and over this a Grate, with Bars almost an inch thick, and near an inch from one another. Let the Base of the Ash-hole, and the Grate above, be of a circular figure, and 12 inches in diameter, and above the Grate let the Cylinder be continued to the height of 6 inches. Upon this Cylinder let there be erected a paraboloid Cone, whose *Axis* must be 8 inches, and lowest ordinate 6, whence its Parameter will be 4 inches and a half, and its *Focus* one inch and $\frac{1}{8}$ from its *Vertex*. When this Paraboloid is built to 6 inches height above its cylindrical Base, raise a cylindrical Chimney over it 2 feet high, whose diameter will be 3 inches. In the fore part of the Fire-place 2 inches above the Grate, let there be a door 5 inches wide, and 6 high, and arched above with the arc of a circle of 12 inches diameter. At an inch distance above the arch of the door let there be a conical hole in the Furnace of 2 inches aperture, that you look down through it into the Fire-place if you want to see whether the Matter is melted in its Vessel; and make a Stopper to put in or take out of this hole at pleasure. This Furnace must be built of very good Bricks and Mortar, its walls must be 5 inches thick, and its internal surface must be smooth'd over with very dry Lime. This, when it is once hot, raises a prodigious Fire, especially in the middle of the *Axis*, and the upper part, as is demonstrated geometrically with a geat deal of ease. The iron door must be let in so as to shut very close; and the bottom of the Ash-hole must be a plate of Iron, that if any thing happens to fall through the Grates it may readily be come at again.

Fourth Furnace.
Pl. XVI.

But a chemical elaboratory must be still furnished with another Furnace for the distillation of acid Salts, from Nitre, Sea-Salt, Fountain Salt, *Sal-Gem*, Vitriol, Copperas, and Alum. This then, after having tried various sorts of them, we build after the following manner. Upon the pavement under the Chimney let there be erected a Parallelipiped, the breadth of it in the front 20 inches, and length 38; and the breadth of its cavity in the front 12 inches, and its length 22; whence the thickness of the Wall is evident. Let this Parallelipiped.

Fifth Furnace.
Pl. XVII.

rallelipiped be raiſed 11 inches high. In the middle of the front let there be an opening carried from the Pavement 11 inches high, and 4 broad, round the edge of which let the brick-work be let in a little, that a door, made of an iron plate may be received into it, when you want to ſtop it cloſe: This is for the Aſh-hole, and draught to the Furnace. Here, inſtead of a Grate, let there be fixed ſome priſmatical iron bars, an inch ſquare, 14 inches long, and an inch diſtant from one another, and let them lie parallel with the breadth of the Aſh-hole. Upon the upper hollow of the Parallelipiped let there be deſcribed an Ellipſis, whoſe *Foci* muſt be 22 inches diſtant, and tranſverſe Diameter 12, and then the breadth of the Fire-place at the beginning and end will be nearly 10. With this elliptical Figure then let there be a cavity formed, within 4 inches and a half deep, and let the external parts be compleated in a parallelipipedal form. In the front Wall, directly over the Aſh-hole, let there be an opening into the Fire-place, 7 inches broad, and 9 high; and let this Hole have its lower edge declining inwards 1 inch and a half, and have an iron Door made exactly to fit it. Let the lower part of the Door be 3 inches above the upper part of the Aſh-hole. In the other longer ſide there muſt be an arched aperture, whoſe lower limb muſt be placed 10 inches above the Grate. The length of this Limb muſt be 20 inches, its height 12, and the Arch muſt be an Ellipſe, whoſe *Foci* are 20 inches diſtant, and has a tranſverſe Diameter of 24. At this aperture are put in the long Necks. On the inſide of the Wall, oppoſite to this aperture, and 9 inches above the Grate, there muſt be raiſed a Ledge of an inch and a half breadth for the Veſſels to reſt upon during the diſtillation; and in the middle of the ſame Wall at top there muſt be a ſquare Hole for a Chimney, 3 inches broad, and 2 high. This being done, you muſt build the uppermoſt elleptical arch of your Furnace, whoſe vertical point muſt be 21 inches diſtant from the Grate; the *Axis* of the Ellipſe 22 inches, and its tranſverſe diameter 10. This Arch, therefore, will be formed by the rotation of ſuch an Ellipſe about its *Axis*, ſuppoſing this to be 16 inches from the Grate. When you diſtill in this Furnace, you take 2 Long-necks, 11 inches high, 9 wide, with cylindrical Necks 5 inches long, and $3\frac{1}{2}$ diameter, and place them horizontally, and parallel, ſo that their bottoms ſhall reſt upon the Ledge in the oppoſite Wall, their mouths being parallel to the aperture they lie in. With Bricks, and Mortar, then, you cloſe up intirely the whole aperture; and to the mouths of the Long-necks apply a cylindrical Tube, and to that a Receiver. With ſuch a Furnace as this you may raiſe an incredible heat. It is ſafe, and eaſily managed; and makes the Fire exert all its ſtrength upon the diſtilling Matter alone; and by means of the Aſh-hole, it is eaſily regulated.

Other Furnaces.

The aſſaying Furnace is ſo plainly deſcrib'd by the induſtrious, candid *Lazarus Erker*, that there is no room to add any thing upon this head; and a very accurate cut of it you may ſee in *George Agricola*.

And as for the Furnace with the *Veſica*, Alembic, Worm, and Refrigatory that is too well known to need any deſcription. I may now, therefore, diſmiſs this ſubject too, and thus put an end to the firſt and ſecond part of theſe Inſtitutions.

4

FINIS.

PLA: I.

FIG: I.

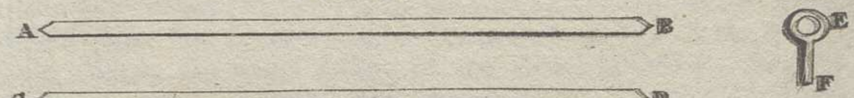


FIG: II.

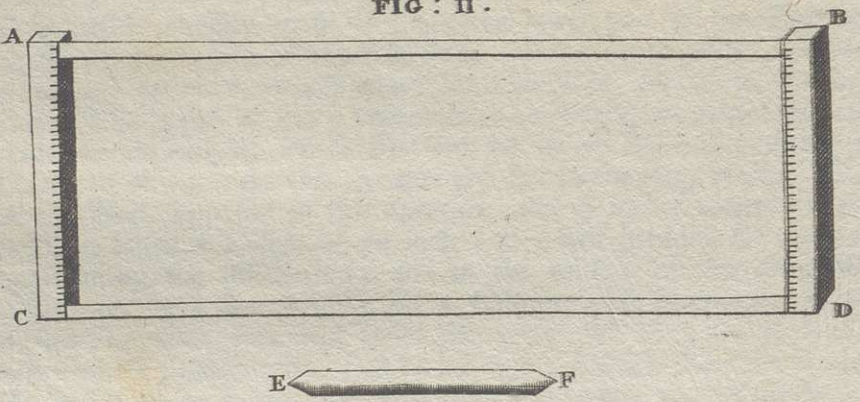
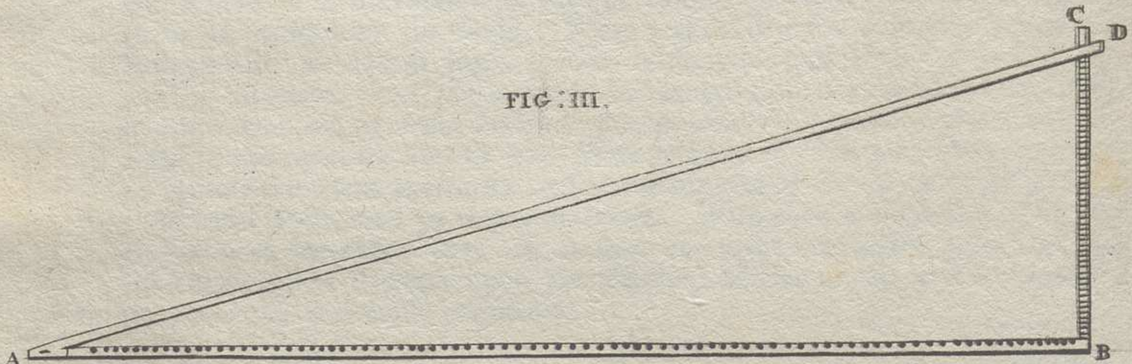


FIG: III.



PLA. II.

FIG: I.

FIG: II.

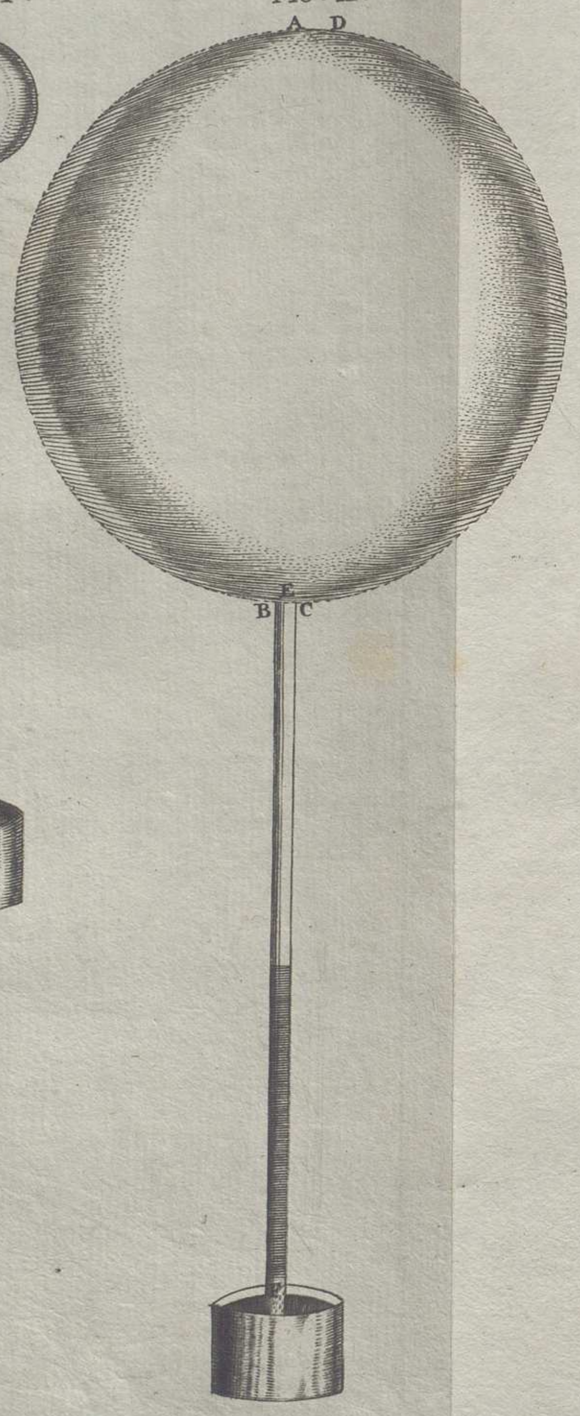


FIG: III.

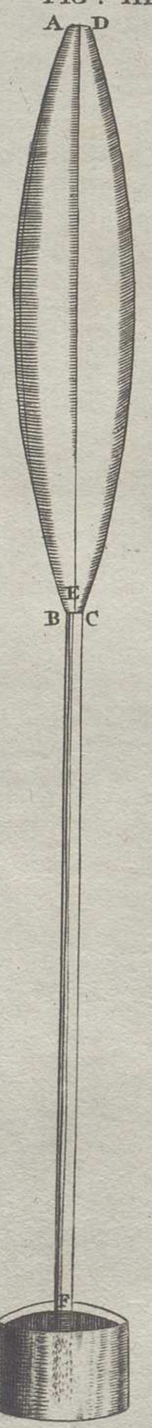


FIG: I.

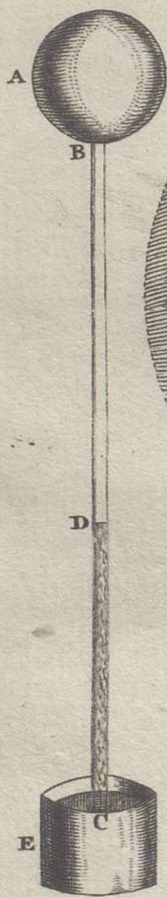
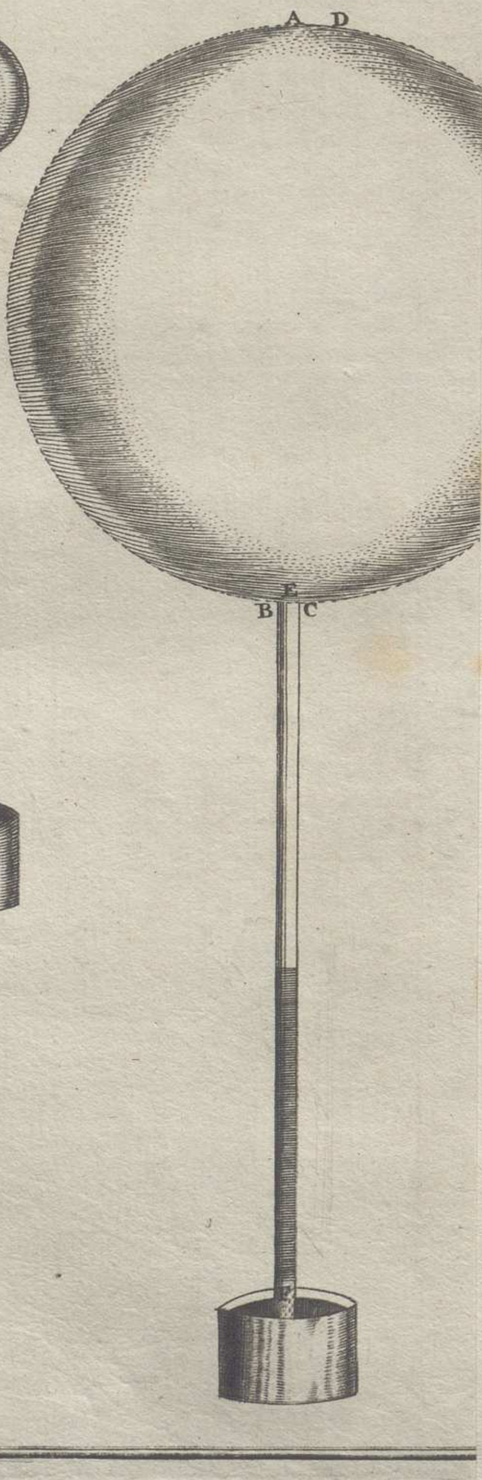


FIG: II.



The Explanation of the PLATES.

PLATE I.

FIG. 1.

AB, CD. Two cylindrical iron Rods three feet long.
E. A Ring with a handle F, whose cavity measures exactly the thickness of both Rods when they are cold.

FIG. 2.

AC, BD. Two parallel Plates, divided into very small equal parts.
AB, CD. Two parallel Plates, which may be moved up and down by means of two Grooves, in AC and BD.
EF. The iron Rod to be measured when it is cold, and after it is heated.

FIG. 3.

AB. A brass Ruler divided into very small parts.
BC. Another, perpendicular to the former at B, graduated with very minute, and equal divisions.
AD. A third fixt upon an Axis at A, so that it may move upon the Ruler BC, and by this means may give you the number of parts upon BC, that the Rod made red hot, and set upon a certain point of A B, will elevate the Hypothenuse AD, higher than it did when it was cold, and plac'd upon the same point.

PLATE II.

FIG. 1.

ABDC. The common Thermometer of *Drebbelius*.
A. Its hollow Sphere.
BD. The Neck full of Air to D, with which the Sphere is filled likewise.
DC. That part of the Neck that is filled with a colour'd Liquor.
E. A Vessel containing the same Liquor.

FIG. 2.

AB, DC, EF. A Thermometer of *Drebbelius*, more sensible than the former.
ABCD. An anterior view of the same.

FIG. 3.

ABCDEF. The same seen sideways; that the Segments of the Sphere of which the upper Cavity is formed, may come in view.

PLATE III.

FIG. 1.

A. A smaller Sphere, in which the contained Fire expands itself equably.
B. A larger Sphere concentric to the former, and including it, into which the Fire diffuses itself equally out of the other.

FIG. 2.

AFIG, BDIE. Two equal Spheres touching one another in the point I.
CD. A right Line drawn from the Center C, of the first Sphere, which is a Tangent to the other at D.
CE. A right Line drawn from the same Center C, touching the second Sphere at E.
CFG. The Sector in which is contained that part of the Fire in the Sphere A, that may be equably communicated to the Sphere B, the proportion of which being found to the whole Sphere, shows what quantity of Fire thus equably expanding itself from the Center of one Globe can fall upon another of the same Magnitude in contact with it.

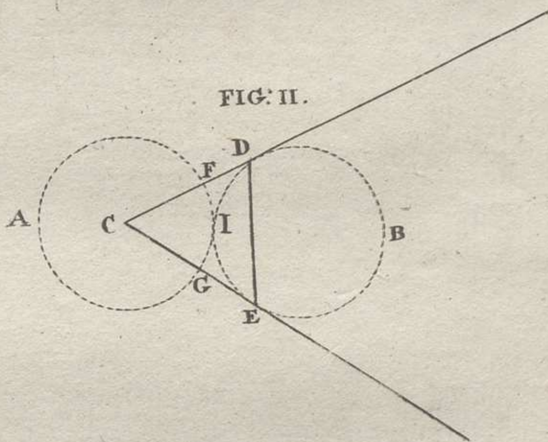
FIG. 3.

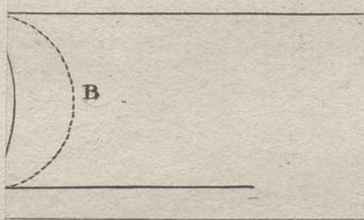
A, B. Two Spheres equal to the former, and in contact.
C. The Center of the Sphere A.
D. The Center of the Sphere B.
K. The point of contact of the Spheres.
CKD. A right Line joining their Centers.
EG. A Line parallel to CKD, touching both Spheres.
FI. A Line parallel to EG, touching them both likewise.
EFGI. The Cylinder through which all the Fire of the Sphere A being directed in parallel Lines, falls intirely upon the Sphere B; which therefore collects all the Fire that was before diffused through the whole superficies of the Sphere A: Whence the Fire will be four times denser in the Circle GDI, than it was in that Superficies.

PLATE IV.

PLA: III

FIG: II.





PLA: III

FIG: I.

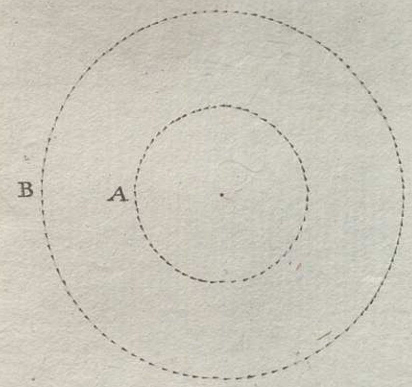


FIG: II.

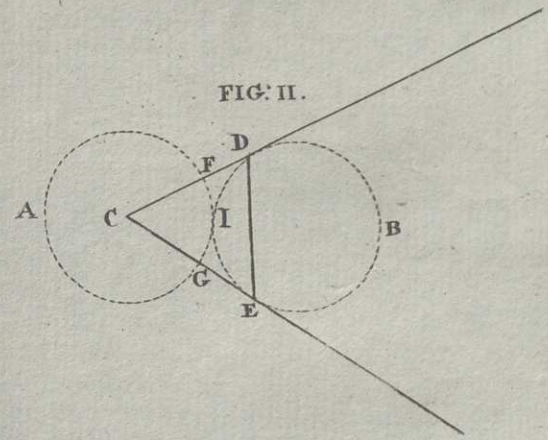


FIG: III.

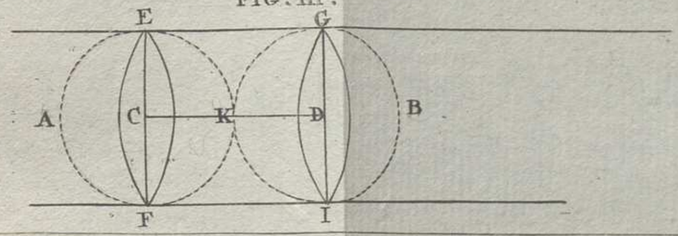


FIG. I.

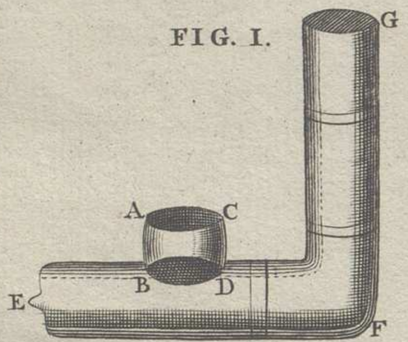


FIG. II.

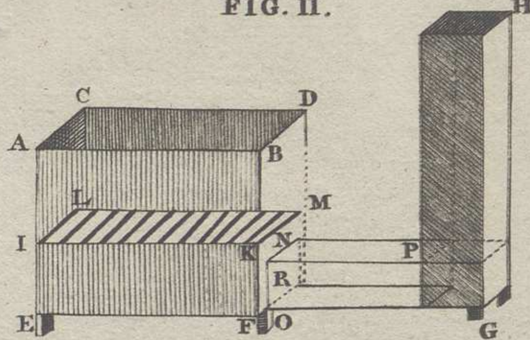


FIG. III.

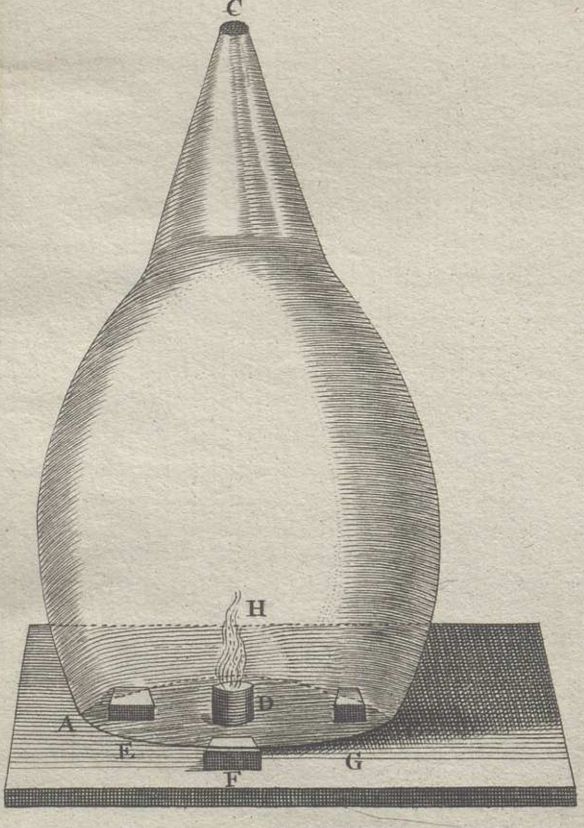


FIG. IV.

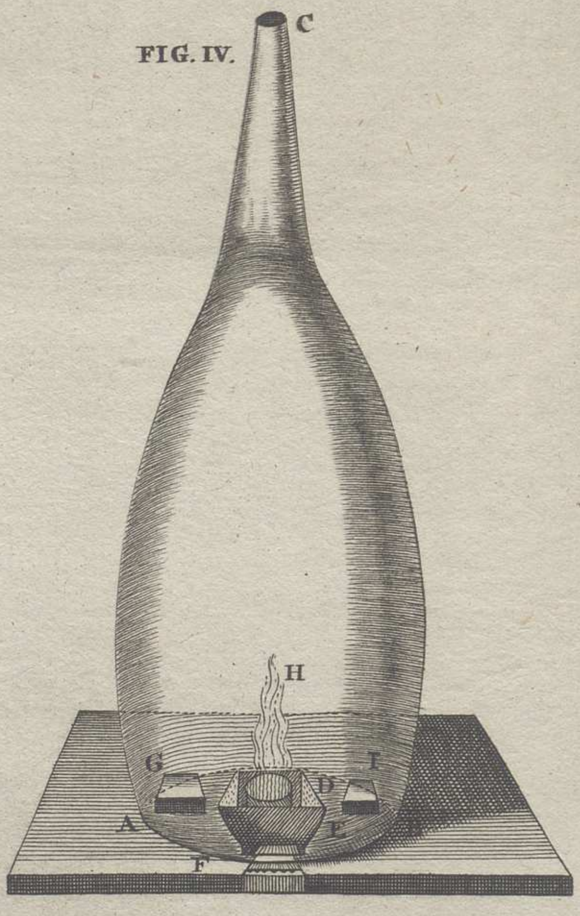


PLATE IV.

FIG. 1.

ABCD. A hollow Cylinder made of Iron Plates, and open at both ends, which is the Fire-place of the Machine.

BD. Its lower aperture where it communicates with the other Cylinder, by means of a Grate.

EFG. A hollow Cylinder made of the ſame Iron turn'd up at F, ſhut at E, and open at BD, where the Grate is, and at G, where the inviſible Smoke paſſes out.

FIG. 2.

ABCDEF. A hollow Parallelipiped open at ABCD, in which the Fire-place is at ILKM.

ILKM. The Grate of the Fire-place, upon which is laid the combuſtible Matter.

EM. The place under the Grate into which the Flame and Smoke are depreſſed as ſoon as ever the Tube OGH grows very hot.

NO. The aperture, which is here ſquare, but may likewiſe be made oval as in the Text. If it is made ſquare, it muſt be a little narrower than KM, if elleptical, its Diameter muſt be of that length.

NOGH. A hollow Tube of the ſame Iron, either parallelipipedal or elliptico-cylindrical, as in the Text, open under the Grate at NO, and at the top H.

FIG. 3.

ABC. The biggeſt Glaſs-Receiver I could get, open at C.

AB. The bottom of it cut out in a circular form, and therefore open there too.

D. A braſs Cylinder in which the Liquor being ſet on fire gives the Flame H, confined under the Bell.

EFG. Three Bricks which the Bell is ſet upon, that the Air may have free admiſſion to it underneath.

FIG. 4.

ABC. A glaſs Veſſel, as before.

E. A Pan with a live Coal.

D. A braſs Diſh, in which the Alcohol burns, the Diſh ſtanding upon the Coal.

F, G, I. Three Bricks on which the Glaſs ſtands.

H. The Flame of the Alcohol ſet on Fire under the Bell.

PLATE V.

PLATE V.

FIG. 1.

ABC. A Thermometer fixed to the board DEFG by the braſs rings M,N,O.

DEFGHIKL. A wooden Machine made to ſtand upon a table with the Thermometer.

PQ. A veſſel in which the Bulb of the Thermometer may be placed, and then any liquors, you have a mind to make trial of, may be poured in ſucceſſively and mixed together.

FIG. 2.

ABC. *Fahrenheit*'s firſt Thermometer, which by the dilatation of the tinged ſpirit indicates the increaſe of the heat of the Atmoſphere.

AB. Its Bulb, which in the greateſt obſerved natural cold contained 1933 parts of tinged ſpirit, of which the Pipe BC contained 96.

BC. A Pipe produced from AB and by a Scale fixed to it divided into 96 equal parts, that the ſpirit when it dilates, and aſcends, may diſcover the augmentations of Heat.

FIG. 3.

ABC. *Fahrenheit*'s ſecond Thermometer meaſuring the increments of Heat in the Atmoſphere by the dilatation of Mercury.

AB. Its Bulb, which in the greateſt obſerved natural Cold contained 11520 parts, of which the Pipe BC contained 96.

BC. A Pipe produced from AB, and divided by a Scale into 96 equal parts, by which the Mercury when it aſcends determines the increaſe of Heat.

FIG. 4.

AB. *Fahrenheit*'s third Thermometer to meaſure the Heat of the Human Body.

AB. A clear glaſs Tube, perfectly cloſed hermetically, within which it is placed.

DC. The Thermometer within, either by its tinged ſpirit, or Mercury, indicating the increments, or decrements of Heat.

DE. Its Bulb.

EG. Its neck.

EF. The fluid in the neck, by its aſcent pointing out the Heat, by its deſcent the Cold.

EFG. A paper divided into equal parts or degrees.

This Thermometer being held a good while under the arm, upon the breaſt under one's clothes, or in the mouth, will determine the Heat of the Body at that time.

PLA: V.

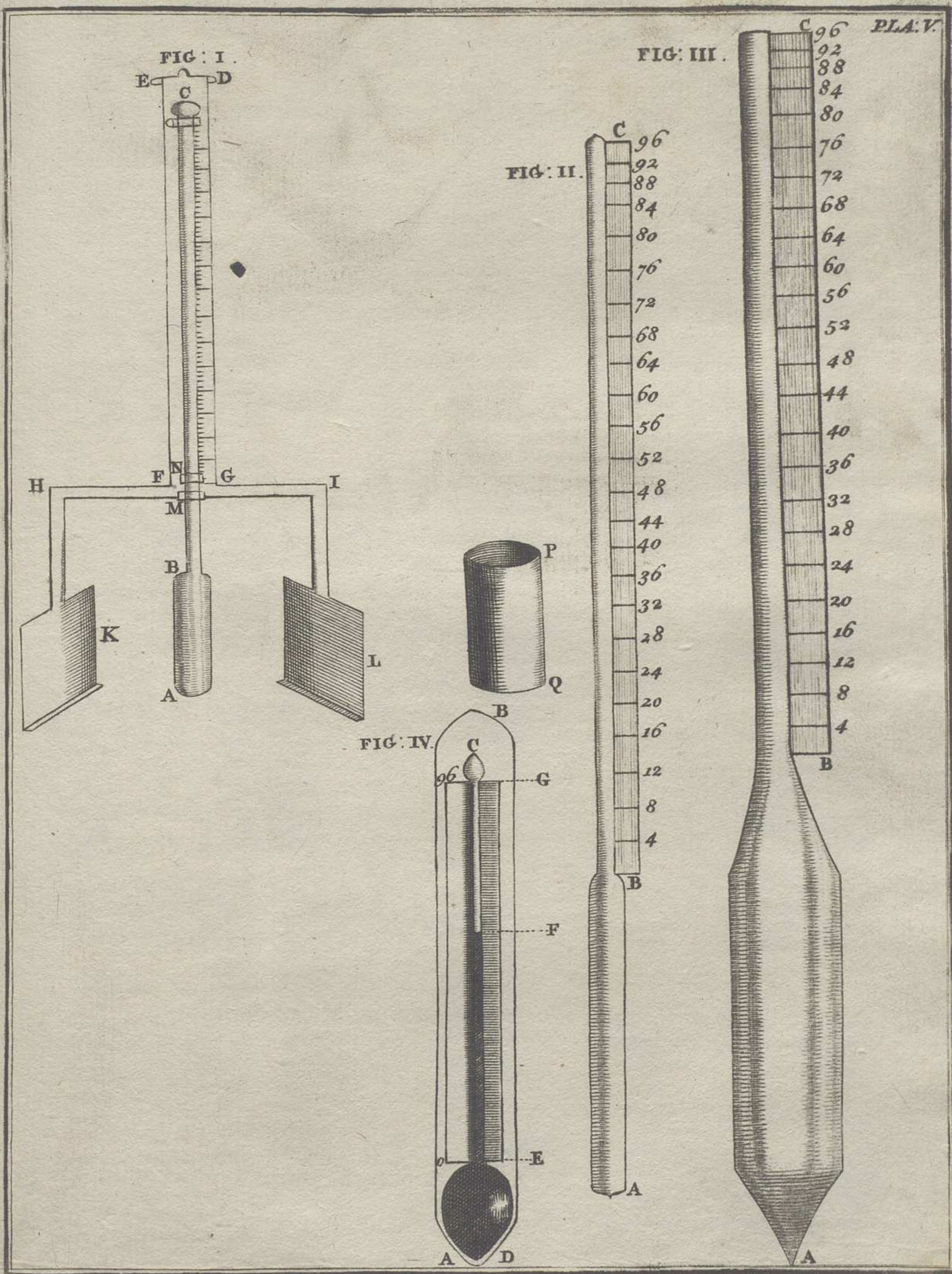


FIG: I.
E
D
C
H
F
N
G
I
M
B
K
L
A
FIG: II.
C
96
92
88
84
80
76
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
B
A
FIG: III.
C
96
92
88
84
80
76
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
B
A
P
Q
FIG: IV.
B
C
96
G
F
0
E
A
D

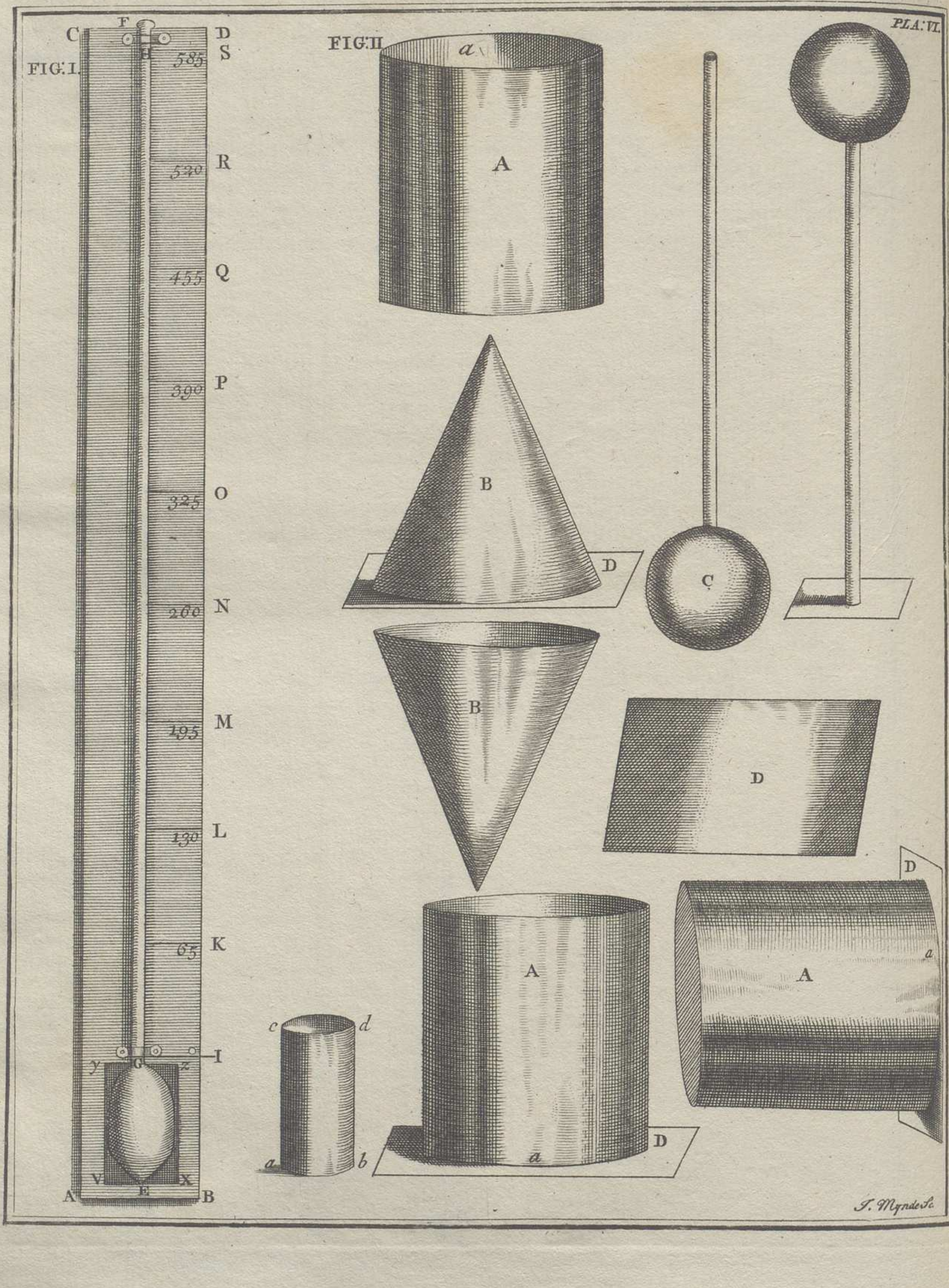

PLA: VI.
FIG. I.
C
F
D
H
S
585
520
R
455
Q
390
P
325
O
260
N
195
M
130
L
65
K
I
y
G
z
V
E
X
A
B
FIG. II
a
A
B
D
B
C
D
D
A
a
A
c
d
a
b
a
D
T. Mynde Sc.

PLATE VI.

ABCD. A braſs Plate hollowed at vxyz that the Bulb of the Thermometer may be let into it.

EF. A Thermometer made with Mercury in ſuch a manner, that in the greateſt obſerved natural cold the Mercury may ſtand at I, and in the heat of boiling Mercury at F.

GE. The Bulb of the Thermometer.

GF. The pipe of the Thermometer divided by means of the braſs Plate into 600 equal parts, which in this ſhort Figure cannot be all repreſented diſtinct, and therefore here we have divided it into larger portions IK, KL, LM, *&c.* each containing 65 of ſuch equal parts.

G, H. Two braſs Semi-circles by which the Thermometer is ſo fixed to the Plate, that you may take it off whenever you pleaſe.

abcd. A braſs veſſel, into which the Thermometer may be put when taken off of the plate, that the heat of the Liquor to be examined, whilſt it boils in this Veſſel may be marked upon the neck GF, which then being applied to the Scale, will give you the degree deſired.

FIG. 2.

A. A hollow cylindrical Veſſel open at a, quite full of water, but its mouth covered with the paper D, which is then inverted without any Water running out. The ſame Veſſel covered in the ſame manner, and lying horizontally, without any Water running out.

B, B. Conical Veſſels, with which the Experiment ſucceeds in the ſame manner, as it does likewiſe in

C. A ſmall Bolthead.

PLATE VII.

PLATE VII.

FIG. 1.

ABbc. A ſtrong glaſs Tube every where equally wide.
AB. The longer Leg, ſome feet high.
bc. The ſhorter, 12 inches high, and nicely divided into lines:
A. The Mouth at which the Mercury is poured in.
c. The extremity hermetrically ſealed.

FIG. 2.

ABC. A very ſmall Bolthead filled with Water and inverted.
BC. The Bulb, at whoſe top C is contained the Air, which entering in the form of Bubbles aſcended and burſt aſunder.
AB. The Neck, whoſe orifice A is 5 lines diameter.
A, d, e, f, g, h. Bubbles, in which form and ſize the Air admitted into the Neck is collected and aſcends, not mixing with the Water, but aſſociating into a large Body.

FIG. 3.

ABC. A Glaſs like the former, full of Water, and inverted.
BC. The Bulb ſtill full of Water.
BA. Its Neck, whoſe Mouth A is 8 lines in diameter.
d, e. Large Air-bubbles, in which form and ſize the Air enters and aſcends without mixing with the Water.

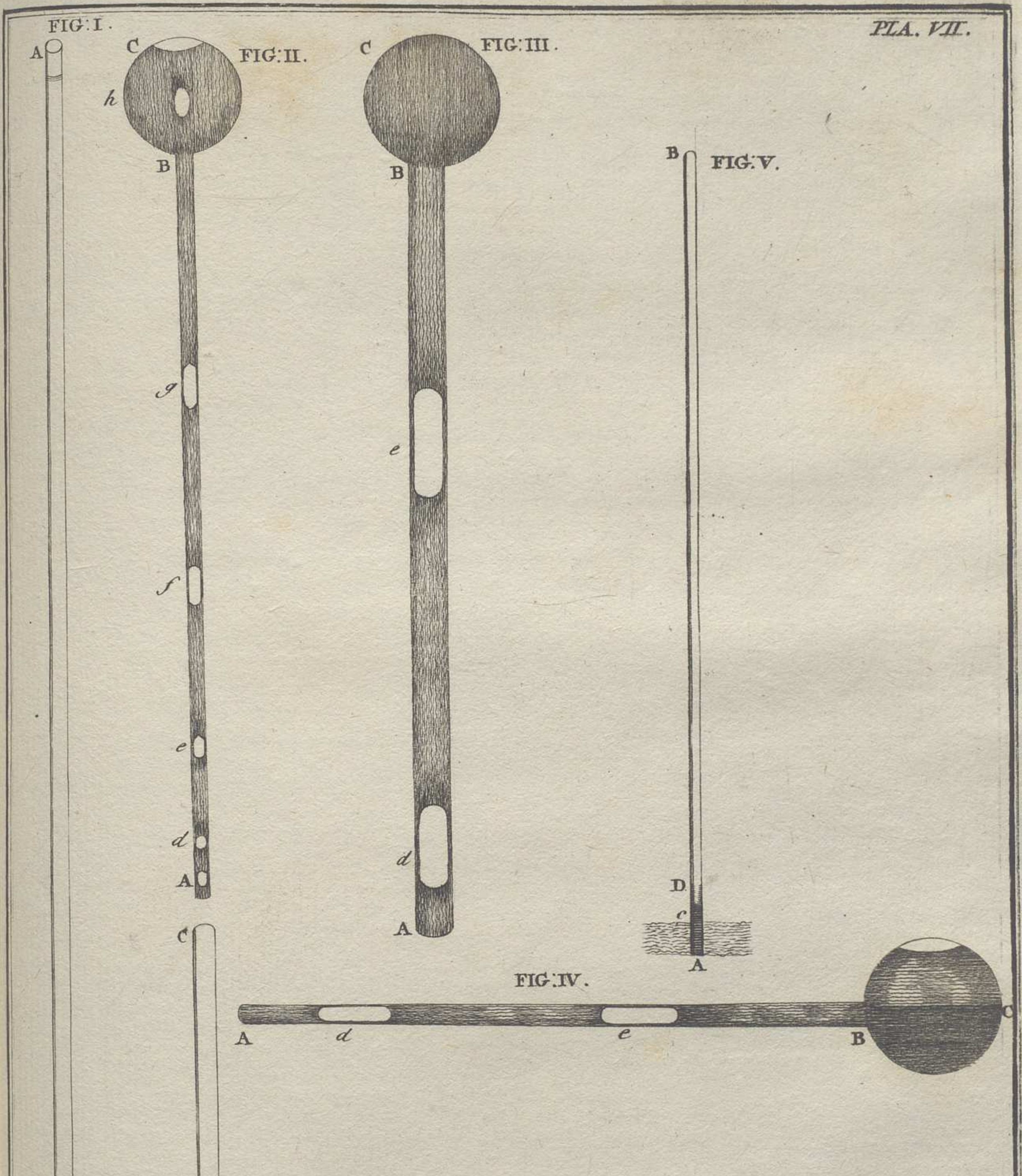
FIG. 4.

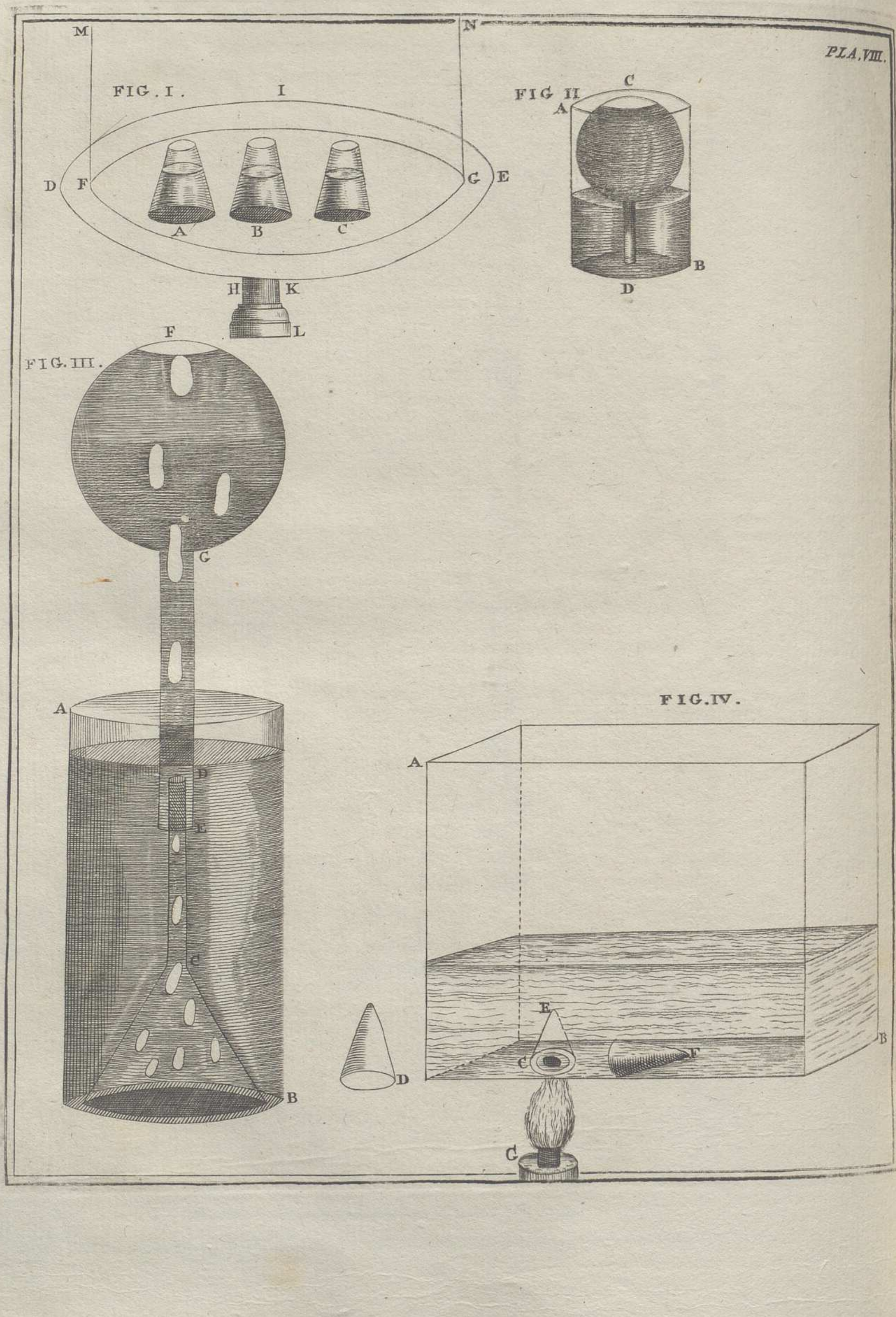
ABC. The ſame ſort of Veſſel in a horizontal poſition, and full of Water.
d, e. Large Air-bubbles, which continue thus a good while in the Water, without dividing.

FIG. 5.

AB. A narrow glaſs Tube open at both ends.
Ac. Water in which the part Ac of the Tube is immerſed.
cD. Water aſcending in the Tube ſpontaneouſly.

PLATE VIII.


PLA. VII.
FIG: I.
FIG: II.
FIG: III.
FIG: IV.
FIG: V.
J. Mynde sculp.


PLA. VIII.
FIG. I.
M
N
I
D
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C
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K
L
FIG. II.
C
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D
FIG. III.
F
G
A
D
E
C
B
D
FIG. IV.
A
E
C
F
B
G

PLATE VIII.

FIG. 1.

A, B, C. Three glaſs Veſſels with Water of different degrees of Heat.

DHEI. The braſs Plate joined to the Tube KL of the Air-pump.

FGMN. The Bell that ſtands upon this Plate and covers the Veſſels A, B, C. from under which the Air is exhauſted by means of the Tube KL.

FIG. 2.

AB. A cylindrical glaſs Veſſel, with a plain bottom B.

CD. A glaſs Bottle, whoſe Belly C may be placed within the Cylinder AB, that its mouth D may reſt upon the bottom B.

FIG. 3.

AB. A cylindrical hollow Veſſel open at A, with a plain bottom B, and filled with Water.

BCD. A Funnel open at D, whoſe upper part ED is inſerted into the neck EG of the Bolthead EGF.

EGF. The Belly and Neck full of Water.

FIG. 4.

AB. A parallelipipedal braſs Veſſel.

B. A plain bottom, which at C has a cavity impreſſed in it, in which there is placed a drop of Water not boiled.

D. A conical glaſs Veſſel, whoſe baſe is ſo large that it can ſurround the Cavity C.

E. The Conoid plac'd over the drop of Water in the cavity.

F. The ſame lying upon its ſide whilſt the Oil boils, that the Air may be expelled, and the Oil may enter.

G. A lighted Candle, placed under the cavity in which the Water lies under the Oil.

PLATE IX.

FIG. 1.

AB. A brass Cylinder.

B. A hole in AB, into which the Tube BCD was soldered.

AE. A Cock fixed in AB, by which all the Air might be let out of the upper part AF, as the Water rose in the Cylinder, and which might be shut when that was perfectly full.

BCD. A brass, hollow, cylindrical Tube opening into the Cylinder at B, and open above at D, so that the Cylinder AB might be fill'd with Water, by pouring it in at D.

FIG. 2.

AB. A steel Cone divided into equal parts.

CD. A hollow wooden Cone, which, when dry in a certain degree, would just admit the Cone AB within its cavity.

FIG. 3.

ABCD. A cylindrical Vessel made, as they call it, of double Glass.

BCE. The bottom of the Vessel rising a little inwards in the middle.

FGHI. The neck of the Vessel, with the cylindrical Mouth HI, an inch and a half in diameter.

KL. A Rim round the Mouth, for dropping out the Liquor, which would otherwise run down the sides of the Neck.

MN. A glass Stopper whose cylindrical part N is exactly ground to the Neck of the Vessel HG. M, the Top of this, thick and flat.

QROP. A Vessel contrived for the more valuable Oils.

FIG. 4.

A, B, C. A Crucible, and Vessels made use of for fixed Bodies in the Fire.

PLATE X.

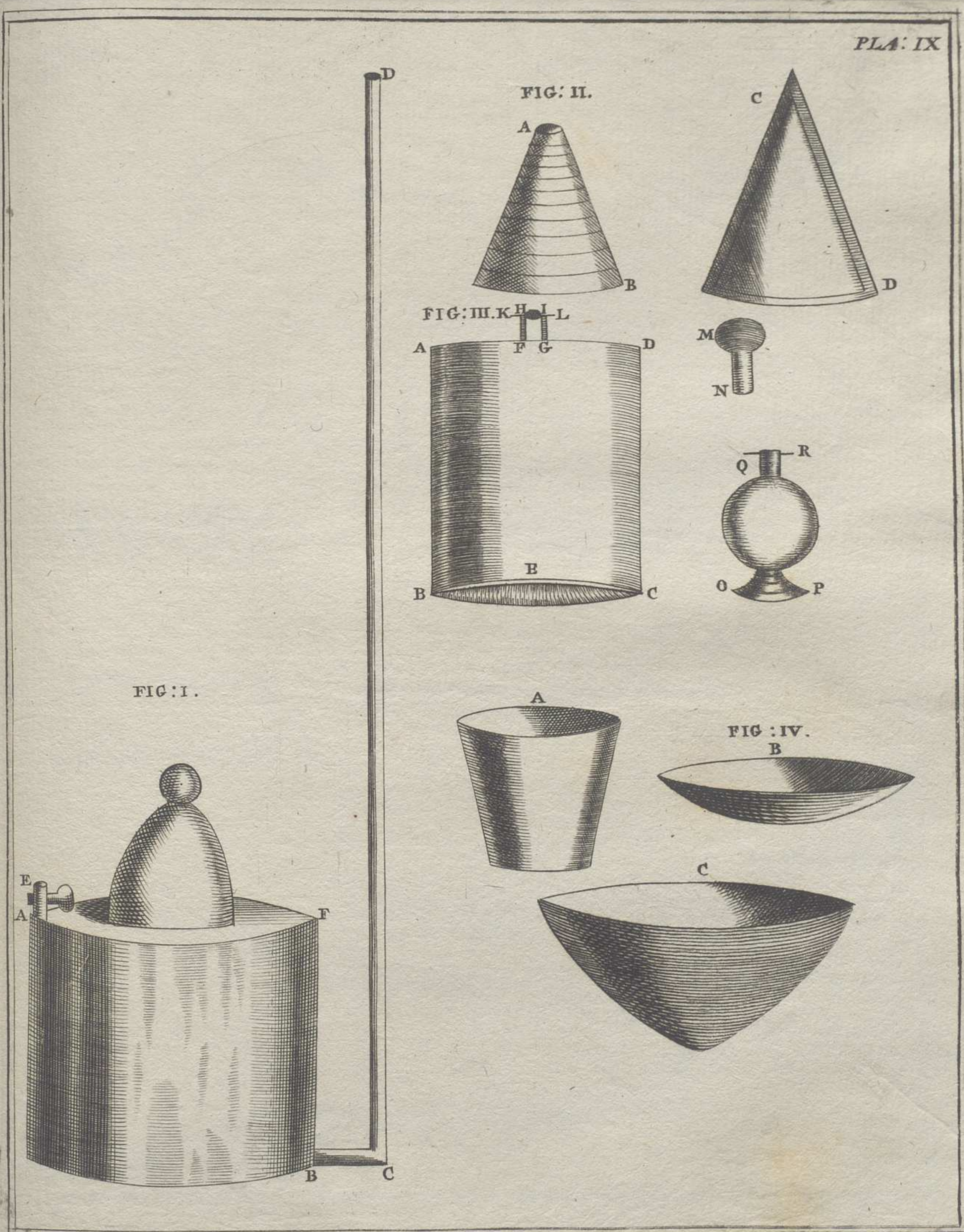
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FIG: I.
A
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C
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FIG: II.
A
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C
D
FIG: III.
A
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G
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P
Q
R
FIG: IV.
A
B
C

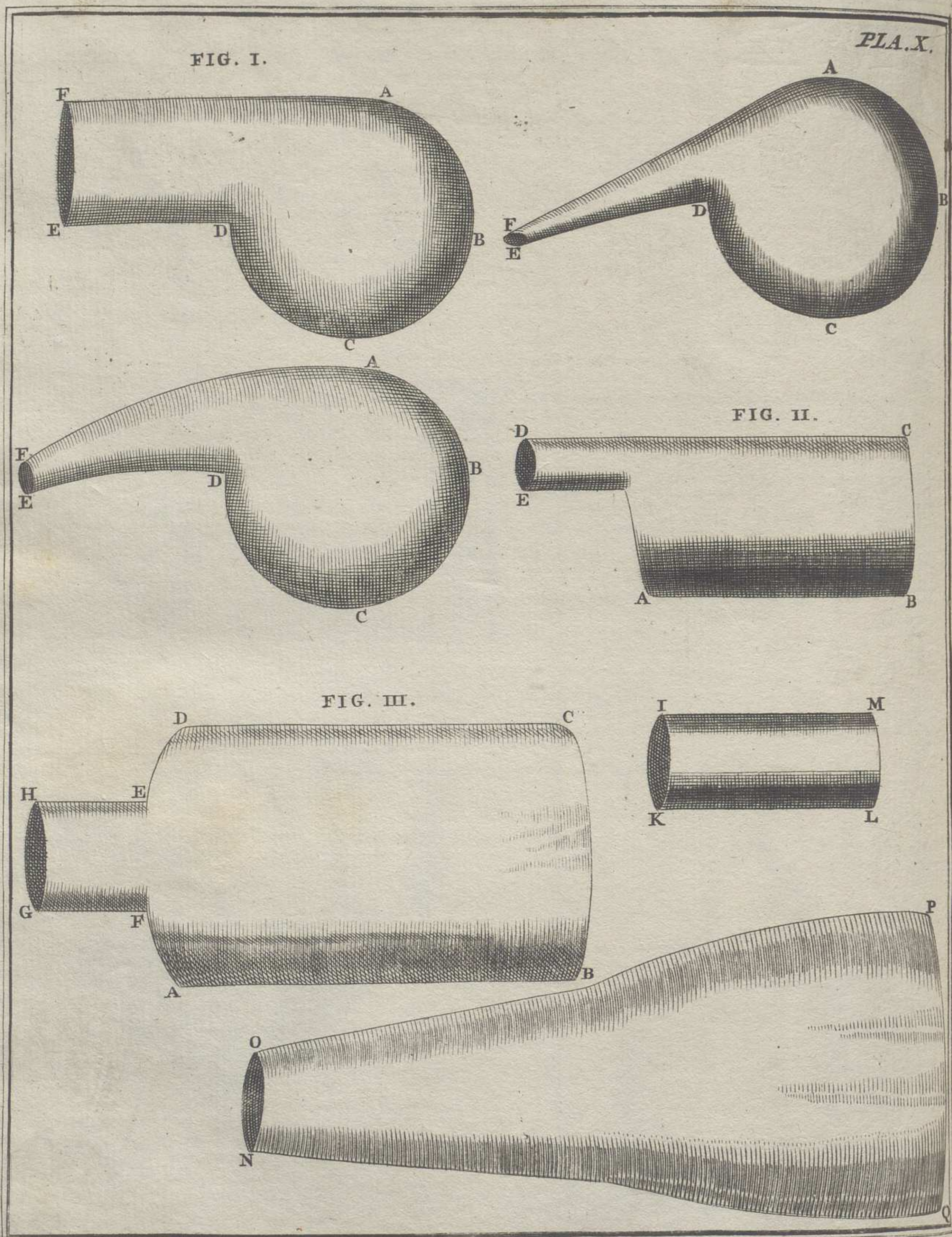
PLA. X.
FIG. I.
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FIG. II.
D
C
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FIG. III.
D
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Q

PLATE X.

FIG. 1.

ABCDEF. The true figure of a diſtilling Veſſel, called a Cornute, or Retort.

ABCD. A hollow Sphere, the Belly of the Retort.

AF. A Tangent to the Sphere in the Vertex A.

DE. A right Line parallel to the Tangent AF, drawn from the point D, where the Diameter parallel to that Tangent cuts the Sphere.

Of theſe three forms, the laſt is the beſt.

FIG. 2.

ABCDE. A Veſſel contrived for the diſtillation of the moſt fixed Bodies, as Phoſphorus, *&c.*

FIG. 3.

ABCDEFGH. A Long-neck to be placed horizontally in the Furnace, ſo that the mouth may be a little way out.

IKLM. A hollow, cylindrical Tube, one of whoſe ends may be received into the mouth HG of the Long-neck, whilſt the other is inſerted into that of the Receiver ON.

ONPQ. A very large Receiver, which being placed horizontally receives the extremity LM of the cylindrical Tube.

PLATE XI.

FIG. 1.

ABCD. A Tin Cylinder 6 inches wide, ending in
CDE. A Conical Tube 4 feet high, and an inch in diameter at the vertex E.
EF. A cylindrical Tube 4 feet long, and an inch wide.
FG. The ſame produced, that it may be inſerted into the mouth of the Worm in the Refrigeratory.
HIK. Holdfaſts to keep the aſcending and deſcending Tubes tight together.
This is the Head uſed in the Diſtillation of Alcohol.

FIG. 2.

Glaſs Veſſels ſo contrived as to fit into one another, by luting which together, you may increaſe the diſtance between the diſtilling Veſſel and Receiver, to what length you pleaſe.

FIG. 3.

A Pelican.

FIG. 4.

A more compendious Pelican with two Boltheads.

PLATE XII.

FIG. 1.

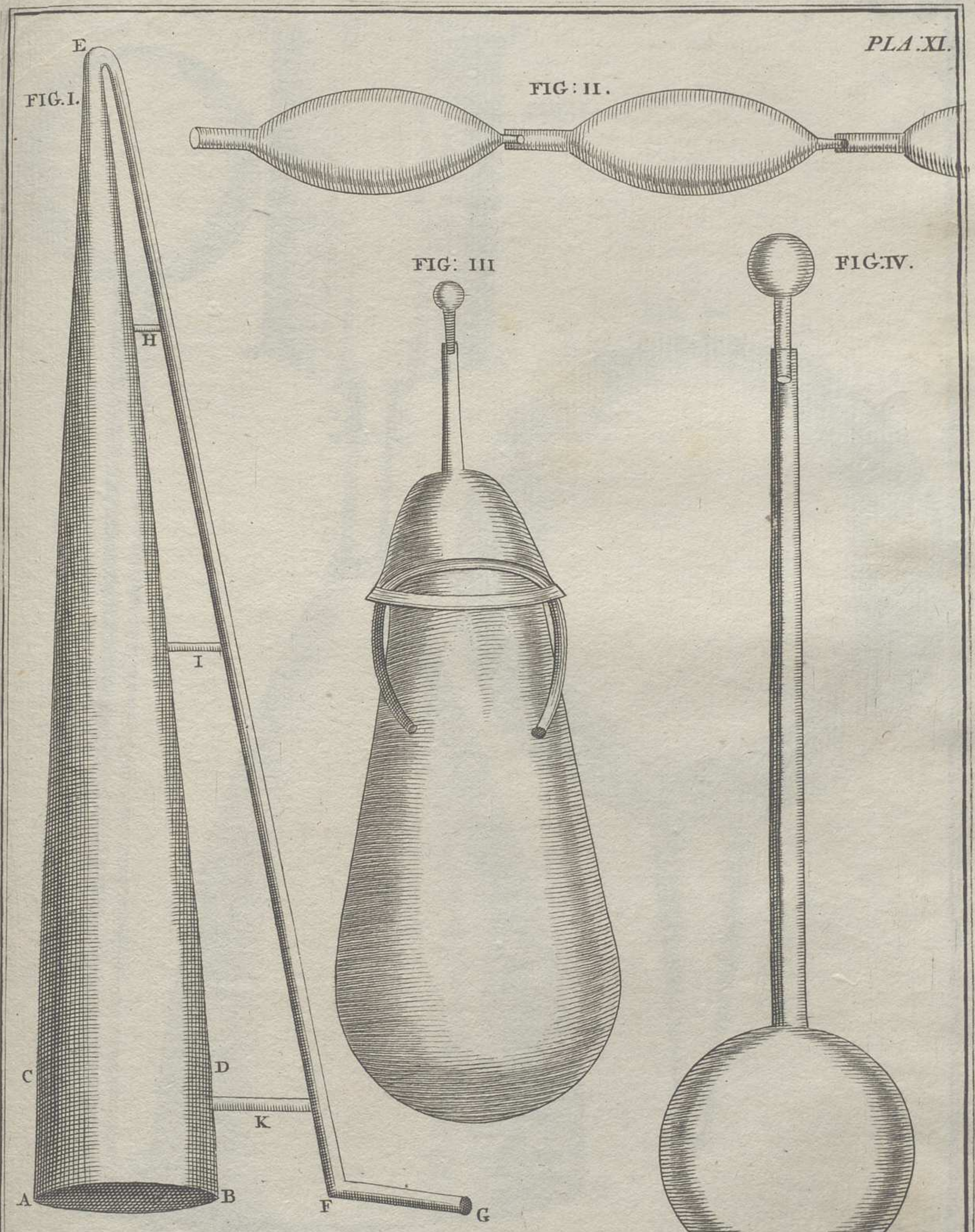
The whole Apparatus as uſed in diſtilling.
ABCDEFGH. The earthen Long-neck placed horizontally in the Furnace.
IKML, A hollow cylindrical Tube inſerted into the mouth of the Long-neck HG, and that of the Receiver ON.
ONPQ. The Receiver.

FIG. 2.

A chemical Vial, Bolthead, or Matraſs.

FIG. 3.

The biggeſt Receiver the workmen could blow, which ſort the Chemiſts now-a-days make uſe of.


PLA. XI.
FIG. I.
FIG: II.
FIG: III
FIG: IV.
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H
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C
D
K
A
B
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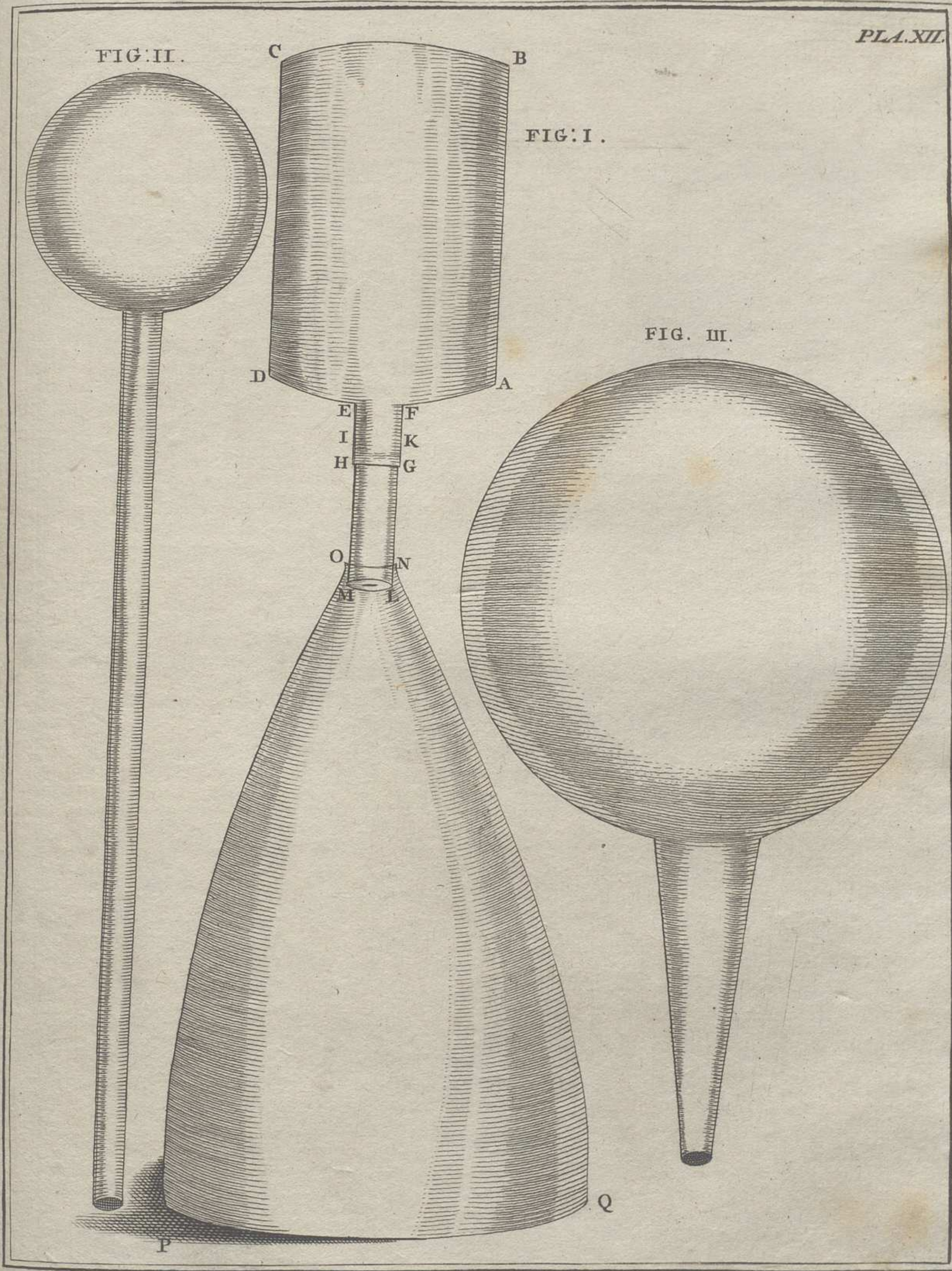
G

PLA. XII.



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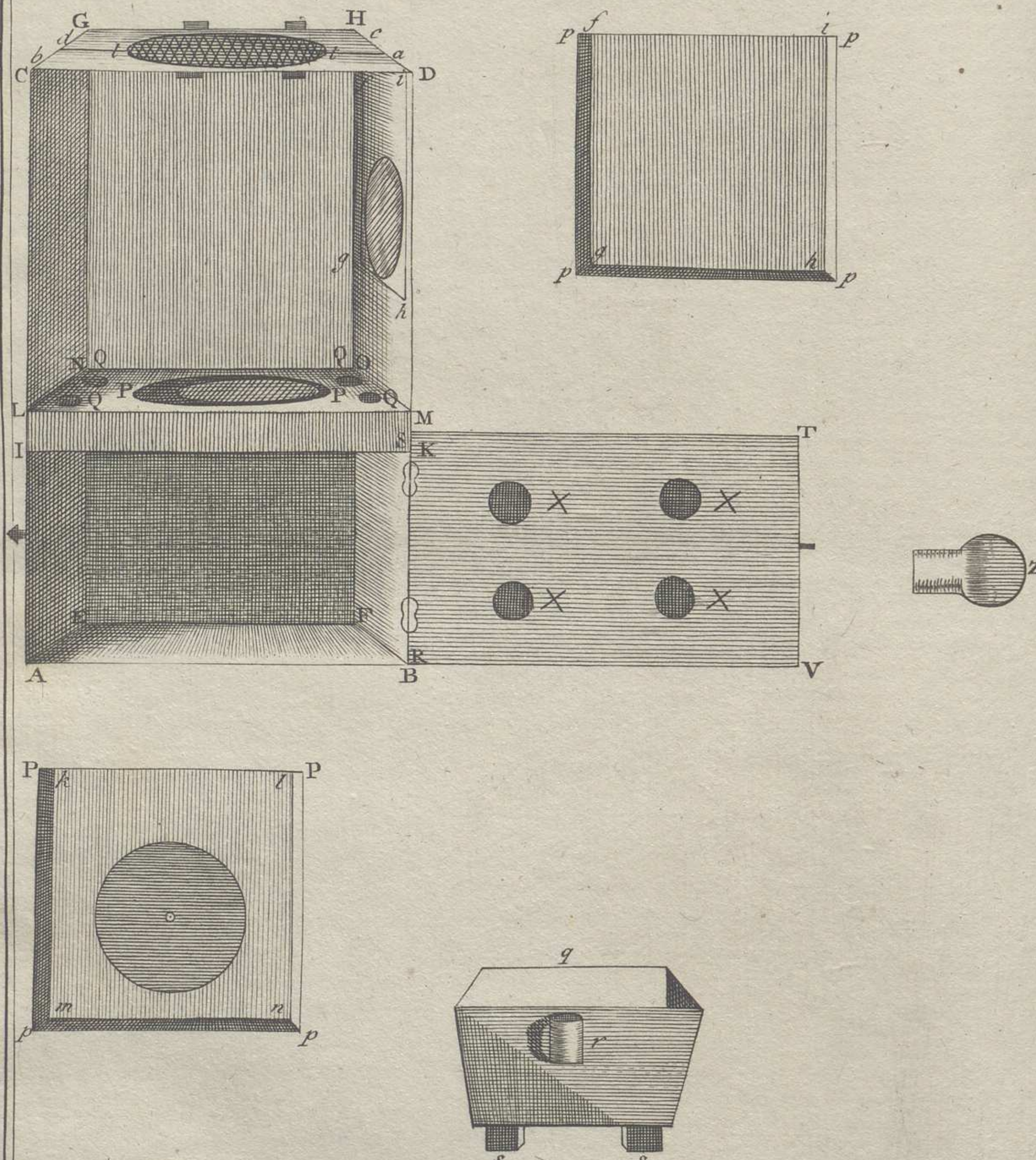


G H b d c a C D l t i
p f i p
g h
N Q Q O
L Q P P Q M
I S K T
X X X X
Z
E F
A B R V
P k l P
m n p p
q
r
s s

PLATE XIII.

The First Furnace.

AB. One ſide of the ſquare baſe 9 inches long.
ABEF. The ſquare baſe.
ACBD. The height and breadth of the priſmatical Furnace, which is 14 inches high.
AI, BK. The height of the Fire-place 5 inches.
IL KM. The thickneſs of the partition 1 inch.
LC, MD. The height of the upper cavity of the Furnace 8 inches.
PP. A circular hole 5 inches in diameter cut out in the middle of the Partition, in which is placed the bottom of the Cucurbit, Retort, or Bolthead, and whoſe upper edge is par'd away.
QQQQ. Four ſmaller circular holes in the ſame, each an inch in diameter, made to tranſmit the heat from the Fire-place into the upper part of the Furnace.
fghi. A ſquare hole cut in the upper part of the ſide BDHF, the ſame letters repreſenting the ſquare board that fits into it, and is in the Plate placed on the ſide of it.
fp, gp, kp, ip. The edge of this board cut away to half its thickneſs, which is to be put into the hole gH, hD, when you diſtill with a Cucurbit.
klmn. Another ſquare board exactly like the former, but with a circular hole in the middle O, of $2\frac{1}{2}$ inches diameter, to be uſed when you diſtill with a Retort.
fg, hm. Each $5\frac{1}{2}$ inches.
RSTU. The door by which the Fire-place is exactly cloſed up, which riſes to the middle S of the Partition KM.
XXXX. Four round holes in the door, to let the Air into the Fire-place.
Z. Wooden Stoppers to fit into thoſe holes to regulate the Fire.
Cb Da, Gd Hc. Two folding Doors, which are ſo cut out in the middle, that when they are ſhut, they form a round Hole of 5 inches diameter tt.
q. The Pan uſed in this Furnace.
r. The Handle.
s, s. The Feet.

PLATE XIV.

PLATE XIV.

Second Furnace.

AC, BB. Iron Feet 12 inches long.

CNOD. The bottom of the Furnace, being an iron Plate covered with a braſs one 17 inches in diameter.

CGHD. A hollow iron Cylinder upon the Baſe CNOD, 19 inches high.

ELMF. The Grate conſiſting of an orbicular iron rim, and the bars in the middle y, which is ſupported by the bars E F, and is parallel to the baſe CNOD.

FL, MF. The breadth of the rim of the Grate $3\frac{1}{2}$ inches.

EC, FD. The diſtance of the Grate from the bottom 4 inches.

NOPQ. The door of the Aſh-hole, 6 inches broad, and 4 high.

QR, PS. The diſtance of the door of the Fire-place from the upper part of the Grate 3 inches.

RSTV. The opening into the Fire-place, 6 inches broad, and $4\frac{1}{2}$ high.

ILKM. An Ellipſe whoſe ordinates at the *Foci*, LM IK are 5 inches long, from which is formed the elliptico-conoidal, internal ſurface of the Furnace, by the rotation of the wooden pattern bc de, upon the axis cb.

a. The Stopper of the Hole of the Fire-place ſeen ſide-ways.

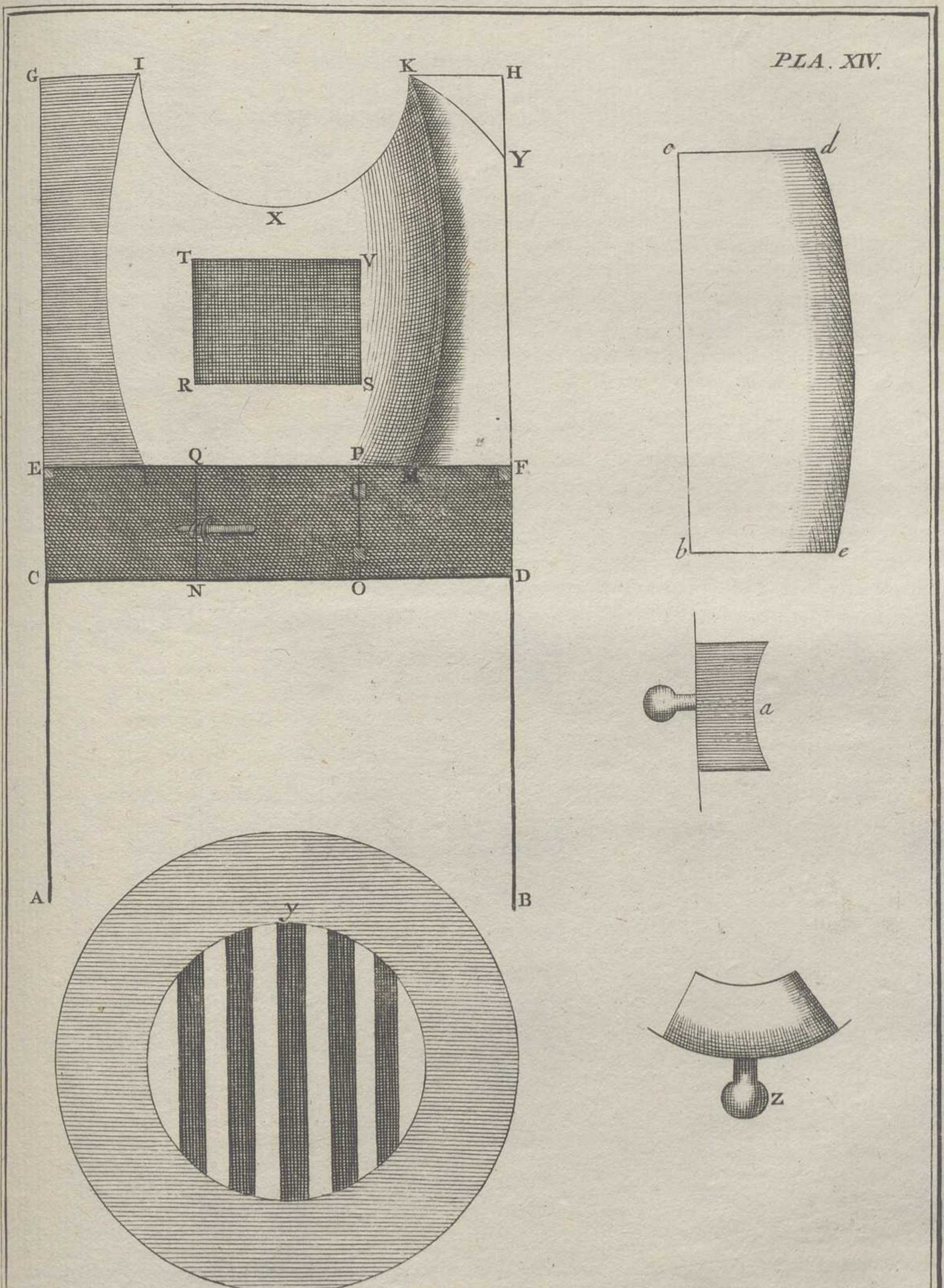
Z. The ſame ſeen from above.

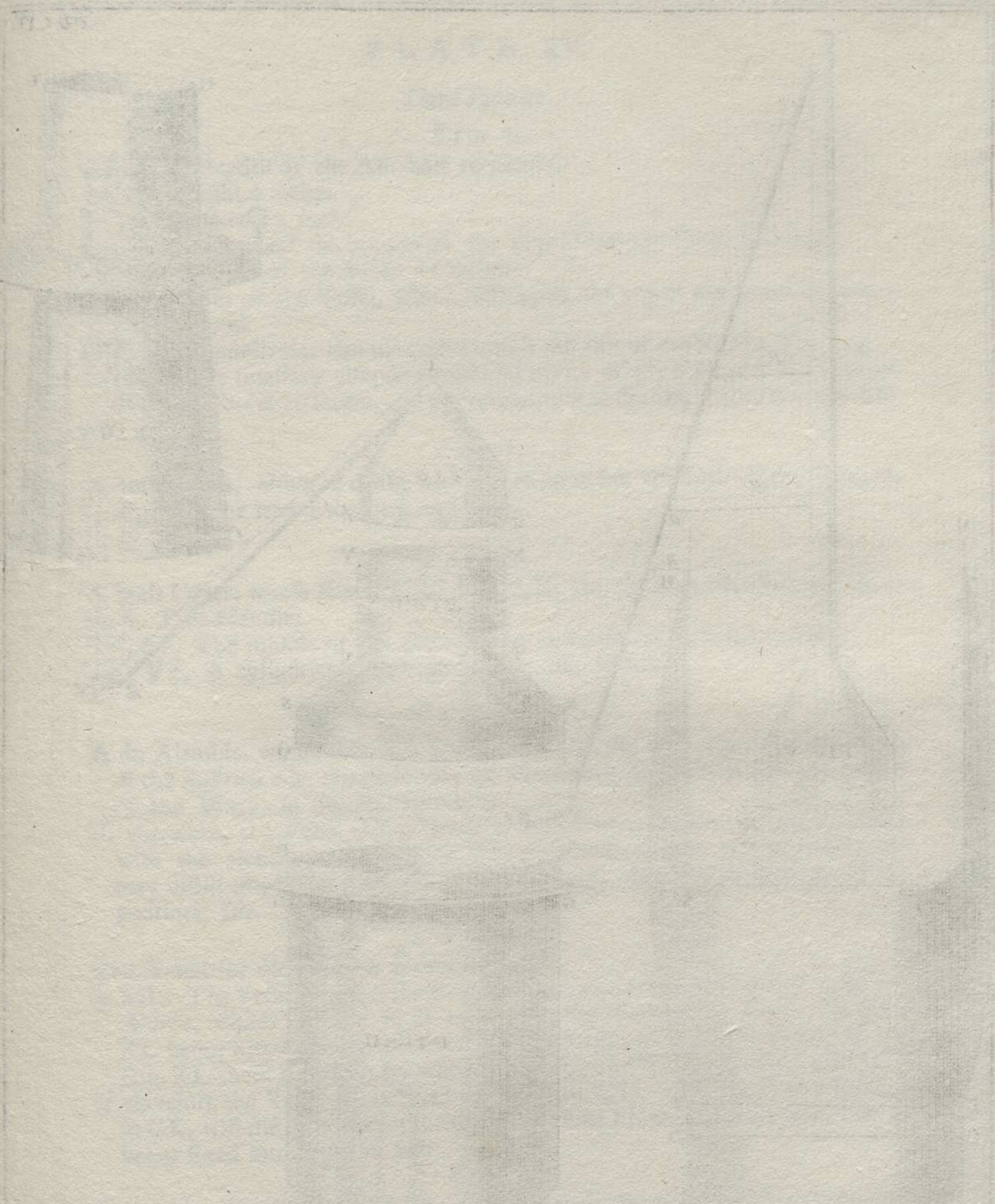
KHY. A Segment cut out for the Neck of the Retort to lie in.

IKX. A Pot 10 inches wide, and 5 deep.

PLATE XV.

PLA. XIV.





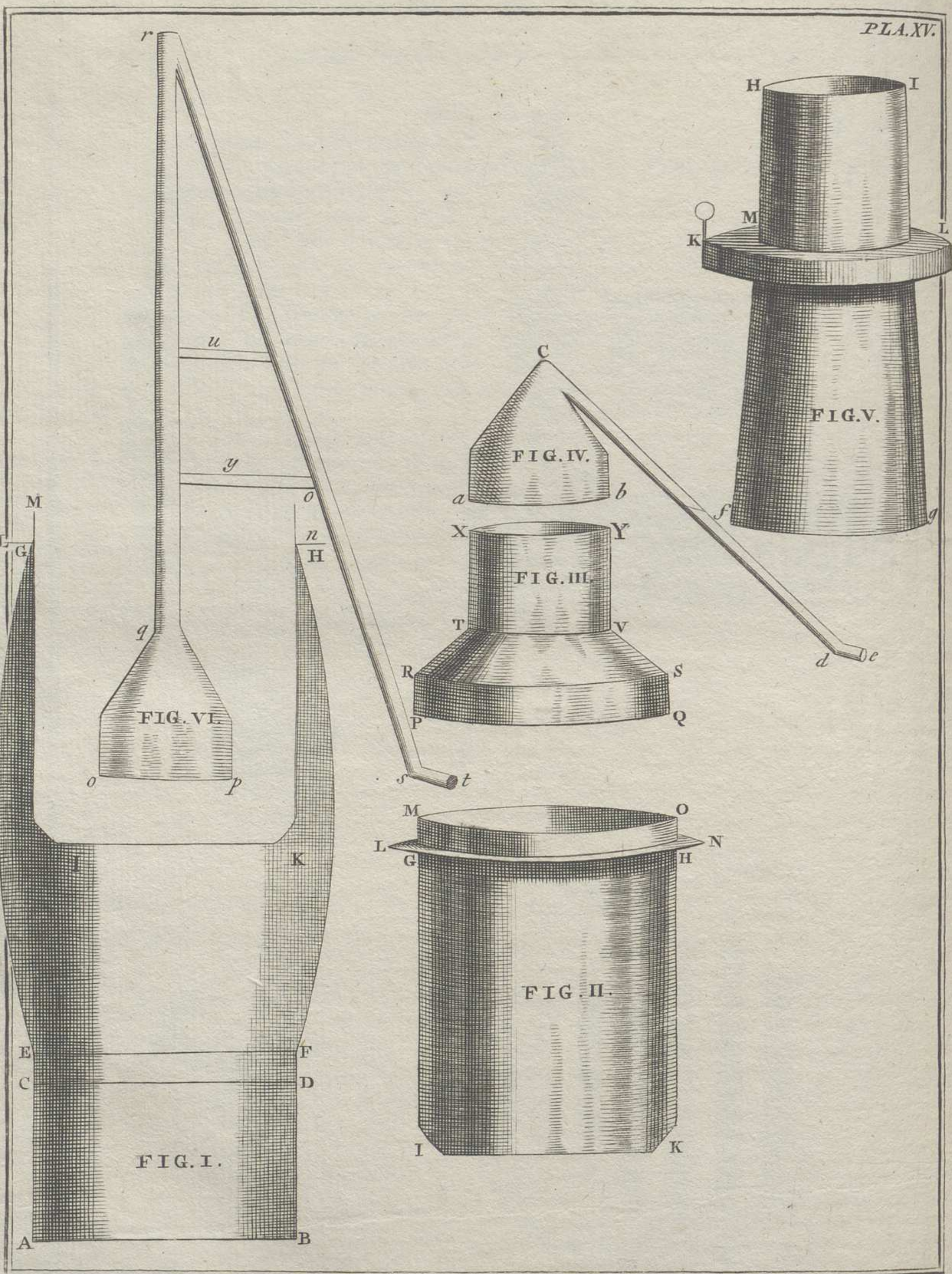

PLA.XV.
FIG. I.
FIG. II.
FIG. III.
FIG. IV.
FIG. V.
FIG. VI.

PLATE XV.

Third Furnace.

FIG. 1.

AB. The breadth of the Ash-hole 10 inches.
AC. Its height 6 inches.
EC. Its thickness 1 inch.
EI. The distance of the bottom of the Vessel from the Grate 8 inches.
IG. The height of the Vessel 12 inches.
LG. The rim of the Vessel, which rests upon the top of the Furnace, and is 1 inch broad.
GM. A perpendicular rim to receive into it the rim of the Vessels, Fig. 3. 4.
EGHF. The interiour elleptico-conoidal cavity of the Furnace, the distance of whose *Foci* is 20 inches, and a perpendicular to the axis at the *Focus* 5 inches.

FIG. 2.

A brass Vessel, either to distill with, or to serve for the bath of the Furnace, Fig. 1. The letters the same as before.

FIG. 3.

A brass Cover, whose Rim PQRS fits exactly into the Rim MOGH of Fig. 2.
R, S. Two Handles.
RT. SV. The middle of the Cover rising obliquely to be produced into
TX, VY. A cylindrical Neck to receive the Alembic.

FIG. 4.

A tin Alembic, whose Rim a b fits exactly into the Rim x y, and head ends in the *Rostrum* cde, the extremity of which may be inserted into the mouth of the Worm in the Refrigeratory.

If, therefore, the Vessel GK is perfectly closed with the Cover py, and that with the alembic, and is fitted into the Furnace, then in this Vessel you may distill any thing with Water and a Worm, as likewise Balsams, Turpentines, &c.

FIG. 5.

The Vessel for distilling *in Balneo Mariæ.*

fg ML. The Vessel in which the Bodies are put that are to be distilled in *Balneo Mariæ*, which is made so as to go into the Vessel GK, Fig. 1. its Rim KL being fitted exactly to the receiving Margin MO. In the surface of the Rim KL there is a Hole, by which you may pour Water into the Vessel GK.

If therefore the Vessel f I is fitted to the Rim MO, then the Water boiling in GK, will distill *in Balneo* through the Vessel f I, the Alembic abc, Fig. 4. being fixed into the Rim HI.

FIG. 6.

A tin Alembic described Pl. XI. whose Margin op being exactly fitted into the Rim HI, Fig. 5. serves for the distillation of Alcohol, the common Spirit of Wine being in the Vessel f I.

PLATE XVI.

PLATE XVI.

Fourth Furnace, which is the melting Furnace.

abcd. A hollow ſtone Baſe arched at cd, and 3 feet high.
cdef. The Aſh-hole, plain at bottom, and 5 inches high.
efih. The Grate.
ab, cd, ef, hi. 12 inches each.
hk, il. The Fire-place 6 inches high to kl.
kmnl. A paraboloid Cone, whoſe Axis is 8 inches, and inferiour ordinate 6 inches.
mnpo. A cylindrical Chimney 3 inches wide, and 2 feet high.
au, y4, bx, z3. The thickneſs of the Stone-work of the Furnace 5 inches.

PLATE XVII.

Fifth Furnace.

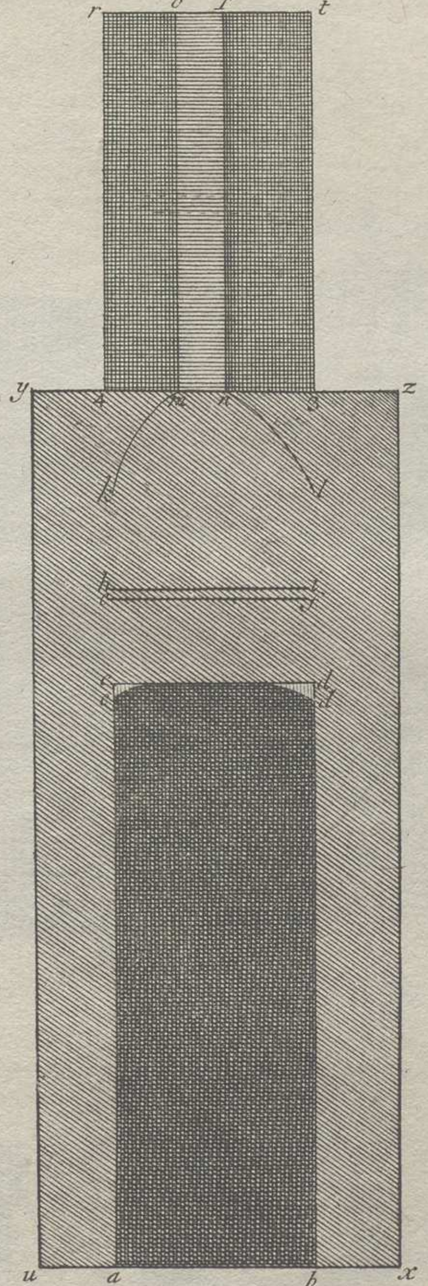
FIG. 1.

AB. The breath of the Furnace 20 inches.
AH, IB. Each 8 inches long.
HI. The breadth of the Aſh-hole 4 inches.
HK. IL. The height of it 11 inches.
KM. LN. The diſtance of the Door of the Fire-place from the Aſh-hole 3 inches.
MN. OP. The breadth of the Door 7 inches.
MO. NP. The height 9 inches.
BG. DF. The length of the Furnace 38 inches.
QRS. The Aperture in the middle of the ſide to place the Long-necks in.
QR. The length of the Limb of this Aperture 20 inches.
US. The height of the middle of it 12 inches.
ST. The thickneſs of the upper Wall of the Furnace 6 inches.

FIG. 2.

AB. A little braſs Furnace for our firſt proceſs, in which there is fitted a braſs Plate, juſt at the top of the door of the Fire-place B.
CDEF. A tin Alembic fitted to the upper Rim of this Furnace.

PLA. XVI.



PLA. XVII.

FIG. I.

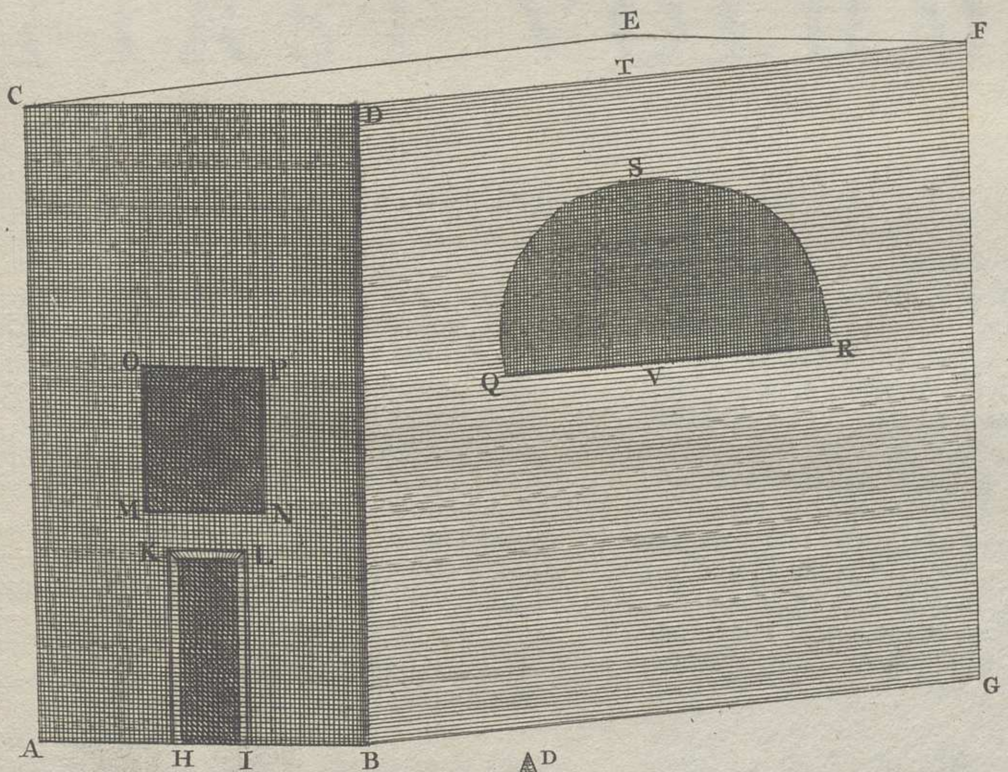
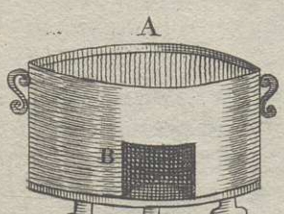
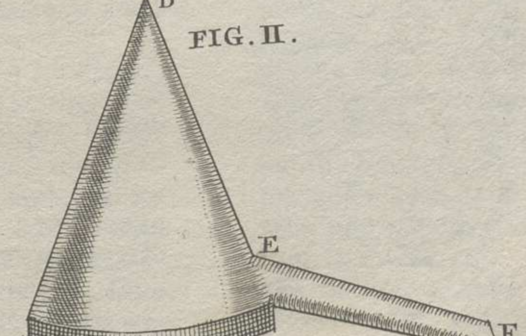


FIG. II.





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