Gorham Parsons

THE

Philoſophical Grammar;

BEING A VIEW OF THE

PRESENT STATE

OF

EXPERIMENTED PHYSIOLOGY,

OR,

NATURAL PHILOSOPHY.

IN FOUR PARTS.

PART I. SOMATOLOGY, treateth of the univerſal Nature and Properties of Matter, or Subſtance, and the ſpecific Qualities of natural Bodies.

PART II. COSMOLOGY, exhibiteth a general View of the Univerſe, and its great conſtituent Parts; the Sun, Moon, Planets, Comets, fixed Stars, *&c.*

PART III. AEROLOGY, compriſeth the Philoſophy of the Atmoſphere, ſhewing the wonderful Nature and Properties of the Air, Wind, Meteors, and other Phænomena therein.

PART IV. GEOLOGY, containeth a Philoſophical View of the terraqueous Globe in all its Parts and Productions: As Minerals, Metals, Stones, *&c.* The Laws of Fluids; the Sea, its Tides, *&c.* Of Rivers, Springs, *&c.* Of Vegetation, and the Nature of Plants, Trees, *&c.* Of the Parts of animal Bodies; and a Survey of the Nature of Beaſts, Birds, Fiſhes, Inſects, Reptiles, Shell-Animals, *&c.*

THE EIGHTEENTH EDITION,
With *Alterations*, *Corrections* and very large *Additions*, by Way of *Notes*.

BY BENJ. MARTIN, Φιλότεχνος.

The Works of the Lord are great, ſought out of all them that have Pleaſure therein
Pſalm cxi. 2.

Philoſophia mater omnium bonarum artium, nihil eſt aliud, niſi, ut Plato ait, donum et inventum Deorum, *Cicero*, 1 *Tuſc.*

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MDCCLXXVIII.

THE

PREFACE.

THE favourable Reception the former Editions have met with, inclines me to hope that this ſeventh Edition will find further Encouragement from the Public; eſpecially when it is known what great Improvements are made through the whole Work ſince the firſt Edition of this Book, both by the Advice and Remarks of many learned and judicious Perſons, (which I here gratefully acknowledge) and my own Obſervations. All this has produced conſiderable Alterations, Corrections, and Additions; for many new and curious Subjects, and ten new Plates, are added: And the moſt approved Authors, who have treated more largely *of these Things, than can be expected in this small Volume, are referred to. I shall add no more, but that this Book is designed for the Instruction and Entertainment of the Youth of both Sexes: And that it may so delight and allure them, as to engage them to pursue true Knowledge to a greater Perfection, is the sincere Desire of*

Their humble Servant,

BENJAMIN MARTIN.

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THE

Philosophical Grammar.

CHAP. I.

Of the Science of Philosophy in general; of Natural Philosophy in particular; its Parts and Subjects, and various Uses in Life.

A. WHAT is the genuine Meaning of the Word *Philosophy?*

B. By Philosophy, you are to understand the Science or Knowledge of the Nature, Causes, Properties, and Effects of all created Beings, so far as they are capable of being known by Reason, discovered by Art, or any Ways adapted to the human Comprehension *.

* The Word PHILOSOPHY among the Ancients was used in a various Sense; for, (1.) It sometimes was taken for *Universal Knowledge*, viz. of all Things, *Human* and *Divine*. (2.) In a stricter Notion, for the *Contemplation of Nature only*; and in this Sense a Philosopher was called by *Plato*, φίλος τῆς φύσεως, A *Friend*, or *Lover* of *Nature*. (3.) Sometimes for *Ethics*, or the Doctrine of Manners; which we call Moral Philosophy. (4.) It also included the Mathematical Arts and Discipline, especially *Arithmetic* and *Geometry*. (5.) The Science τȣ̃ ὄντως ὄντος, of Existence or Being in the Abstract, called *Metaphysics*. (6.) For the Knowledge τȣ̃ πρώτȣ καλȣ̃, of the Prime or Chief Good, *i. e. God*; and this was their *prima Philosophia*, or Theology. (7.) It was sometimes applied to *Logic*, or *Dialectics*, which gave Rules for reasoning about the Nature of Things.—But on the Whole, the Knowledge of *God*, *Nature* and *Arts*, was so very imperfect and scanty, that Philosophy seems but *dawning* in the Works of its greatest Professors among them.

A. Pleaſe to be a little more particular in your Definitions, or I cannot ſo eaſily (as I would) apprehend you: What do you mean by the *Nature of Things?*

B. By the *Nature* of any Being, or Thing, is meant that peculiar State or Condition, whereby it is differenced in its Kind from all other Beings whatſoever: Thus it is the Nature of God to be perfect; of Man to be ſociable; of Fire to be hot; of Ice to be cold, *&c.*

A. In like Manner explain what you mean by the *Cauſes of Things,* that I may the better apprehend you on theſe Philoſophical Subjects.

B. By *Natural Cauſes* are to be underſtood the Means by which Things come at firſt to have their Being or Exiſtence: Thus God is the Cauſe of all created Beings, becauſe from him they firſt received their Being; and hence *God* is called by way of Preheminence the *firſt* and *primary Cauſe* of all Things.

A. I have heard, and alſo read of *ſecondary Cauſes*; pray, what is the Reaſon of this Diſtinction?

B. I'll endeavour to inform you. *Secondary Cauſes* are thoſe which produce their Effects according to the Direction and Influence of ſome eſtabliſhed and original Laws and Rules, implanted in their Natures at their firſt Creation by God, the *primary Cauſe*; of all other Cauſes he is the original Cauſe; and conſequently they, with Regard to the *firſt Cauſe,* can be only properly termed *ſecondary*

Causes: So the Sun causeth Vapours; and Vapours cause Clouds; and Clouds condensed cause Rain; Rain causeth Springs, Rivers, Vegetation, *&c.* but yet they all act in a secondary Manner, under the original Influence of the first Cause, as aforesaid *.

A. Please next to define what you call the *Properties* of Bodies.

B. By Bodies, I suppose, you mean the several Kinds of Beings in general, as they appear to our Sight; and, in this common Sense of the Word, the Properties of Things are those Qualities and Operations peculiar to themselves, and which distinguish them from all other Kinds of Beings: Thus it is the Property of Man to laugh, and reason; of Glass to be transparent; of Air and Wind to be invisible; of Space to be infinite; of God to do Good, *&c.*

A. The Knowledge of Effects you mentioned as a Part of Philosophy; what am I to understand thereby?

B. This: That an Effect is whatever is produced or brought to pass by the Action or Operation of any natural Cause: Thus Vapours are the Effect of the Sun's Attraction; Ice is the Effect of a cold Air; Visibility the

* The Doctrine of *Secondary* and *Final Causes*, is of the last Importance in true Philosophy; since the former are the *Means by which*, and the latter, the *Ends for which*, all Things receive their Being from the Primary Efficient Cause, which is *God* alone.

Effect of Light; and Purging and Vomiting the Effects of divers Herbs and Medicines.

A. Having given this general Account of Philoſophy, I ſhould be glad if you'd oblige me with a more particular one; pray, how many Sorts of Philoſophy are there?

B. Philoſophy is divided generally into Moral and Natural.

A. What do you call Moral Philoſophy?

B. This is properly called *Ethics*, from the *Greek* Word ἦθος, and *Morality*, from the *Latin* Word *Mos*, plural *Mores*, both ſignifying *Manners* or *Behaviour*.

A. Pray, what is the Buſineſs of Moral Philoſophy?

B. To give Rules and Laws for the Behaviour, Manners, and Conduct of Man, as Man, or as a rational Creature.

A. Pleaſe to tell me the End or Deſign thereof.

B. The great End and Deſign of Morality is to make Mankind acquainted with the Means and Methods of being happy, or to obtain the greateſt Felicity in this Life.

A. What do you properly call Natural Philoſophy?

B. This hath two proper Appellations; one in *Phyſic*, from the *Greek* φύσις, *Nature*, or φυσικὴ, *Natural*; and ſo it imports to us the Science or Knowledge of Nature, or natural Bodies.

A. But you ſay it hath another Name; what is that?

B. Phy-

B. Phyſiology; ſo called of φύσις, *Nature*, and λόγος, a *Diſcourſe*; and by this is implied a Diſcourſe of Nature, and natural Bodies; and ſuch is the enſuing Book *.

A. Since the Word *Philoſophy*, then, is general; what is implied by it?

B. The Word *Philoſophy* is compounded of the two *Greek* Words φιλία, *Love*, and σοφία, *Wiſdom*, or *Knowledge*; and thus it implies the Love of Wiſdom, or the Study of Knowledge or Learning in general, as aforeſaid †.

A. How came the Word *Philoſophy* firſt in Uſe?

B. Pythagoras, a learned *Greek* Philoſopher of *Samos*, from his great Modeſty, eſteemed the Appellation σόφος, a *wiſe Man*, too arrogant, (though the general Character of a learned Man before his Time) and therefore he was content to call himſelf φίλος, a *Lover*, σοφίας, *of Wiſdom*: And ſince him the Science has been called *Philoſophy*, i. e. *Love of Wiſdom*; and thoſe who ſtudy it, *Philoſophers*.

* The Greek Word φύσις and the Latin *Natura*, (whence the Engliſh Word *Nature*) are both derived from Verbs, *viz.* φύω and *Naſcor*, which ſignify to *make*, *produce*, *beget*, or *give Being* to any Thing. Thus *Nature*, properly ſpeaking, is the *General Birth* of all Things.

† The Word *Philoſophy*, though literally *Greek*, yet is of an *Hebrew* Derivation; for φιλία ſeems to be from פלה, to *ſeparate*, ſet apart, ſelect; which is the Act of *Love* in a moſt eminent Degree: And σοφία is evidently from צפה, *to obſerve*, *explore*, *view*, and *contemplate* Things; which is the proper Buſineſs of a *Naturaliſt*. And thus from צפים came the Greek σοφοὶ or Contemplative Wiſe Men.—Yet notwithſtanding this, ſuch *poor Philoſophers* were the *Hebrews*, that their Language affords not one Word for *Nature* or *Philoſophy*.

 A. Very

A. Very good; but ſay, what is the proper Subject of Natural Philoſophy?

B. Subſtance or Matter, under all the various Forms and Figures we behold it, which we call Natural Bodies, with all their Properties and Affections.

A. What is the Deſign of Natural Philoſophy?

B. To improve human Knowledge, to make us better acquainted with Nature, to give us a rational Senſe of Things, by diſcovering the Reaſon of the various and different Affections, Qualities, and Effects of Objects, which offer themſelves to our Senſes, ſo far as is poſſible.

A. What are the more principal Uſes of Philoſophy in the Affairs of human Life?

B. They are almoſt innumerable; for hereby Men are diſtinguiſhed from Brutes, who indeed behold the various Phaſes of Nature, but can tell the Reaſon or Cauſe of none. By this Art, the *Phyſician* acquires the Knowledge of the Virtue and Effects of Plants and Herbs; the *Chymiſt* hereby obtains the Method of analyzing and diſſolving Metals, Minerals, Plants, animal Subſtances, *&c.* and reducing them to their firſt Elements; the *Apothecary* hence underſtands the Reaſon of the various Compoſitions of Simples for the making his Medicines; the *Aſtronomer* hence learns the Frame and Conſtitution of the Heavens, and the Magnitude, Diſtance, and Phaſes of all the heavenly Bodies; the

Huſband-

Husbandman also may know, from the Rules of this Science, the most advantageous Methods of cultivating and manuring his Land; the *Navigator*, from hence, borrows the Theory of his Art; and, in short, there is no State, Art, or Capacity, in Life, which does not directly, or indirectly, receive Advantage and Benefit therefrom.

CHAP. II.

Of the Parts and Subdivisions of PHYSIOLOGY.

A. HOW many are the Parts of this Science of natural *Physiology*?

B. It may properly be divided into four general Parts.

A. Which are they?

B. These following, *viz.*

I. *Somatology*, which treateth of the common Nature, Properties, and Qualities of *Matter*, and its various Combinations in *natural Bodies*.

II. *Cosmology*, or *Uranology*, which treats of the Nature, Constitution, and component Parts of the *Universe* in general, and particularly of our *solar System*.

III. *Aerology*, which treats of the Nature of the *Atmosphere*, or Region of *Air*, and

and all the *Phænomena* thereto belonging *.

IV. *Geology*, which treats of the Nature, Make, Parts, and Productions of the *Globe of Earth* on which we live.

A. I ſuppoſe each of thoſe general Parts receive a Subdiviſion, do they not?

B. Yes, into ſeveral other Branches.

A. What are the Subdiviſions of the firſt general Part, *Somatology?*

B. Somatology, as it conſiders the common and ſpecial Properties of natural Bodies, is divided, with reſpect to them, in the Manner I ſhall by and by name to you, when we diſcourſe of that Part.

A. What are the particular Branches of the ſecond general Part?

B. Coſmology, or more properly *Uranology*, comprehends the following Branches, *viz.*

1. *Heliography*, which treats of the *Sun.*
2. *Selenography*, which treats of the *Moon.*
3. *Planetography*, which treats of the *Planets.*
4. *Cometography*, which treats of the *Comets.*
5. *Aſtrography*, which treats of the fixed *Stars.*

* The Word *Phænomenon* being of moſt frequent Uſe, it is proper the Reader ſhould be acquainted, that it is derived from the Greek Verb φαίνω, to appear; whence *Phænomenon* ſignifies an *Appearance*, and plurally, *Phænomena*, the *Appearances* of Things.

A. How

A. How is the third Part ſubdivided?

B. *Aerology* I divide as follows, *viz.* into,

1. *Aerography*, which treats of the *Atmoſphere*, or Body of *Air*.

2. *Anemography*, which treats of the *Winds*.

3. *Meteorography*, which treats of the *Meteors*.

4. *Phantaſmatography*, which treats of the *celeſtial Appearances*, or ſuch *Phænomena*, as exiſt only in Viſion, and not corporally.

A. How do you ſubdivide the laſt general Part?

B. *Geology* is moſt naturally divided into the following ſubordinate Branches, *viz.*

1. *Geography*, which treats of the *Earth*, or *Land*.

2. *Hydrography*, which treats of *Water*.

3. *Phytography*, which treats of *Plants* and *Vegetables*.

4. *Zoography*, which treats of *Animals* of all Kinds.

And thus you have a conciſe View of the ſeveral Parts or Subjects of our enſuing *Colloquies*.

A. *Sir*, nothing will ſo much delight me, as Reflections on ſuch Topics as theſe; I always love to hear People talk of the Wonders of Nature, and being now directly engaged in a Converſation of that Kind, my Deſires are excited almoſt beyond Expreſſion.

B. I'll

B. I'll do my Endeavour to ſatisfy you if poſſible, and am very glad to find you hunger and thirſt after uſeful Knowledge; while others vainly ſpend their precious and irrevocable Time in idle and profane Amuſements, you have the Happineſs of ſuperior Senſe to dictate to you the more noble, manlike, and virtuous Methods of improving your Time; which will yield you not only Abundance of Delight, and rational Pleaſure, but at the ſame Time make you wiſe and happy: To this End, I ſhall communicate to you whatever I have found in the Writings of the great *Sages* and *Virtuoſo's* of the laſt and preſent improving and inquiſitive Age, and will endeavour to make all Things plain and eaſy, as I go along, by familiar Inſtances, and plain demonſtrative Figures and Schemes.

C H A P. III.

Of AXIOMS *relating to* PHYSICS; *of the* RULES *of* PHILOSOPHIZING.

A. ARE there not ſome fundamental *Principles,* or *Axioms,* on which this Science depends?

B. Yes, moſt certainly; the chiefeſt of which I ſhall here lay down.

A. What do you make the firſt *Axiom?*

B. *Axiom* I. *Nothing hath no Properties.*

A. Pleaſe

A. Pleaſe to exemplify this *Axiom.*

B. I will: But firſt underſtand, that by *Nothing*, is meant a ſtate of *Non-Exiſtence*, or *Not-Being*; and therefore to ſay nothing is hot, is cold, hath Parts, is great or ſmall, *&c.* would be abſurd.

A. What is the ſecond *Axiom?*

B. *Axiom* II. *Somewhat doth exiſt.*

A. That is ſomewhat merry, *Sir*; I believe No-body will deny that to be an *Axiom*, indeed.

B. You may think of it as you pleaſe, but I aſſure you I have met with thoſe who have had recourſe to *Logic*, to prove their own Exiſtence*.

A. Pray, let me know your third *Axiom.*

B. *Axiom* III. *There is no Medium between Something and Nothing, Exiſtence and Non-Exiſtence.*

A. This is moſt certainly true, and to ſuppoſe the contrary were abſurd; pray, let me know your fourth *Axiom.*

B. *Axiom* IV. *That which doth exiſt, and is dependent on any other created Being for its Exiſtence, is properly the Eſſence or Subſtance of the Thing exiſting.* The Truth of this, though extremely evident to thoſe who have been uſed to a philoſophical Way of Thinking,

* Witneſs the trite *Enthymem* of the Schools, *Ego cogito, ergo ſum*, i. e. I think, therefore, I am, or do exiſt. The *Sceptics*, it is well known, were abſurd enough to deny the Certainty of any Thing, and, conſequently, of their own Exiſtence.

will,

will, perhaps, appear more clear to you farther on.

A. Let me hear your next *Axiom.*

B. *Axiom* V. *No Subſtance, or Eſſence, can be produced out of Nothing; or it is impoſſible Nothing ſhould be made Something* *.

P. This indeed is very true; for if Nothing could be made Something, it would then have ſome Property, which is contrary to your firſt *Axiom*; and conſequently abſurd. I pray, your ſixth *Axiom.*

B. *Axiom* VI. *No Matter, Subſtance, or Eſſence of any Thing, is capable of being reduced to mere Nothing, or annihilated.*

A. True likewiſe; for if Something could be converted into Nothing, then would Nothing have a Property, contrary to *Axiom* I. Alſo, as it is impoſſible for a Thing to be, and not to be, in the ſame Moment; therefore, between the Time of its Being and Not-being, there muſt be ſome intermediate State of Exiſtence, contrary to *Axiom* III. Pleaſe to relate your next *Axiom.*

B. *Axiom* VII. *Every Effect hath ſome Cauſe, pre-exiſtent to itſelf.*

A. That I, and every Body elſe, muſt believe, or be abſurd †. Pray deliver your next *Axiom.*

B. *Axiom*

* This is the famous Axiom of the Philoſophers, *Ex nihilo nihil gignitur*; and is ſo evident a Truth (as well as the following Axiom) that I wonder how any Perſon can think it unfit to be believed, or inſerted here, which is a proper Place for it; ſince I cannot ſee that it contains any Thing *unreaſonable* or *irreligious*, if it be granted that God cannot perform Impoſſibilities.

† For to ſay, that any one Thing is the Cauſe of itſelf, is to ſay

B. Axiom VIII. *If we ourſelves are not the Cauſe of any Effect, then that Effect muſt depend on, and reſult from, ſome other Cauſe.*

A. This is a plain Conſequence of the foregoing; your next *Axiom*, if you pleaſe.

B. Axiom IX. *All Things, as far as in them is, continue in the ſame State in which they began their Being.*

A. I believe I take you right; you mean what was at firſt made *Straight, Crooked, Square, Round,* &c. would of themſelves always perſevere in that State, and of their own Accord would never aſſume any other Figure.

B. Very good; that is the full Meaning of the *Axiom.*

A. Pray let me hear your next.

B. Axiom X. *Every Change is produced from ſome external Cauſe.*

A. Moſt certainly; for ſuppoſe I ſee a Flower in full Bloom lie withered on the Ground, I preſently conclude ſome external Cauſe hath made that Change in the Flower; which elſe would have continued vivid and freſh.

B. That is the Caſe. I have one *Axiom* more to propoſe, and that is,

Axiom XI. *That every Change made in any Body, is always proportionable to the Powers of the Cauſe producing it. Thus the Motion of a Body is always in Proportion to the Greatneſs*

ſay that it *exiſted before it did exiſt*, which is abſurd; or elſe that its Exiſtence was *neceſſary*, which can only be ſaid of the Deity.

of

of the Power, or Stroke, that put it firſt into Motion.

A. And are there no other Maxims of this Science, that are neceſſary to be diſcourſed of before we go farther?

B. Thoſe already related are ſufficient for this Place; but as this Science depends on certain Principles, ſo it is likewiſe to be conducted by certain ſtated *Rules.*

A. I doubt not but this Part of Knowledge, which (according to the Notion I have of it) is very abſtruſe and difficult in many Parts, muſt require proper *Rules* and *Precepts* for a due Improvement, as well as moſt other Arts. Pray, *Sir*, then, what and how many are the *Rules* of *Philoſophizing?*

B. They are in Number few, and are as follow, *viz.*

Rule I. We muſt take Care to admit no more Cauſes of natural Things than what are true, and ſufficient to explain their *Phænomena.*

Rule II. We muſt obſerve always to aſſign the ſame Cauſes for the ſame natural Effects.

Rule III. Thoſe Qualities which cannot be increaſed or diminiſhed, and agree to all Bodies in which Experiments can be made, muſt be adjudged the Properties of all Bodies in general.

Rule IV. Propoſitions and Concluſions, deduced from actual Experiments, muſt be eſteemed true and accurate, notwithſtanding

any

any *Hypotheses*, or received *Suppositions*, to the contrary; and must be insisted on, till some other *Phænomena* either render them more accurate, or liable to Exception.

A. What is the Reason of the first *Rule*?

B. It is founded on this Principle: Nature doth nothing in vain; but it is in vain to do that by many Means, which may be done by fewer: Now Nature is simple, and never luxuriates in superfluous Causes of Things. Therefore, *&c.*

A. That is exceeding good, indeed. Pray illustrate the second *Rule*.

B. By the second *Rule*, we are to assign the same Causes of Respiration in Beasts, as in Men; of Heat in Water, as in Fire; of Light in Fire, as in the Sun; and of the Reflection of Light in the Planets, as in the Earth, *&c.*

A. Pray give the Reasons of the third *Rule*.

B. The Qualities and Properties are not known to us but by Experiments; and therefore whatever we find to answer by all Experiments we can try, must be allowed an universal Property of all Bodies; on those on whom we cannot, as well as of those on whom we can, make Experiments: Nature being always consentaneous and analogous to itself.

A. Indeed the Reason of the last *Rule* is so obvious, that, I think, none can doubt it; no Person being so perverse and preposterous, as to affirm there is more Reason in a bare *Hypothefis*, than in *Facts* of *Experiments* *.

B. Yet, it is ftrange, you'll fay, that, by this very *Rule*, the Syftem of the *Cartefian Philofophy* muft fall; that *Burnet*'s Theory of the *World* and *Deluge* muft be valued at no greater Eftimation, than an ingenious *Romance:* And thus muft Mr. *Whifton*'s, and all other *World-mongers* Syftems and Theories, diffolve into a philofophical Nothing, which want actual and repeated Experiments to fupport them †.

* Thefe Rules, with the Reafons of them, are taken from Sir *Ifaac Newton's Principia.*

† —— *Monfieur des Cartes*, the great Mafter and Deliverer of the Philofophers from the Tyranny of *Ariftotle*, is to be blamed for all this, for he has encouraged fo very much the prefumptuous Pride of Philofophers, that they think they underftand all the Works of Nature, and are able to give a good Account of them; whereas neither He, nor any of his Followers, have given us a right Explication of any one Thing.—His great Fault was, that he made no Ufe at all of Geometry in Philofophy. *Keill*'s Introduction to his Examination of Dr. *Burnet's Theory of the Earth*, Page 11, 12, 15.

Concerning Dr. *Burnet's Theory*, the fame learned Gentleman obferves, that——His rhetorical Expreffions may eafily captivate an incautious Reader, and make him fwallow down for Truth, what I am apt to think the Author——defigned only for a philofophical Romance.——My Defign therefore is to chufe out fome of the principal Heads of the Theory, and having fhewn them to be *falfe* and *difagreeable to the Laws of Mechanifm*, the reft muft all fall to the Ground of courfe. *Ibid.* Page 26, 27.

As for Mr. *Whifton's Theory*, he fays——I believe it will be evident, by the following Confiderations, that a Comet could never have produced thofe various Effects which Mr. *Whifton* has attributed to it; and it will alfo farther appear that the Deluge was the immediate Work of the Divine Power, and that no fecondary Caufes, without the Interpofition of Omnipotence, could have brought fuch an Effect to pafs. *Remarks on Mr. Whifton's Theory of the Earth.*

CHAP.

CHAP. IV.

Of Hypothesis, of Experiments, of various Instruments for that Purpose, and their Uses.

A. ARE any Kinds of *Hypothesis* to be admitted in reasoning about natural Subjects?

B. The Philosophers of the present Age hold them in vile Esteem, and will hardly admit the Name in their Writings; they think that which depends on bare Hypothesis and Conjecture, unworthy the Name of Philosophy; and therefore have framed new and more effectual Methods for philosophical Enquiries.

A. And must therefore a Philosopher in no wise have Recourse to Suppositions? May he not be admitted to say, he supposeth a Thing may be so or so? Or must he immediately assign an experimented Cause, or else directly confess his Ignorance? What are your Thoughts in this Matter?

B. Why I must confess, to discard all Hypothesis from *Physics,* is to reduce it within very narrow Limits; and in Truth, I think, it is falling from one Extreme to another; I am persuaded that Hypothesis duly qualified, i not absolutely necessary, yet may be very ſubſervient to natural Philoſophy; and I know not what Kind of Philoſophers we ſhall have in ſucceeding Ages, if they will receive no ſyſtem of Philoſophy, but what is wholly founded on mathematical Experiments and Demonſtrations *.

A. What Kind of Hypotheſis, and how qualified, do you allow may be uſed in *Philoſophy?*

B. They muſt have moſt or all of the following Qualifications.

1. They muſt be agreeable to juſt Reaſoning.

2. They muſt be neceſſary for Want of Experience.

3. They muſt be conſentaneous to Experience.

4. They muſt be ſufficient to ſatisfy the *Phænomena.*

5. They muſt be naturally adapted to the Caſe.

6. They muſt be poſſible on every Account.

7. They muſt be probable in their own Nature.

8. They muſt be free from all Suſpicion of Prejudice, Affection, or Prepoſſeſſion, in their Author.

* When the Reaſon or Cauſe of Things does not appear, it is much more ingenuous to acknowledge our Ignorance, than to advance abſurd and extravagant Hypotheſis, or, which is much worſe, to have Recourſe to *occult* (or *hidden*) *Cauſes and Qualities,* the infamous Refuge of a vain and ignorant Race of Philoſophers.

A. I believe, *Sir*, few will deny you the Use of Hypothesis thus circumstanced and qualified: But pray, what Kinds of Demonstrations are those by Experiments, which you intimate they rely so much upon?

B. The very best all Nature can produce; they far exceed the keenest Glance of the Eye of Reason, and nothing but Divine Revelation can inform us more truly of the intimate Nature of Things.

A. Very wonderful indeed! Happy the Age in which this Art received Improvements from such extraordinary Inventions. Pray, who were the first Authors of improving *Philosophy* by Experiments?

B. Their Names are recorded in the Book of Fame; have you not seen therein the glaring Characters of *Bacon, Boyle,* Sir *Isaac Newton, Woodward,* Dr. *Halley, Ray, Derham,* and several other exalted *Philosophers?* Some of whom are now living; and others subsist in marble Monuments to gratify the Curiosity of, and be admired by, all Posterity.

A. Yes, I have heard of those great Names you mention; but not being very conversant in the learned World, know but little about them; yet take an excessive Pleasure in hearing Relations of them, and the wonderful Things they have discovered.

B. I am glad to find in you such a Disposition, and question not but you will be highly gratified with the Series and Sequel of our Discourse.

A. I believe I ſhall; but to the Point: In what Manner, I pray you, are thoſe Experiments performed? for, as you have ſeen the Manner thereof, you can well inform me.

B. They who have reduced experimental Philoſophy to Method, and make it their Buſineſs to teach it others, prepare a large *Apparatus* of Inſtruments of all Kinds, to the Value of five or ſix hundred Pounds; and at ſtated Times, in a very large Room, there is an Operator appointed to perform a Courſe of Experiments therewith, in all the various Parts of natural Philoſophy, in the open View of all who are preſent to ſee and learn the Manner thereof.

A. Cannot you give me ſome particular Account of thoſe Inſtruments, and the Manner of uſing them?

B. It is the Subject of a large Volume to deſcribe them with their Uſes in particular: However, of ſuch as are moſt common, to be had in the eaſieſt Manner, and which you yourſelf may underſtand, and uſe if you pleaſe, you may take the following Account.

The *Teleſcope* is an optic Inſtrument, wherewith to view diſtant Objects, which it greatly enlargeth, and makes them ſeem near us; by which Means the Aſtronomers and Philoſophers have made wonderful Diſcoveries in the Sun, Moon, and Planets*.

The

* The Word *Teleſcope* is derived from τελέω, to perfect, and σκοπέω, to view; as being an Inſtrument that *perfects our View* or

The *Microscope* is contrived to augment and render visible very minute and small Objects, which otherwise escape the Sight *.

The *Helioscope* is a Sort of *Telescope*, fitted so, as to look on the Body of the Sun without Offence to the Eyes †.

The *Barometer*, or *Baroscope*, is contrived to estimate the small Variations of the Weight or Pressure of the Air ‡.

The

or Sight of distant Objects, to the greatest Degree possible. *Telescopes* are of two Sorts; *Dioptrical*, which perform all by *Refraction*; and *Cata-dioptrical*, which perform by *Reflection* and *Refraction* jointly. Since the Surfaces of Bodies are increased in Proportion to the Squares of the Diameters or like Sides, the Light falling on them will be diminished in that Proportion; and consequently the more an Object is magnified, the more obscure also it appears: Thus if one Glass magnifies the Breadth or Length of an Object ten times more than another, it will appear indeed an 100 times bigger, but withal an 100 times less bright than in the other. Therefore the more a *Telescope* exceeds the Length of five or six Feet, the worse it is for viewing *Terrestrial* Bodies; but for *Celestial* ones, the greatest Magnifier is the best, because their Light cannot be lessened to any Disadvantage, it being so very great.

* *Microscope* is compounded of μικρὸς, small, and σκοπεῖν, to view; because by it small Objects are apparently magnified to the Sight. In this, also, the larger the Object is made to appear, the more obscure it will be; and therefore in large Magnifiers, it is necessary to illumine the Object very strongly with the Light of the Sun or Candle, by means of a *Lens*, or reflecting Mirrour.

† *Helioscope*, from ἥλιος, the Sun, and σκοπέω, to view; it is best made by smoking a Piece of Glass with a Candle, and putting it before the Eye-Glass of a Telescope next the Eye; for then the Sun may be viewed in his Meridian Splendour without the least Offence.

‡ *Barometer* is so called of βάρος, Weight, and μετρέω, to measure; because it *measures* the *Heaviness or Weight* of the Atmosphere. The common Barometer (called the *Torricellian Tube*, from its Inventor *Torricellius* an *Italian*) is a Glass Tube of

The *Anemoscope* is an Instrument invented to foreshew the Change of the Air or Wind *.

The *Æolipyle* is contrived to shew the Nature and Force of pent-up Air, rarefied and breaking forth, resembling a Tempest †, *&c.*

about three Feet in Length, and $\frac{1}{10}$ or $\frac{2}{10}$ of an Inch Bore, hermetically sealed at one End, and at the other it is filled quite full of Quicksilver; and thus immersed in a small Vessel of Quicksilver, that in the Tube will sink down, or run out into the Vessel till it remains in the Tube between 28 and 31 Inches perpendicular Height; and this Column of Mercury in the Tube is equal in Weight to a Column of Air of the same Base, and of the Height of the Atmosphere, and consequently is suspended by it; which therefore, by its rising higher or falling lower, shews the proportionally greater or lesser Weight or Pressure of the Atmosphere. Now since the Difference of the least and greatest perpendicular Height is in this Tube but about three Inches, therefore divers Contrivances have been made to render this Motion of greater Length in some other Direction, that thereby the Variation of the Air's Weight might be rendered more sensible, or more exactly measured: Hence arose divers Kinds of this Instrument, as the *Diagonal*, the *Wheel*, the *Machine*, &c. in *Barometers*; for a large Account of which, see *Harris's Lexicon*, or *Rowning*'s Dissertation on the Barometer.

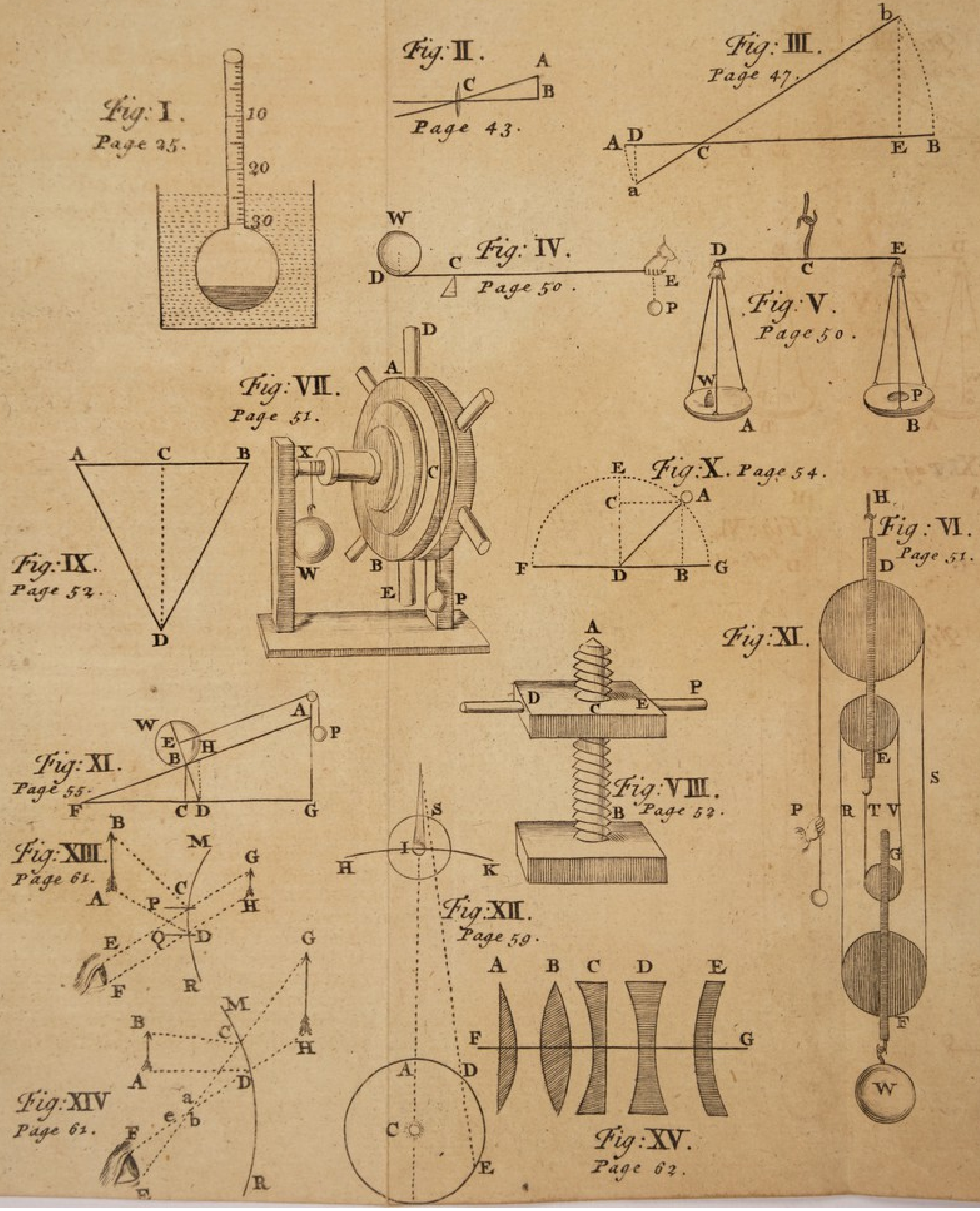
* *Anemoscope*, from ἄνεμος, the Wind, and σκοπέω, to view; because by it we see what Point or Part of the Horizon the Wind is upon at any Time. A very good *Anemoscope* may be made on the Top of the House (affected directly by the Wind on all Sides) by means of an Iron Rod standing a considerable Height in the Air, with a Vane fixed on the Top to render it versatile; the lower End of which descending, the Covering shall have a large Index or Hand, turning upon the Cieling of the Room, in the Center of the *Compass* duly described thereon; for then the *Index* will always shew the Point to and from which the Wind blows.

† *Æolipyle* (from Αἰόλȣ πύλαι, the Gates of *Æolus*, the God of the Winds) is a small hollow Globe of Brass, *&c.* with a small Neck and Hole, which being heated red hot, and thrown into a Vessel of Water, the Water will rush into the Cavity almost void of Air, and fill it; the Ball then set on the Fire again, the Water will be forced out, in vaporous Streams, with great Noise and Violence, and by Fits, by the Rarefaction and Spring of the internal heated Air.

The

To front Page 45.

Plate I.



The *Areometer* is an Instrument to measure the specific Gravity of Liquids *.

The *Hygroscope* is an Instrument to shew the Moisture and Dryness of the Air †.

The *Thermometer* measureth the Degrees of Heat and Cold in the Air ‡.

The

* *Areometer*, I suppose, is from ἀραιὸς, rare, and μετρέω to measure; tho' it measures not the *Rarity*, but *Gravity* of Liquids. The common *Areometer*, or Water-Poise, is made of thin Glass, of the Form represented in *Plate I. Fig.* 1. fronting *p.* 25, which being hollow, receives so much Mercury as will keep it swimming in an erect Position; then the Stem being nicely graduated, the Surface of the Liquids, into which it is immersed, will cut off more or fewer Degrees; that is, the Ball will sink more or less, as the Liquids are severally of a lesser or greater Gravity. A new *Areometer* is described in Philos. Trans. N° 262, which see.

† *Hygroscope* (derived of ὑγρὸς moist, and σκοπέω to view) is an useful Instrument to be made several Ways. The easiest and best of all is that made with a String of Whipcord fastened to a Hook in the Cieling, and at the lower End of which is fixed a Weight of about half a Pound, with an Index at the Bottom thereof a Foot long; and under it a Table, &c. with a large Circle divided into an 100 equal Parts or Degrees, so fitted that the Centre of the Index hangs just over the Centre of the Circle. For this, after the String has been duly stretched, nicely shews, by its Twisting and Contraction, the *Moisture*, and by untwisting and lengthening, the *Dryness* of the Air, in the Motion of the Index this Way and that over the small Divisions of the Circle. See several other Kinds in *Harris's Lex. Tech.* under the Word *Hygroscope*.

‡ *Thermometer* comes from θέρμη, Warmth, and μετρέω, to measure; the common Sort is the best, which is generally added to the *Barometer*. It consists of a Glass Tube filled with Spirit of Wine of a red Tincture; in making it, the Tube is heated very much in the Flame of a Candle, which causes a *Vacuum* in some Degree therein; then immediately the open End is dipt into the said Spirit in a Vessel, which, by the Pressure of the Air, is made to ascend therein, till the Ball and Tube-part be filled to a necessary Height. Then having a Piece of Paper, &c. graduated from a certain Point on each Side, to 100 Degrees, put the Ball into Water just beginning to freeze, and place the Surface of the Spirit in the Tube at that Time against the

The *Hydrostatic* Balance is an exceeding exact fine Pair of Scales for making Experiments, relating to the Gravity of Fluids *.

Dioptric Instruments of various Sorts explain the Nature of refracted Rays of Light through various Mediums †.

Catoptric Instruments are also manifold, which shew the Nature of reflected Rays of Light ‡.

The *Pneumatic* Engine, called the *Air-Pump*, is the most universal of all others; it is the very Basis of the Philosophy of the Air, and hath opened a greater Door to the Secrets of Nature, than any Thing that was ever invented besides ||.

The

the (o) in a graduated Line, and the Thermometer is adjusted for Use. This is an Instrument of admirable Use in the Hands of a skilful Person, in discovering the Degrees of Heat and Cold in Air, Animal and Vegetable Bodies, Liquids, Hot-beds, *&c.* See a farther Account hereof in Dr. *Hook's Micrograph.* Page 38, *&c.*

* *Hydrostatic* is from ὕδωρ, Water, and στατική, the Art of Weighing. The Instrument I make use of for finding the specific Gravity of Solids and Fluids is different from, and much better than, the common Hydrostatic Balance, as I shall shew when I am arrived at that Part of Philosophy.

† *Dioptric* (of διόπτομαι, to see thro' any Thing) is a Term applied to all Optic Instruments which consist of Lenses, one or more; as *Telescopes*, *Microscopes*, *Magic Lanthorns*, and *Camera Obscura*, &c. because by them we *see Objects thro' the Medium of* Glass, *i. e.* by Rays refracted through the Lenses.

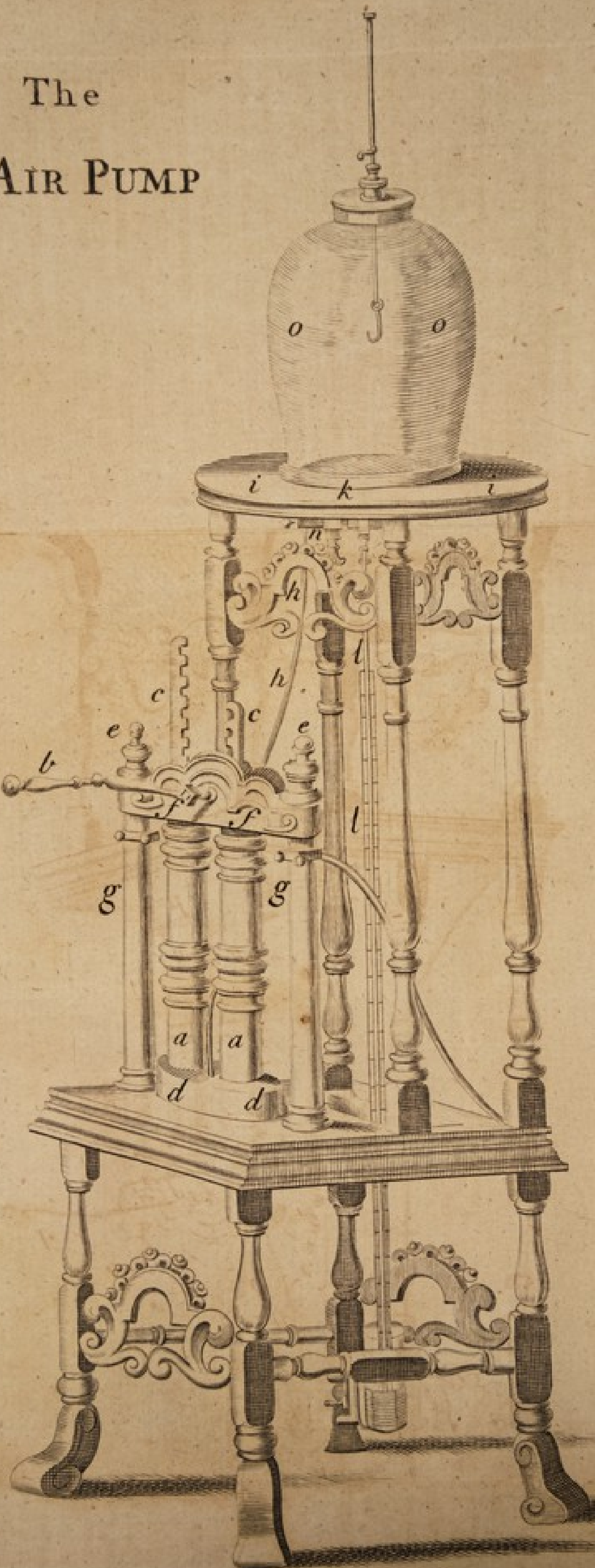
‡ *Catoptric* (κάτοπτρον, a Mirrour) is a Term applied to all Kinds of Glass, *&c.* Mirrours, whether *plane*, *convex*, *concave*, *circular*, *cylindrical*, &c. because by them we see Objects by Rays of Light *reflected* from their Surface, which is called *Reflex Vision.*

|| *Pneumatic* is from πνεῦμα, Spirit, Air, Wind; because the *Air-Pump* exhausts the *Air* out of Bodies, placed in a proper Vessel, called a Receiver.

A De-

The

AIR PUMP



E. Bowen Sculp.

The *Orrery*, which ſhews the Movements of all the Heavenly Bodies in the Solar Syſtem about the Sun (by a noble Piece of Mechaniſm) all the Phænomena whereof are nicely correſponding to the Truth *.

A Deſcription of this moſt ſuprizing and uſeful Engine, according to Mr. *Hawkſbee*'s Improvements thereof, take as follows.

The whole Structure of the *Air-Pump*, in which *a*, *a* are two ſtrong hollow Barrels, or Tubes of Braſs, in which two *Emboli*, or Suckers, are moved up and down by their Racks *c*, *c*, in whoſe Notches a Cog-wheel falls, which moves upon the Axis *f*, when the Winch *b* is turned; *g*, *g* are two Pillars of Wood fixed on the Frame at Bottom, and having Screws at Top on which the Nuts *e*, *e* do run, and preſs down the Piece *f*, *f* upon the Tops of the Barrels, to fix them at *Top* and *Bottom*; *h*, *h* is a Swan necked hollow Braſs-Pipe, which communicates with an hollow Braſs Piece *n* above, and another in the Box *d*, *d* below; the Piece *n* alſo opens into the Cavity of the Receiver *o*, *o*, by a ſmall Hole in the Top Plate *i*, *i*, on which it is placed: Alſo the Pipe in the Box *d*, *d* communicates at each End by a ſmall Tube with the Barrels *g*, *g*; and thus there is a Communication between the Barrels and the Receiver *o*, *o*, by which Means, the Air in the latter is exhauſted by the Suckers of the former. Moreover, *l*, *l* is a Gage, being a Barometer with its Baſon of Mercury in, and its boxen Index graduated into Inches and (above 28) the Tenths of an Inch; this Index is ſet on a Piece of Cork which floats on the Surface of the Mercury, that it may riſe and fall with it, and ſo exactly meaſure the Height of the Mercury in the Tube above the Surface of that in the Baſon. For this Barometer is open at Top, and communicates with the Receiver, ſo that the greater or leſſer Quantity of Air therein is ſhewn by the leſſer or greater Height of Mercury in the Tube. In the Pipe *n* is a Stop-cock, that alſo communicates with the Receiver, and either excludes or re-admits the Air, as Occaſion requires. On the Braſs Plates *k*, at the Top of the Frame, are placed wet Leathers to ſet the Receiver upon, which effectually exclude all the external Air, while the internal is exhauſting by the Operator. And this is the Conſtruction of the *Air-Pump* in common Uſe. All which is exemplified by the Copper-Plate II. repreſenting an *Air-Pump*, and fronting this Page.

* See the Figure of the Orrery publiſhed by Mr. *Thomas Heath*.

A. Sure

A. Sure, wonderfully curious and delightful muſt it then be, to ſee all thoſe extraordinary Things performed by ſuch nice Inſtruments! Alas! how great is the Ignorance of the Generality of Mankind! what wretched, unworthy, and uncouth Notions have we conceived of the World and Things therein! We think ourſelves learned, if we know how to find out a Word in *Bailey*'s Dictionary, little dreaming ſo much Pains, Expence, and Time, neceſſary to acquire but a partial Knowledge, and to be eſteemed but moderately learned!

B. Well, but don't be diſcouraged; the Knowledge of theſe Things will be much eaſier and cheaper to us, than they were to our Forefathers; what coſt them Pounds, we may have for ſo many Pence; what coſt them Years of Study, Fatigue, and Diſquietude, we may acquire with Eaſe and Pleaſure in a few Days or Months; what they rejoiced to come at by Piece-meals, and in an imperfect Manner, we have preſented, as in one entire methodical View. Wherefore, if we are ignorant, it is becauſe we are idle and indolent indeed: If we live ſatisfied only with the vulgar erroneous Notions of fallacious Senſe, and endeavour not to rectify them by the Precepts of refined and learned Reaſon, and the Methods put into our Power; in vain then hath God given us Ability to be *wiſer than the Fowls of Heaven, and to have more Underſtanding than the Beaſts which periſh.*

THE

THE

Philosophical Grammar:

Or, VIEW of

Modern Philosophy.

PART I.

SOMATOLOGY:

OR,

DOCTRINE of the Universal Properties of MATTER; and the specific Qualities of natural BODIES; with Sir *ISAAC NEWTON*'s Laws of Nature.

CHAP. I.

SOMATOLOGY, *treating of the common Nature and Properties of all natural Bodies.*

A. WHAT do you call *Somatology?*

B. That Part of *Physiology* which treateth of Matter or Substance in general, with the Nature and inseparable Properties of all Bodies consisting thereof.

A. What is implied in the Original of the Word *Somatology?*

B. The very same Thing; for it is composed of the two *Greek* Words, σώματα, *Bodies*, and λόγος, *a Discourse*; i. e. *a Discourse of natural Bodies.*

A. What do you mean by *Matter?*

B. The *Substance*, or *Essence*, of which all Things in the Universe consist.

A. Is there any Difference between what you call *Matter* and *Body?*

B. No; excepting only, that the latter is used often in the *Plural*, for the several small Parts and Divisions of the common Substance of the Universe; *i. e.* they are called *Bodies.*

A. Is the *intimate* Nature of Matter to be known?

B. No; this is concealed from human Knowledge; all we can difcover of natural Bodies, are fome few Properties and Affections thereof, which are more obvious to our Senfes.

A. Is the Matter of all Bodies the fame?

B. Yes; what the Philofophers call the primary conftituent *Particles, Atoms,* or *Corpufcles* of Matter, which conftitute Bodies of infinite Kinds, are yet the fame, or of the fame Nature, among themfelves, in all thofe Bodies *.

A. And is not this the fame Thing as to fay, that *Fire* and *Water,* a *Flint* and *Down, Gold* and *Dung,* &c. are the fame Things with refpect to the Matter of which they confift?

B. Yes, they are fo; and what thence do you infer?

A. What then? why then, I believe, you will have few Difciples amongft the common People; and feveral will think they give it a

* Dr. *Woodward* afferts Matter to be originally and really very different; being at its firft Creation divided into feveral *Ranks, Sets,* or *Kinds* of *Corpufcles*; that thofe of the *fame Kind* are every where alike and uniform; but thofe of *different Kinds,* differ not only in *Subftance,* but in all the Qualities obfervable in Bodies compounded of them. And that from hence arife the Differences in Colour, Tafte, Smell, Hardnefs, Gravity, &c. in all Bodies. See his Effay towards a natural Hiftory of the Earth. Part v. p. 229, 230. This is the Doctrine alfo of the *Cartefians,* tho' abundantly confuted by the *Newtonians.* See *Newt.* Princip. p. 388. Optics, p. 313. *Muffchenbroek*'s Elem. Phyf. Matth. § 61, 83, 383. *Cheyne*'s Phil. Princip. p. 59. *Boyle* on the Principles of natural Bodies. *Ray* on the Creat. p. 68, 85. *Keill*'s Introd. ad ver. Phyf. Sect. viii.

better

better Term than it deſerves, if they call ſuch Aſſertions *philoſophical Romancing.*

B. It is very probable, that it may be ſo; but the real Nature and unchangeable Truth of Things are ſtill to be inſiſted on, though they are unknown to, and gain no Credit with, the Vulgar.

A. Is Matter *finite*, or *infinite*?

B. Finite; and limited within certain Spaces and Bounds, in the various Parts of the Univerſe *.

A. How is Matter, or Body, commonly conſidered?

B. As having three Dimenſions, *viz. Length, Breadth,* and *Thickneſs.*

A. Is this Conſideration of Matter the moſt philoſophical?

B. No; it is too vulgar and defective.

A. What is a more accurate Method to acquire the beſt Knowledge and Ideas of Matter, or Bodies, that we are capable of?

B. By conſidering thoſe Properties and Affections thereof, which are obvious to us, and beſt known by us.

A. How are the Properties of Bodies diſtinguiſhed?

B. Into thoſe which are common to all alike, and thoſe which are peculiar to each in

* The *Carteſians* abſurdly place the Eſſence of Matter in *Extenſion*, and conſequently make it *infinite*, as being then the ſame as Space itſelf. But the *Newtonians* placing it in *ſolid impenetrable Corpuſcles*, or *Atoms*, make it *finite*. See *Newt.* Princip. p. 316. *Cotes*'s Pref. thereto. *Muſſchenbroek*, Part i. Chap. iv. *Keill*'s Introd. Lect. ii. *Clarke*'s Notes on *Rohault*, p. 22.

particular: The firſt are called Common and Eſſential, the latter Specific and Accidental.

A. Which are the Properties of the firſt Sort?

B. They are generally reckoned thoſe which follow:

I. *Extenſion*, for all Bodies are extended.

II. *Diviſibility*, for all Bodies may be divided.

III. *Solidity*, for the Particles of all Bodies are hard.

IV. *Figurability*, for all Bodies have ſome Form or Figure.

V. *Mobility*, for all Bodies are capable of being moved.

A. Is this Enumeration of the common Properties of Bodies every Way juſt, and equal in all Things?

B. No, I do not think it is; for, firſt, they may all be aſſerted of the whole Body, except *Solidity*, which agrees only to the Particles of Bodies: Again, other Properties may as univerſally be aſſerted of Bodies as ſome of theſe, as *Durability*; for a Body is no leſs infinitely durable, from its Nature, than it is infinitely diviſible.

A. Which are thoſe other Properties of Bodies, which you call *Specific* or *Accidental*?

B. They are generally reckoned the following:

I. *Light.*

I. *Light.*
II. *Colours.*
III. *Sound.*
IV. *Gravity* and *Levity.*
V. *Attraction* and *Electricity.*
VI. *Transparency* and *Opacity.*
VII. *Density* and *Rarity.*
VIII. *Hardness* and *Softness.*
IX. *Rigidity* and *Flexibility.*
X. *Consistence* and *Fluidity.*
XI. *Heat* and *Cold.*
XII. *Humidity* and *Siccity.*
XIII. *Elasticity.*
XIV. *Odours* and *Sapours.*

A. What do you call the *Elements* of natural Bodies?

B. Those pure and simple Substances, of which all gross and mixed Bodies are said to consist; and into which they may ultimately be resolved, or reduced.

A. How many are those Elements?

B. The Ancients counted seven, *viz. Fire, Air, Water, Earth, Salt, Sulphur,* and *Mercury.*

A. How many do the Moderns reckon?

B. Some of the modern chymical Philosophers reckon five, *viz. Mercury, Phlegm, Sulphur, Salt,* and *Earth.* Others reduce them to three, *viz. Mercury, Sulphur,* and *Salt.* Whereas, in Reality, there are no other Elements of natural Bodies than the primogenial Particles of Matter, or Substance, of which they conſiſt univerſally, and endued with the Properties above mentioned *.

CHAP. II.

Of EXTENSION, *and the* MAGNITUDE *and* DIMENSIONS *of natural* BODIES.

A. I Remember you ſaid, the firſt of the univerſal and eſſential Properties of Matter, or Body, was *Extenſion*; pray explain what is meant thereby.

B. Extenſion of *Matter*, is the Quantity of Bulk, or Size, into which the primogenial Particles of Matter are diſtributed, or extended, in any natural Body.

A. What ariſeth hence?

B. The Doctrine of Magnitude, and Dimenſion of Bodies.

A. What do you call the Magnitude of Bodies?

B. Their Size, or Bulk, or Quantity of Space, which they take up.

A. How do you compute, or eſtimate the Magnitude of Bodies?

B. By the Quantity of their Dimenſions.

A. What do you call the *Dimenſions* of Bodies?

* That there is but *one Element* of all Bodies, *viz. Subſtance*, or *Matter*, is largely ſhewn by the Authors quoted in Page 33.

B. Their *Extension* in *Length*, *Breadth*, and *Thickness*, or *Depth*; and these are the common Terms or Bounds, which limit the Substance of all Bodies.

A. Have all Bodies these three Dimensions?

B. Yes, they have; though one, or two, or all of them, escape our Senses; yet, they nevertheless exist together in all Bodies.

A. How do some then say that a Point hath no Dimensions?

B. They mean by this, a Point, or the smallest Part of Space, which, naturally speaking, is *Nothing*, and therefore hath no Properties.

A. How are Bodies differenced, with respect to their Dimensions?

B. They are by Mathematicians, on that Account, distributed into *Points*, *Lines*, *Superficies*, and *Solids*.

A. As how?

B. They call that a *Point*, when all the three Dimensions are so very small, as to be altogether imperceptible, as the Speck A: A *Line*, is that which appears to have no Breadth or Thickness, as BC: A *Superficies*, that which hath Length and Breadth, but no perceivable Thickness, as ABCD: *Lastly*, they call that a *Solid*, which hath evidently all the three Dimensions, as the Solid S; whose Length is AC, its Breadth AB, and its Thickness, or Depth, AE. See *Fig.* I, II, III, and IV. on *Plate* IV, fronting *p.* 70.

A. How many are the *Degrees* of *Magnitude*?

B. They are infinite; for no Body, however great or ſmall, can be given, but another may be conceived greater or ſmaller than it; as I ſhall demonſtrate to you when we diſcourſe of the *Diviſibility* of Matter.

A. How are Bodies, or Things, ſaid to be *great* or *ſmall?*

B. Greatneſs, or *Smallneſs*, are only relative Terms; and Things are great or ſmall only, as they are compared one with another: Thus a Mountain two or three Miles high, is a great one, and one not above two or three Perches high, is a ſmall one, when they are compared together.

A. Then, I ſuppoſe, you count it improper and unphiloſophical, to ſay any Thing is *abſolutely great* or *ſmall?*

B. Moſt certainly it is; becauſe the ſame Thing is either great or ſmall by Compariſon only: Thus a *Hog* is a ſmall Creature, compared with the largeſt *Elephant*; but it is a great Creature, when compared with a *Louſe* that crawls on his Back.

CHAP. III.

Of the DIVISIBILITY *of Matter, of the* INFINITY *thereof, and of the wonderful* DUCTILITY *and* DIVISIBILITY *of ſeveral* BODIES.

A. WHAT is the *Diviſibility* of Matter? *B.* It is that univerſal Property or Diſpoſition of a Body, whereby it is capable of being divided or reduced into Parts, either actually or mentally.

A. How far are Bodies capable of being divided?

B. A Body is diviſible in *infinitum*, or without End.

A. This is a wonderful Doctrine! What will you ſay, that a very ſmall Particle of Matter is capable of being divided into Parts ſtill leſſer and leſſer, through all the Ages of Eternity?

B. Yes; and as wonderful as it is, it is capable of no leſs than a plain mathematical Demonſtration.

A. Do you ſay ſo! I wiſh it may be ſuch as I can underſtand; pray let me ſee it, however.

B. I will, and I'll engage that you or any one may underſtand it; and it is thus. Let EF (*Fig.* V. on *Plate* IV, fronting *p.* 70.) be a right Line, I ſay, that Line may be divided into a Number of Parts, exceeding any finite Number; and it is thus demonſtrated. Through E and F, the two Extremities of the Line, let there be drawn the two parallel Lines AB, CD; and ſuppoſe they were infinitely extended to the right Hand, then it is evident, that in the Line CD, infinitely extended, there may be taken an infinite Number of Points, *a, b, c, d, e,* &c. Now if to each of thoſe Points there be drawn ſtraight Lines from the Point A (taken in AB, to the left of the given Line EF) each of thoſe Lines A*a*, A*b*, A*c*, &c. will cut off a ſmall Portion of the Line EF; but becauſe the Points *a, b, c,* &c, are infinite in Number, ſo likewiſe are the Lines A*a*, A*b*, A*c*, &c. and conſequently the Parts, or ſmall Portions, they will cut off of the Line EF, will be infinite in Number alſo; and thus it is manifeſt, that the Line EF, however ſmall, may yet be divided into an infinite Number of Parts.*

A. Indeed it is ſo plain, that I muſt confeſs and believe it: And what may we infer from this wonderful Property of Matter?

B. Firſt, That the leaſt Particle of Matter is capable of an infinite Diviſion, as well as the greateſt.

* For it is impoſſible that all the Parts of the Line EF, or the leaſt Particle thereof next E, ſhould be cut off, unleſs we can draw a Line from the Point A to the Line CD which ſhall at the ſame Time coincide with AB: But that this is impoſſible, every *Tyro* in Geometry can eaſily conceive and demonſtrate. See this Property in various Ways demonſtrated by Dr. *Keill*, in his third and fourth Lectures in his Introduction to Natural Philoſophy.

Secondly,

Secondly, That there is no ſuch thing as infinitely ſmall Particles of Matter.

Thirdly, That the original or primogenial Particles of Matter, into which it may be ultimately reduced, are altogether paſt human Comprehenſion.

Fourthly, Hence we learn what wonderous Effects a ſmall Piece of Matter may produce by its *Diviſibility* and *Ductility.*

A. What do you call the *Ductility* of Matter?

B. That Diſpoſition of it, whereby it is eaſily drawn out into Length, or Breadth.

A. What curious and extraordinary Inſtances have you of this Kind?

B. I think the following very remarkable, *viz.*

Mr. *Boyle* ſaith, a Piece of Silk, weighing two Grains and a half only, was drawn out into a Thread three hundred Yards long.

He ſaith alſo, that one Grain of Gold may be beat into a Leaf of fifty ſquare Inches.

If then an Inch in Length be divided into two hundred Parts, the Eye may diſtinguiſh them all; wherefore in one Grain of Gold are 2000000 of viſible Parts.

An Ounce of Silver may be gilt with eight Grains of Gold, which afterwards may be drawn out into a Wire of 1300 Feet long.

Dr. *Halley* has made it appear, that 124500 of thoſe very fine Skins of Gold, uſed in gilding Silver-wire, do not in Thickneſs exceed an Inch. Beſides ſeveral other Inſtances.

A. Theſe Things are very admirable indeed. What other remarkable Diſcoveries have iſſued from the Diviſibility of Matter?

B. The extraordinary Subtility of Matter, and the Tenuity or Fineneſs of its Parts, will appear by theſe Inſtances.

A. Mr. *Boyle* hath found, that one Grain of Copper will tinge 28534 Grains of Water; and therefore in a Drop of Water, whoſe Diameter is one hundredth of an Inch, there are contained 211400 viſible Parts of Copper, reckoning only an 100 to an Inch.

Again, Dr. *Keill* hath computed the Magnitude of a Particle of *Aſſa Fœtida*, to be $\frac{38}{1000000000000000000}$ Parts of a Cubic Inch.

He has likewiſe ſhewn, that one of thoſe Globules of Blood, which circulate in the Veins of ſome very ſmall Creatures, doth not exceed the $\frac{8}{100000000000000000000000000000000}$ Parts of a Cubic Inch.

Once more, he hath alſo demonſtrated, that one Grain of Sand will contain 12500000000000000000000000000 of the aforeſaid Blood Globules; that is, 10256 Times more than the higheſt Mountain upon Earth contains Grains of Sand.

Laſtly, He hath ſhewn the leaſt Particle of Matter ſhall be made to fill the greateſt Space (ſuppoſe the Orb of *Saturn*) ſo that there ſhall be no Pore therein, whoſe Diameter

ſhall

ſhall exceed the 100000000000000th, *&c.* Part of an Inch *.

* They who would ſee much more on the extreme Ductility and Subtility of Bodies, may conſult *Rohault*'s Phyſics, *Part* I. *Chap.* 9; Dr. *Clarke*'s Notes thereon; Mr. *Boyle* in his Book of *Effluvia*; Dr. *Halley* in the *Philoſ. Tranſ.* N° 194; and eſpecially Dr. *Keill*'s Fifth Lecture of his Introduction to Natural Philoſophy.

It may not be acceptable to the Reader to have ſome Idea of the ſurpriſing Smallneſs of Microſcopic Animalcules, from Calculation. Suppoſe ſuch an Animalcule be AB (See *Fig.* II. on *Plate* I, fronting *p.* 25.) which is made viſible by the Lens C at the Diſtance of BC, which ſuppoſe one Tenth of an Inch; then will the Angle ACB be equal to one Minute, for under ſuch an Angle an Object will but juſt appear or be viſible.

Then in the Right-angled Triangle ABC, there is known the Side BC $= \frac{1}{10}$ of an Inch, and the Angle C $= 0° \; 1'$, to find the Side AB, the Length of the Animalcule, which is thus found, by Trigonometry.

As Radius	——— ———	10.
To the Baſe	——— AC = 0. 1	9.000000
So is the Tangent of ACB	= 0° 1′	6.463726
To the Side	——— AB = 0.000029	5.463726

That is, ſuppoſe an Inch divided into a Million of equal Parts, this Animalcule AB will be no more than 29 of thoſe Parts in Length.

Suppoſe it were as wide as long, the whole Surface thereof would be 0.000000000084; that is, 84 of an Hundred Thouſand Million of equal Parts of an Inch Square.

Laſtly, Suppoſe it of a Cubic Figure, it will then be but 0.00000000000000024. *i. e.* $\frac{24}{100000000000000000}$ or 24 of a *Thouſand Millions of Millions* of equal Parts of a Cubic Inch.

If then the Animalcule itſelf be of ſuch an inconceivable and ſtupendous Smallneſs, how ſmall muſt the fineſt Particles of the Fluids be which flow through the fineſt Veſſels of its organized Body! This doubtleſs exceeds all Calculation, and the Force of Imagination itſelf.

CHAP.

CHAP. IV.

Of the SOLIDITY *and* FIGURABILITY *of* BODIES.

A. WHAT is that common Property of Matter, or Body, which you call *Solidity?*

B. *Solidity* is that Property, whereby a Body refifteth all others that prefs it on every Side, and whereby it hinders all other Bodies from entering into that Place which it poffeffeth, though they are forced againft it ever fo violently.

A. Then fuppofe I prefs a Body ever fo forcibly between my Hands, that Property which prevents my Hands from coming to a mutual Contact, you call *Solidity*, if I underftand you right?

B. Yes, I do fo; and this Property is the Ground or Caufe of all Refiftance in Bodies.

A. Is not this a new Term for this Property?

B. Yes, it hath been formerly called *Impenetrability*; becaufe two Bodies cannot penetrate each other, or be in the fame Place at once*.

* Some have compounded thefe two Terms, and called this Property of Matter *Impenetrable Solidity*; and which does certainly better exprefs it than either of the Words fingly.

A. And

A. And is this Property of Matter the ſame in liquid or fluid Bodies, as it is in hard or fixed ones?

B. The very ſame; for a Drop of Water, or a Particle of Air, remaining fixed between any two Bodies, will no leſs hinder their Contact, than an equal Quantity of Steel or Diamond would do.

A. Pray what is that you call Figurability of Body or Matter?

B. That univerſal Diſpoſition thereof, whereby it is neceſſitated to appear in, or put on ſome Sort of *Shape*, or *Figure*, or other.

A. Wherein doth the *Shape* or *Figure* of Matter conſiſt?

B. In the Manner, or Mode, or Faſhion, of its Extremities, or external Superficies, within which it is contained.

A. Is it not the ſame with what is called the *Form* or *Modification* of Matter?

B. Yes; and ſince the Forms of Matter are only the Shape, or Faſhion, of its terminating Extremities, we muſt exclude *ſubſtantial Forms*, as the *contradictious Nonſenſe* and *Jargon* of the Schools*.

A. Doth this Property of Matter you now diſcourſe of, equally relate to the original primogenial

* The Doctrine of *Subſtantial Forms* is doubly abſurd, becauſe it teaches that *Form is itſelf a Subſtance*, and yet incorporeal, and of itſelf incapable of Quantity, Dimenſion, and Diviſion. They are certainly poor *Ontologiſts*, as well as *Philoſophers*, who talk at this Rate. Let thoſe who would ſee a great deal to little Purpoſe ſaid on this Head, read *Sennertus*'s Epitome of Natural Science, *Lib.* i. *Cap.* 3.

primogenial Particles of Matter, as well as to the groſſer Compoſition thereof in natural Bodies ?

B. Yes; but in theſe inconceivable Particles of Matter, the Forms, no doubt, are much more ſimple, regular, and determinate, than in thoſe heterogeneous Compoſitions which we are acquainted withal.

CHAP. V.

Of MOBILITY *of Matter, and the Nature of* MOTION *and* REST.

A. PRAY what is meant by the *Mobility* of Matter ?

B. It is that eſſential Property, whereby any Part of Matter is capable of *Motion*, or being moved.

A. What is *Motion ?*

B. A continual and ſucceſſive Change of Place.

A. What is *Reſt ?*

B. The Continuance of a Body in the ſame Place, for any Time.

A. What is the *Cauſe* of Motion ?

B. An external Force or Power applied to any Body; which being ſuperiour to its Reſiſtance, impelleth or driveth it out of its Place*.

A. How

* Motion may be conſidered, (1.) as *abſolutely free*, or at leaſt ſo far as to be affected with nothing but the Reſiſtance of the Medium

A. How is Motion diſtinguiſhed ?

B. Into *abſolute* and *relative.*

A. What is *abſolute Motion ?*

B. The real Motion of a Body, from one Part of abſolute Space to another.

A. What do you call *relative Motion ?*

B. It is the Change of Place, with Reſpect to ſome other Things at Reſt: And abſolute and relative Reſt is juſt the contrary to theſe.

A. What do you obſerve hence ?

B. That a Perſon may relatively be at Reſt, who yet is really and truly in abſolute Motion.

A. Pleaſe to exemplify this Matter.

B. I will. Suppoſe a Perſon ſeated in a Ship, he appeareth to all within the Ship to be at Reſt; though at the ſame Time he is moved with the ſame Motion, with the ſame Swiftneſs, and according to the ſame Courſe, as the Ship itſelf is, with regard to abſolute Space.

A. What are the general Affections of Motion ?

B. They are theſe three, *viz.*

1. The *Celerity* or *Velocity* of *Motion.*
2. The *Quantity* of *Motion.*
3. The *Direction* of *Motion.*

Medium thro' which the moving Body paſſes. (2.) As *determinate*, and under *reſtraint*, when the moving Body is obliged to move upon or about a *fixed Point*, which is called the *Centre of Motion.* Thus, ſuppoſe the Line AB be moved on the Centre C into any other Poſition, as *ab*; the Point C is ſaid to be the Centre of that Motion. See *Fig.* III. on *Plate* I, fronting *p.* 25.

A. What

A. What do you mean by the *Celerity* of *Motion?*

B. It is that whereby a Body paſſeth over a given Space, in a given Time: So that if in one Minute a Body A paſſeth over the Space *ab*, and another Body B paſſeth over the Space *cd*, in the ſame Time; then the *Celerity* or *Swiftneſs* of the Body A will be to the *Celerity* of the Body B, as the Line *ab* is to the Line *cd*. See *Fig*. VI.* on *Plate* IV. fronting *p*. 70.

A. How do you compute the *Quantity* of *Motion?*

B. By compounding the Proportion of the Quantity of Matter, and the Velocity of Motion. Thus, if the Body A hath two Parts of

* That is, the Celerities are to each other, as the Spaces paſſed thro' by the moving Bodies. And thus, while AB is moving into the Situation *ab*, the Point B will deſcribe the circular Arch B*b*, in the ſame Time that A deſcribes the Arch A*a*; and conſequently the Celerity of the Motion of the Point B will be to that of the Point A, as the Length of the Arch B*b* is to the Length of the Arch A*a*, as being the Spaces paſſed thro' in the ſame Time; and this is the Foundation of all *Mechanics*, or the Science of Motion.

Now the Arch B*b* is to the Arch A*a*, as C*b* is to C*a*; for they are the *Radii* by which thoſe Arches are deſcribed. From *b* and *a* let fall the Perpendiculars *b*E and *a*D on the Line AB; then in the ſimilar Triangles *a*CD and *b*CE, we have *b*C to *a*C, as CE to CD; and therefore the Arch *b*B is to the Arch *a*A, as CE is to CD; conſequently, if any heavy Body were placed on the Point B, and another on the Point A, ſince all heavy Bodies, at Liberty, tend to the Earth in perpendicular Directions, while the Line AB is raiſed to the Situation *ab*, the Weights would, according to their proper Direction, or Propenſion, be moved thro' the Spaces *b*E and *a*D only; and ſo their Velocities, or the Spaces they paſs thro' round the Point C, will always be proportional to the leaſt Diſtances CE and CD, of their proper Directions *b*E and *a*D, from the ſaid Centre of Motion C.

Matter,

Matter, and ſix Degrees of Velocity, the Motion of that Body will be twelve. See *Fig.* VII. * on *Plate* IV, fronting *p.* 70.

A. Then by this Means I perceive you have an eaſy Method of comparing the Quantity of Motion in any two or more Bodies?

B. Yes, very truly: For, ſuppoſe the Body A hath two Parts of Matter, and ſix Degrees of Velocity; and the Body B hath four Parts of Matter, and ten Degrees of Velocity; then the Quantity of Motion in A, paſſing from *a* to *b*, will be to the Quantity of Motion in B, paſſing the Space *cd*, as 12 to 40. See *Fig.* VII. on *Plate* IV, fronting *p.* 70.

A. Why then I find, that if the Quantity of Matter in any two Bodies be equal, and their Velocities unequal, and the contrary, their Quantity of Motion will likewiſe be unequal?

B. It will be ſo; for the Quantity of Motion in two Bodies will never be equal, if their Matter or Velocity differs, unleſs in this one Caſe, when the Quantities of Matter and Velocity are in reciprocal Proportion to each other: As thus, 4 : 2 : : 6 : 3. Wherefore the Motion of B, with three Degrees of Velocity, is equal to the Motion of A, with ſix Degrees

* What I here call the *Quantity* of Motion, Mechanical Philoſophers call the *Momentum* or *Force* of Motion; by which they mean all the Power that can be given to any Body, by Means of any Machine in regard of the *Gravity* or *Velocity* thereof; from which two Principles, either *ſingly* or *compounded*, all the Force or Power of Bodies is derived.

thereof. See *Fig.* VII.* on Plate IV, fronting *p.* 70.

A. What

* From hence the *Theory* or *Reason* of the Use and Advantage of every *Mechanical Power*, or *Machine*, is evident.

I. The LEVER, *Fig.* IV. of *Plate* I, fronting *p.* 25.

Let DE represent a *Lever*, moveable on the *Fulcrum* C; let P, a Weight of 2 Pounds, hang freely from the Point E, and W, a Weight of 8 Pounds, be placed on the Point D: Now if the Lever be moved, the Distance CE will represent the Celerity of the Body P, and CD that of the Body W, by Note (*), in Page 40. Let CD be 3, and CE be 12: Then, since it is P : W :: CD : CE, *i. e.* 2 : 8 :: 3 : 12, it is evident the Power P (2) with its Celerity CE (12), will be equivalent to the Weight W (8) and its Celerity CD (3); for the Bodies P, W, being in a reciprocal Proportion to their Celerities (or nearest Distances from the Center C) being equal (*viz.* 24) on each Side, make the Force on each Side equal; and consequently the Lever DE will not be moved, but remain in *Equilibrio.*

Therefore, if an Hand be applied to the Point E, and press on the Lever, with a Force any thing greater than that of 2 Pounds, it will raise the Weight W of 8 Pounds, placed as here supposed.

Now tho' there be Levers of several Sorts, what is here said is equally applicable to them all.

II. The BALANCE, *Fig.* V. of *Plate* I, fronting *p.* 25.

The Balance is a Machine for trying the Equality of Weights.

Let DE be the Beam of a Balance, suspended and moveable on the Point C, whose Arms (or *Brachia*) CD and CE are equal, as in a just Balance they should be; and A and B be two Scales hanging from the Points D and E: Now if any Standard Weight W be put in the Scale A, and any Thing, suppose P, a Cheese, be put in the other Scale B, and the Scales remain in *Equilibrio*, then is the Body P of the same Weight as W; because the Distances from the Center C (*viz.* CD and CE) are equal.

Therefore if the Scale A rise or descend, so much must be *taken from*, or *added to* the Body P, as will reduce the Scales to

4 an

A. What do you call the *Direction* of Motion?

B. It

an *Equilibration*; as is always done in *buying* and *ſelling* by *Weight*.

III. The PULLEY, *Fig*. VI. of *Plate* I, fronting *p*. 25.

The Pulley is a Machine for raiſing Weights to a great Height.

Let DEGF be a *Tackle* of Pullies, in which D and E are fixed, and G, F move or riſe and deſcend with the Weight W. Let any Power be applied to the Rope at P to raiſe the Weight W; now it is plain, that if the Weight W be raiſed one Foot, the Pullies F and G will each of them be raiſed one Foot, conſequently the two Ropes R, S, belonging to F, and the other two T, V, belonging to G, will each be ſhortened one Foot; therefore four Feet will be loſt in the four Ropes, R, S, T, V, all which will be gained by the Power P; or it will deſcend four Feet, while the Weight W riſes one; and therefore the Velocity of the Power being four Times greater than that of the Weight, the Weight will be four Times greater than the Power, that at P will ſuſtain it.

And in all Tackles of this Kind, the Power is to the Weight it ſuſtains, as One or Unity to the Number of Ropes applied to the lower Pullies.

IV. The WHEEL and AXIS, *Fig*. VIII. of *Plate* I, fronting *p*. 25.

Let ACB be a Wheel, in which is fixed the Axis X; now it is eaſy to conceive, that if any Power P be applied to the Circumference of the Wheel, in order to ſuſtain a Weight W hanging from the Axis X, the Power P ſhall be to the Weight W, as the Circumference of the Axis to the Circumference of the Wheel. For while the Wheel turns once round, the Power P deſcends through a Space equal to the Circumference thereof, and the Weight in the ſame Time is raiſed thro' another Space equal to the Circumference of the Axis; but the *Celerities* are as the Space paſſed thro', and therefore as the Circumferences; whence the Propoſition is evident.

But ſince the Circumferences of Circles are as their Diameters, the Power P will be to the Weight W, as the Diameter of the Axis X, to the Diameter of the Wheel AB, or (if Spokes be added) to the Diſtance of the Extremities of any two oppoſite Spokes, as D, E.

B. It is a right Line, ſuppoſed to be drawn towards the Place where the moving Body tends:

V. The SCREW, *Fig.* VIII. on *Plate* I, fronting *p.* 25.

The *Screw* is uſed for *Preſſure*, and ſometimes for raiſing Weights.

Let AB be the Male Screw, DE the Nut or Female Screw, which is forced round by a Power applied to the Letter P, which is fixed thereinto. Now it is evident, that when the Lever P is turned once round, the *Nut* will be raiſed thro' a Space equal to the perpendicular Diſtance between two contiguous Threads of the Screw; wherefore the *Power* will be to the *Force* of this Machine, as the Diſtance between two Threads of the Screw is to the Spiral Circumference paſſed thro' by the Power.

VI. The WEDGE, *Fig.* IX. on *Plate* I, fronting *p.* 25.

Let ABD be the triangular Face of the Wedge, and ſuppoſe it were driven into a Piece of Wood quite to the Top AB; it is plain the Wedge will have paſſed thro' the perpendicular Space CD, while the Wood hath paſſed thro' the horizontal Space CB or CA on each Side. And therefore it is inferred, that the *Power* is to the *Reſiſtance* to be overcome on each Side the Wedge, as the Thickneſs of half the Wedge CB to its Height CD. But there are various Proportions ſtated by different Authors concerning this Matter, as appears from the Authors quoted in *Johnſon's Quæſtiones Philoſ.* Page 69, 70. And they who would ſee them all well accounted for, may conſult *Rowning's Comp. Syſtem of Philoſ.* Part I. Chap. 10. Page 72, 73.

Theſe, with the *Inclined Plane*, are all the ſimple Mechanical Powers, of which all others, how complicated ſoever, do conſiſt.

Hence the greateſt Artifice in *Mechanics* is to contrive the Machine, ſo that the Power may have the greateſt Degree of Velocity, and the Weight to be raiſed the leaſt Degree poſſible.

From hence alſo it is plain, that what is gained in Power is loſt in Time; and that, ſince the Force of the Power ariſes from the Product of the Celerity into the Quantity of Matter, tho' the Quantity of Matter be infinitely diminiſhed, yet it ſhall effect as much as before, by means of a greater Celerity.

Suppoſe a Man can preſs with the Force of 200 Pounds, and that the Weight of the Earth be 3997847001180744647789750; now imagine the Earth placed at one End of a Lever, at the Diſtance of 6000 Miles from the Prop or Centre of Motion; then tends: As *ab* is the Direction of the Body A, in *Fig.* VI. of *Plate* IV, fronting *p.* 70.

A. What other Divisions of Motion do you make?

B. According to the Force impressed on Bodies, their Motion is either *simple* or *compound.*

A. Pray, *Sir*, what is *simple Motion?*

B. When only one Force or Power acts on any Body, the Motion produced thereby is simple, and according to the Direction of the impressed Force.

A. And, next, please to explain *compound Motion.*

B. This is produced when two or more Forces act on any Body in different Directions: Thus, suppose a Power H acts on the Body A, with eight Degrees of Force, in the Direction AB; and another Power I acts on it, with six Degrees of Force, in the Direction NC; I say, the Motion of A is not simply in either of the Directions AB or AC, but in a Direction compounded of both, *viz.* AD, and that with ten Degrees of Force, and arrives to D in the same Time as it would have ar-

then must the Person or Power be applied at the Distance of 1199354100354223394369250O Miles to sustain it. If the Earth be raised but one Mile, the Power must move through the Space of 199892350059032232394 8¾ Miles. The Distance of Saturn from the Sun (equal to its mean Distance from the Earth) suppose 770310000 Miles, by which divide the Number 1199354100354223394369250O, the Quotient is 15569745951035731, which is so many Times Saturn's Distance from the Earth, that the Person must be placed from the *Fulcrum* to sustain the Earth.

rived to B or C with thoſe Forces ſingly. See *Fig.* VIII. * of *Plate* IV, fronting *p.* 70.

CHAP.

* 1. For ſince the Body A is urged by a Force repreſented by the Line AB=8, and by another repreſented by AC=6, the Line AC may be conceived to move parallelly along the Line AB, while the Line AB, in like Manner, and in the ſame Time, moves thro' the Line AC; and the Body A being neceſſarily found in both theſe Lines, it muſt be in that Point where they interſect each other; therefore drawing BD parallel to AC, and CD parallel to AB, theſe Lines BD and CD will be the Directions of the Forces for the given Time, and conſequently the Point of their Interſection D, will be that in which the Body A will be then found; and the Line AD, the Path deſcribed by the Body A, or the Point D, in the ſeveral Moments of that Time.

2. Hence it is eaſy to conceive how any given *ſimple* Motion, as AD, may be reſolved into two other ſimple Motions, AB and AC, whoſe joint Efficacy is equivalent to that of AD; and hence any Motion may be conſidered as *ſimple* or *compound*; on which Principle the Doctrine of the *Compoſition* and *Reſolution* of *Motion*, or *Forces*, depends.

3. Let FG (*Fig.* X. of *Plate* I, fronting *p.* 25.) be the Section of a Plane, on which a Body impinges in the oblique Direction AD; then is the Force with which it ſtrikes the Plane in D, repreſented by AD, which is reſolvable into the two Forces AC and CD, of which AC being parallel to the Plane FG, does not affect it in the leaſt; but CD being perpendicular thereto, expreſſes all the Force with which the Body A ſtrikes the Plane in the Direction AD. But CD is equal to AB, which is the Sine of the Angle of Obliquity ADB, and had the Body A impinged perpendicularly on the Point D, its Force had been expreſſed by ED; but ED is equal to AD: Therefore the Force of a direct Stroke is to that of an oblique one as AD to AB; that is, as *Radius* to the *Sine* of the Angle of Obliquity, or Incidence.

4. Suppoſe A to be a Particle of Water, Air, *&c.* then ſince all Surfaces are as the Squares of their like Sides, it is evident that ſeveral Quantities of *Water*, *Wind*, &c. which fall in various oblique Directions on the *Float-boards* of a *Wheel*, the *Rudder* of a *Ship*, the *Sails* of a *Mill* or *Ship*, &c. will have their ſeveral Forces *as the Squares of the Sines of their ſeveral Angles of Incidence*; and therefore are eaſily computable. See *Harris's Lex. Tech.* under the Word *Sail.* *Motte*'s Mechanical Powers.

5. On

CHAP. VI.

Of LIGHT.

B. HAVING thus taken a brief Survey of the moſt general and eſſential Properties of Matter, let us now proceed to thoſe which are more particular, called the ſpecific or accidental Qualities of Bodies.

A. Why are they called *ſpecific* or *accidental?*

B. They are called *ſpecific*, becauſe thereby the ſeveral Kinds of Bodies have their Diviſion into various Species, and are what they are, being thus differenced from one another: Thus, *Fire* by *Heat*, *Glaſs* by *Tranſparency*, *Liquors* by *Fluidity*, *Solids* by their *Fixity*, &c. are different from each other; and are accounted particular *Species* of Matter.

5. On this Principle may we calculate the Ratio of the Power and Weight ſuſtaining each other in *Equilibrio* on an *Inclined Plane*. Let the Plane be AF (*Fig.* XI. of *Plate* I, fronting *p.* 25.) on which the Weight W is ſuſtained by the Power P, the Angle of Inclination is AFG. The Weight touching the Plane in the Point B, thro' the Centre E, perpendicular to the Plane, draw ED; and perpendicular to the Horizon FG draw BC, parallel to which draw DH; then will BD expreſs the Force whereby the Weight gravitates on the Plane, DH the Force whereby it gravitates towards the Earth, and BH the Force whereby it is attracted by the Power P, as being parallel to AE. But BH is to HD (as CD is to BD) as AG is to AF; that is, the Power P is to the Weight W, as the Height of the Plane AG is to the Length AF; or, as the Sine of the Inclination to Radius.

A. But you do not ſay why they are termed *accidental?*

B. I was juſt going to tell you, they are thus called, becauſe they are not *eſſential* to Matter, but happen to be a Part thereof *per Accidens*, or by Accident; for it is purely ſo, that one Part of Matter is diſpoſed to be *hot*, another *cold*, another *dry*, another *light*, another of this Colour, and another of that *.

A. Which of thoſe Qualities will you begin withal?

B. LIGHT †; this being the moſt conſiderable and wonderful of all others; and by which all Things are made viſible and known.

A. Pray what do you call *Light?*

B. That Quality of certain Bodies, whereby they become viſible to us, and render others ſo.

A. What is the true Cauſe of *Light* in thoſe Bodies?

B. No Man can certainly tell; however, ſome affirm it to conſiſt in the extreme vibrating Motions of the Parts of thoſe luminous Bodies.

A. By

* What is here ſaid is in regard only of the Particles of matter in themſelves conſidered; for no doubt the all-wiſe Creator had *perfect Deſigns* and *Ends* in View, in his Choice and Diſtribution of the *Qualities* of natural Bodies; and which we muſt therefore look upon as a great Baſis of the Doctrine of *final Cauſes*.

† *Ariſtotle* defines Light to be ἐνεργεία τοῦ διαφανοῦς, the internal Action or *Energy* of pellucid Bodies. This favours too much of an Hypotheſis.

Des Cartes, and his Followers, diſtinguiſh two Kinds of Light: (1.) *Primigenial*; which, they ſay, conſiſts in a *certain Motion of the*

A. By what Means doth *Light* come to affect our Eyes?

B. It is ſuppoſed this is owing to a very fine ætherial Matter, vaſtly rarer and finer than Air, which is the *Medium* by which the Rays of thoſe luminous Particles are tranſmitted or propagated to our Eyes, and illuminate them with their *Light*.

A. You then ſuppoſe, I find, that what we call Rays of *Light* are real Bodies, or Particles of Matter, endued with the Quality of *Light*, and not the Quality itſelf ‡.

B. You hit it; I do indeed not only ſuppoſe it, but I am ſure of it.

A. Are you indeed! then I am ſure not only myſelf, but thouſands more, have been long

the Particles of a lucid Body, which agitate and propel the *ſubtile Matter* in its Pores every Way, and in all Directions. (2). *Secondary*, or *derivative Light*; which conſiſts in an *Endeavour to Motion*, or *an Inclination of that ſubtile Matter to recede from the Center of a lucid Body in ſtraight Lines*. Such are the curious Fictions of theſe hypothetical Philoſophers.

The *Newtonians* very juſtly make *Primigenial* Light to conſiſt in *a certain Motion of the Particles of luminous Bodies, which force out and off the ſaid Bodies certain exceeding and inconceivably ſmall Particles, which, with incredible Force, are every Way emitted in ſtraight Lines*: And *derivative* Light to conſiſt not in an *Endeavour to Motion*, but in a *real Motion of theſe Particles emitted from Bodies*, as aforeſaid. See *Clarke*'s Notes on *Rohault*'s Phyſics, Part I. Chap xxviii. *Newton*'s Optics. *Boerhaave*'s Chymiſtry, with *Shaw*'s Notes, Page 220, *&c.* *Boyle*'s Experiments to make Fire and Flame ponderable. *Harris*'s Lexicon, under the Word *Light*. *Haukſbee*'s Experiments, and thoſe of *Deſaguliers*, *Graveſande*, &c. *Derham*'s Phyſico-Theology, *&c.*

‡ Sir *Iſaac Newton* computes the Force of Attraction in the ſmall Particles of the Rays of Light to be 1000000000000000 Times greater than the Gravity of Bodies on the Surface of the Earth, according to the Quantity of Matter which is in them.

miſtaken.

miſtaken. Pray is not the Sun the Fountain of *Light* originally?

B. No: He is only the greateſt Body that emits *Light* in our *planetary Syſtem: Light* itſelf being a Quality innate to thoſe Bodies which emit it naturally.

A. But why do you ſay naturally?

B. Becauſe *opaque* or dark Bodies, when heated beyond a certain Degree, will emit *Light*; and all Bodies, eſpecially ſulphureous ones, having their Parts ſufficiently agitated, do ſhine or emit *Light:* Whether this be by Percuſſion, as *Quickſilver*, when ſhaken *in Vacuo*; or by Attrition, as a *Cat*'s Back, or *Horſe*'s Body, *&c.* rubbed in the Dark; or by Putrefaction, as happens in *Wood, Fleſh*, &c. when putrefied; or by any other Way.

A. Is the Motion of *Light* inſtantaneous or ſucceſſive?

B. It being found (by Obſervation) that *Light* is ſucceſſive, or propagated in Time, hath at length ended this long and difficult Controverſy.

A. By what Kind of Obſervations is this diſcovered?

B. Aſtronomical Obſervations; the principal of which is, that of the *Eclipſes* of the *Satellites* of *Jupiter*; for thoſe *Eclipſes*, when the Earth is between the *Sun* and *Jupiter*, happen ſeven or eight Minutes too ſoon; and when the Earth is beyond the *Sun*, they happen as much later than they ſhould by the *Tables*; the Reaſon of which is, that *Light*
hath

hath farther to go in the latter Caſe than in the former, by the Diameter of the Earth's annual Orbit *.

A. Why, if this be the Caſe, you may nearly compute the Motion of *Light*; can you not?

B. Yes, eaſily; for ſince the Diſtance of the Sun from the Earth is known to be about 81 Millions of Miles, if that Number, *viz.* 81000000, be divided by 450, the Seconds in $7\frac{1}{2}$ Minutes, the Quotient will be 180000 Miles; and ſo far doth Light fly every Second of Time.

A. Pray make this incredible Swiftneſs of *Light* a little more intelligible by Example.

B. I will. It is found that a Bullet, at its firſt Diſcharge from the Muzzle of a Cannon, flies one Mile in a little above $8\frac{1}{2}$ Seconds, and therefore would be $32\frac{1}{2}$ Years in arriving to the *Sun*; hence the Proportion of Swiftneſs in a *Cannon-Ball* and *Light*, is as 1 to 1530000 nearly; that is, *Light* flies one million five

* To illuſtrate this important Diſcovery, let ADEB be the Earth's Annual Orb (*Fig.* XII. of Plate I, fronting *p.* 25.) C the Sun, I the Planet *Jupiter* in his Orb HK, and S a Satellite juſt entering his Shadow. Let D and E be two Situations of the Earth in its Orb, whoſe Diſtance DE is equal to the Semi-diameter of the Orb AC. Now it is plain, that if the Motion of Light were *inſtantaneous*, the Satellite S would appear to enter the Shadow at the ſame Moment to a Spectator in E, as to another in D; but, by many Years Obſervations, it has been found, that the Immerſion of the Satellite into the Shadow is ſeen at D about $7\frac{1}{2}$ Minutes ſooner than at E, which is 81000000 Miles more diſtant; and conſequently, as Mr. *Romer* firſt obſerved, the Motion of Light is thereby proved to be *progreſſive*, and not *inſtantaneous*, as was formerly believed.

hundred and thirty thousand Times faster than a Bullet at its first Discharge *.

A. Wonderful are the Works of God! Not only past finding out, but past Belief, when but imperfectly known! But, pray, what other Properties of *Light* are discovered?

B. *Light* is not only found to be a Body, but it is also found to consist of Rays tinctured with all the original Colours in Nature.

A. In what Order are the Rays of *Light* found to be coloured?

B. According to the different Degrees of Refrangibility in the Rays: From Rays less refrangible, to those that are most so, the Colours appear in this Order, *viz. Red, Orange, Yellow, Green, Blue, Indigo,* [deep *Violet*. But more of Colours, when we discourse directly thereof by and by.

A. Pray, what other Affections of *Light* are observable?

B. Its Reflexibility and Refrangibility †.

A. What

* See *Derham*'s Physico-Theology, *Book* I. *Chap*. 4. *Note* 4th and 5th.

† The *Reflexibility* and *Refrangibility* of Light make the Subjects of *Catoptrics* and *Dioptrics*, which are the two great Parts of the most curious and delightful Science of *Optics*. See Notes † and ‡ in Page 26.

I. OF CATOPTRICS.

1. *Catoptrics* is the Science of *Reflex Vision*, or that which is performed by Rays of Light reflected from the polished Surfaces of Mirrours of every Sort; of which there are three very considerable, *viz.*

2. *Plane*

A. What do you call the Reflexibility of *Light?*

B. The

2. *Plane Mirrours*, or Looking-Glaſſes, the chief Properties of which I have taken Notice of in the Text above, *viz.* that all Objects are repreſented in their *Images* juſt as far behind the Mirrour as they are really before it; that they appear ſituated on the ſame Line; and laſtly, that the *Images* are in all Reſpects *alike* and *equal* to the *Objects* in Magnitude.

3. *Convex Mirrours*, or ſuch whoſe Surface is *ſpherically* round, as MR (*Fig.* XIII. of Plate I, fronting *p.* 25;) to underſtand the Nature of which, let AB be an Object, from the Extremities of which A and B, let two Rays BD and AD fall upon the Mirrour in the Points C and D; let PC and QD be perpendicular to the Convex Surface in the ſaid Points C and D; then make the Angle PCE equal to the Angle BCP, and CE ſhall be the Ray BC reflected; in like manner, the Angle QDF being made equal to the Angle ADQ, the Ray DF ſhall be AD reflected. Now it is evident the Object AB will be ſeen by an Eye at EF in the Direction of the reflected Rays EC and FD; that is, in the *Focus* of the Mirrour GH, which will be the *Image* of the Object AB.

4. By theſe Mirrours, (1.) all Objects appear *behind* the Glaſs. (2.) Their *Images* are all *erect.* (3.) The Images are all leſs than the Object. (4.) *Parallel* Rays, or ſuch as come from Objects at a vaſt Diſtance, have their *Focus* or Image at the Diſtance of half the Radius of the Convexity. (5.) *Diverging* Rays, or ſuch as come from near and ſmall Objects, are repreſented nearer the Glaſs than half the Radius. (6.) If the Diſtance of the Object be equal to the Radius of Convexity, the Image will be painted at $\frac{1}{3}$ of the Radius behind the Glaſs. (7.) In *converging* Rays if the Diſtance of the Object be leſs than half the Radius of Convexity, the *Focus*, or Place of the Image will be before the Glaſs; otherwiſe always behind it. (8.) If the Object be a *Right Line*, the Image will be a *Curve*; if the Object be a *Plane* Superficies, it will be repreſented a *curved* one.

5. *Concave Mirrours* are ſuch as are ſpherically hollow on the poliſhed Surface, or that next the Eye. To underſtand the Properties thereof, let AB (*Fig.* XIV. of Plate I, fronting *p.* 25.) be an Object, BC and AD two Rays from the Extremities thereof falling on the Surface of the Concave Mirrour MR in the Points C and D; they will be reflected thereby into the Rays CE and DF, in the Direction of which the Image of the Object will be ſeen.

6. Whence

B. The Diſpoſition of the Rays to be reflected, or turned back from the Surface of any

6. Whence it is plain, (1.) that Rays falling on ſuch a Mirrour, are by Reflection made to converge or interſect each other, as here in the Point *o*. (2.) The Object AB will appear inverted and diminiſhed in its Image *ab*, in that focal Point *o*, to an Eye placed farther diſtant from the Glaſs, at EF. (3.) If the Eye be placed nearer the Glaſs than the *Focus o*, the Image of the Object AB will appear behind the Mirrour, and very much enlarged, as GH. (4.) *Diverging* Rays falling on this Mirrour, if the Diſtance of the Object be leſs than half the Radius of the Concavity, the Image will be behind the Glaſs; if greater, before it. (5.) *Converging* Rays form the *Image always before* the Glaſs. (6.) *Parallel* Rays are converged to a Point at the Diſtance of half the Radius before the Glaſs.

7. From this laſt-mentioned Property of a concave Mirrour, it is eaſy to underſtand how they become *Burning-glaſſes*; for the Rays of the Sun being *parallel*, as coming from a vaſtly diſtant Object, all of them which fall on the Surface of the Mirrour are collected into a very ſmall Space or Circle, whereof the Heat will be to that of the Rays uncollected, as the Square of the Width of the Mirrour to the Square of the Diameter of the Circular Spot, or as the Area of the Glaſs to the Area of the Spot. The Heat then being thus prodigiouſly augmented, will burn violently in that Point; which is the Reaſon why it is called the *Focus*.

II. OF DIOPTRICS.

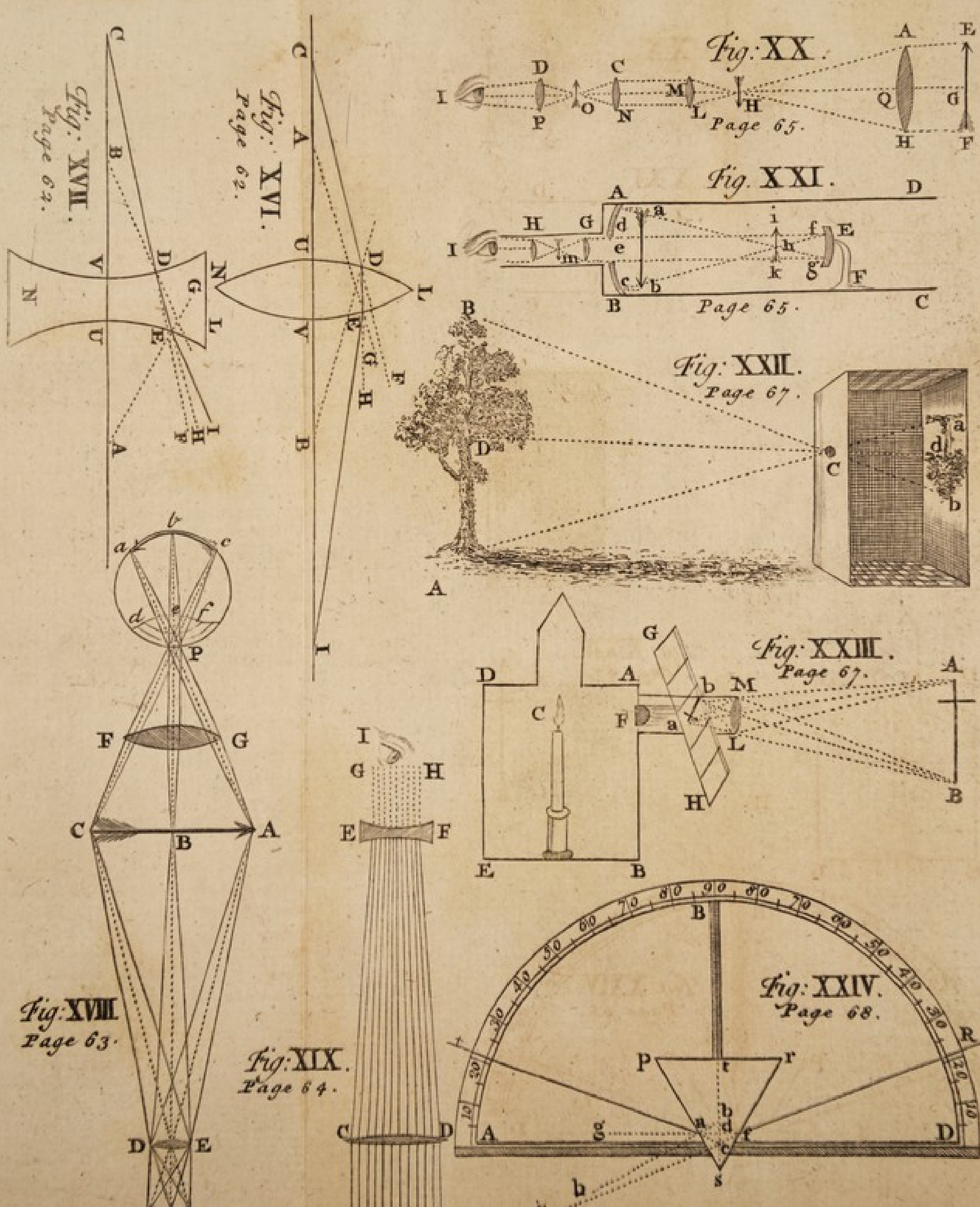
1. This Part of Optics conſiders the Nature of Viſion by Rays of Light refracted through different *Mediums*, but principally through *Glaſs* in thoſe Forms we call *Lenſes*.

2. Of *Lenſes* there are five principal Sorts, *viz*. (1.) A *Plano-convex*, marked A, (*Fig*. XV. of Plate I. fronting *p*. 25.) which has one *plane* Surface, the other a *convex* one. (2.) A *Double-convex*, as B, which has both Surfaces *convex*. (3.) A *Plano-concave*, as C, which hath one *plane*, the other a *concave* Surface. (4.) A *Double-concave*, as D, which has both Surfaces *concave*. (5.) A *Convex concave*, as E; one of whoſe Sides is convex, and the other concave. This *Lens* is uſually called a *Meniſcus*. The Line FG is the Axis common to each of thoſe Lenſes, as paſſing through their middle or *vertical* Point.

3. Let LN be a *double-convex* Lens in *Fig*. XVI. of Plate III, fronting *p*. 62; or a *double-concave*, as *Fig*. XVII. of Plate III, fronting *p*. 62. AV and BU the *Radii* of their Convexities and

To front Page 62.

Plate. III.



any Bodies on which they fall: Thus the Ray

*a*B

and Concavities, which are here equal; from any Point C in the Axis, ſuppoſe a Ray CD proceed *diverging*, and fall on the Surface of the Lens at D, to the Point D draw BD perpendicular, then the Ray paſſing through the denſer Subſtance of Glaſs will be bent out of its Courſe CE towards the Perpendicular DB, and ſo be refracted from D to E on the other Surface; draw the Perpendicular AG through the Point E, then the Ray DE paſſing out of *Glaſs* into *Air*, will be refracted from its ſecond Courſe DH, into a thirdCourſe EI from the Perpendicular EG or AE. Now it is evident from the Schemes, that the Ray EI is, by the *Convex* Lens, made to converge towards the Axis, and to interſect it in I; but in the *Concave* Lens, the ſame Ray E is made to converge from the Axis. And this would have been the Caſe of a *Plano-convex*, and a *Plano-concave Lens*, with little Variation.

4. Concerning the various Properties of all Varieties of Lenſes, and Rays incident upon them, ſee Mr. *Molineaux*'s Optics, Dr. *Gregory*'s Elements of Catoptrics and Dioptrics, with Dr. *Brown*'s Supplement thereto, and Mr. *Rowning*'s Compleat Syſtem of Philoſophy, Part III. All which may be ſeen confirmed by Experiments in *Graveſande*'s Math. Elements of Natural Philoſ. Vol. II. Book III. Part II.

What is here obſerved of the Nature of Lenſes in general, is ſufficient for underſtanding the Structure and Effects of dioptric Machines; as the *Microſcope*, *Teleſcope*, *Camera Obſcura*, and *Magic Lantern*.

III. Of the MICROSCOPE.

1. Let DE be the Object-Glaſs, and FG the Eye-Glaſs of a Microſcope; *Fig.* XVIII. of Plate III, fronting *p.* 62; *abc* a ſmall Object to be viewed by the Eye at P. Draw the dotted Line or Axis *a*A through the Centre of the Lens DE, and let AD be a Ray proceeding from the extreme Point *a* of the Object, and incident on the outmoſt Part D of the Lens; this will be refracted into the Direction DA, and interſect the Axis in the focal Point A. In like Manner a Ray *aE*, incident on the other Side E, will be refracted into EA, meeting the Axis in the ſame Point A. So that the whole Cone of Rays D*a*E will be refracted into the Cone DAE; and therefore the Extremity *a* will be repreſented at A. In the ſame Manner the Cones D*b*E and D*c*E will, after Refraction, become DBE and DCE; conſequently, the three Points *a*,

b, *c*,

*a*B falling on the Surface AC, in the Point B, is

b, *c*, will be repreſented in the Image at A, B, C ; and all Points between the former will be painted ſimilarly between the latter.

2. Therefore the ſmall Object *abc* will have its Image formed in the Focus ABC ; and the Image will be in Proportion larger than the Object, as the Diſtance of the Image is greater than the Diſtance of the Object from the Glaſs DE. Alſo the Poſition of the Object will be inverted in its Image, as is evident from the Figure.

3. The Image ABC is now to be conſidered as an Object viewed through the Eye-Glaſs FG. Now it is to be *well noted*, that Rays falling parallel on equally convex Lenſes are collected together in the Centre of Convexity ; therefore if the Image ABC be placed in the Centre or *Focus* of the Eye-Glaſs FG, all the Rays coming from it, after Refraction through the Glaſs, will proceed parallel till they arrive at the Pupil of the Eye at P ; and that they ſhould do thus, is neceſſary to cauſe diſtinct Viſion.

4. In the Pupil P, the Rays all croſs each other again, and by the *cryſtalline* Humor *(def)* are collected or united in the Focus, which is on the Retina in the Bottom of the Eye, and there the ſecond Image *abc* is formed in its true Poſition, like that of the Object *abc*. Yet, notwithſtanding this, the Mind conceives the Idea of the Object as inverted, the Reaſon of which odd *Phænomenon* I ſhall not here enquire, but proceed to the Conſtruction

IV. Of TELESCOPES.

1. The firſt Teleſcope I ſhall conſider is that called a *Proſpective-Glaſs*, (*Fig*. XIX. of Plate III, fronting *p*. 62.) conſiſting of a *Convex Object-Glaſs* CD, and a *Concave Eye-Glaſs* EF, which is to be ſo placed, that the *Focus*, or Centre of each Lens, may fall on the ſame Point, or coincide , then ſhall parallel Rays coming from any Object AB, and refracted by CD towards EF, by paſſing through EF, be again made *parallel*, and conſequently fit to produce diſtinct Viſion. (1.) This Glaſs ſhews Objects *erect* ; for the Rays do not croſs or interſect each other any where, which alone cauſes Objects to appear inverted. (2.) It *magnifies* Objects in the Proportion of the *focal* Diſtance of the *convex* Lens D, to the *focal* Diſtance of the *concave* one EF. (3.) In this Glaſs no more of the Object is ſeen at one View, than what falls on the Pupil of the Eye I; which therefore is near

is reflected or turned back again in the Direction B*d*. See *Fig.* IX. of *Plate* IV, fronting *p.* 70.

A. In

near; and large Objects is but a very *ſmall Part*, and ſo this Glaſs is in ſuch Caſes but of *little Uſe.*

2. A ſecond Sort of Teleſcope is that conſiſting of two Lenſes alſo, but both *convex* ones, as AH and BI (*Fig.* XX. of *Plate* III, fronting *p.* 62.) Let K be the *Focus* of both Lenſes, then will the Image of a vaſtly diſtant Object EF be there formed and appear inverted to an Eye placed in the Axis, MG, any where behind the *Lens* BL. On this Account it is ſeldom uſed, unleſs to view the Heavenly Bodies, whoſe Poſition is not regarded. This Glaſs alſo magnifies Objects in Proportion of the Focal Diſtance of the Object-Lens QK to the Focal Diſtance of the Eye-Glaſs KL. In this Teleſcope, ſo much of the Object is ſeen at one View as falls on the whole Surface of the Object-Glaſs.

3. The third Sort of Teleſcope is that in common Uſe for viewing Land-Objects; and conſiſts of one Object-Glaſs AH (*Fig.* XX. as above) and three Eye-Glaſſes, all of the ſame *Focus*, as B, C, D. Hence it is plain this is the ſame with the foregoing Teleſcope, only with the Addition of the two Eye-Glaſſes C and D; for whereas the Object was before *inverted* in the Focus K, by adding the Glaſs C, it will be again made *erect* in its Focus O, and will ſo appear to an Eye I, placed behind the third Glaſs D, if the Focus both of C and D be made to fall on the ſame Point O. This Teleſcope then ſhews Objects *erect*, and is in other Reſpects the ſame as the laſt foregoing. See Note *, in Page 22.

4. The fourth Sort of Teleſcope is that lately invented by Sir *Iſaac Newton*, called the *Reflecting* or *Catadioptric* Teleſcope. This conſiſts of a Tube ABCD, two, three, or four Feet long (*Fig.* XXI. of *Plate* III, fronting *p.* 62.) which is open at the End towards the Object CD, and at the other End is placed a concave Metalline Mirrour, as AB, perforated through the Middle at *e*; at a proper Diſtance is placed another ſmall concave Mirrour E (in the Axis of the Tube) which is ſupported by the Stem or Foot F. The two Mirrours are ſo diſpoſed, that the Focus of each may fall on the common Point *h* between them; then the Image of any Object entering the Tube, as *ab*, and falling on the large Mirrour AB in the Point *dc*, is from thence reflected between the Rays *db* and *cb* to the Focus *h*, where the Rays croſſing, invert the Image, as at *ik*; and this Image being now alſo in the Focus of the Mirrour E, after falling thereon in the Points

A. In what Manner or Order is this?

B. The

f, g, it will be reflected from thence back again in *parallel Rays,* which pass through the Hole *e* of the great Mirrour, and falling on a Convex Lens at G, do again cross each other in its Focus *m,* and there represent the Image *erect* to be viewed by an Eye I, through the Eye-Glass H, whose *Focus* is also in *m.*

5. This Telescope magnifies the Diameters of Objects in the Proportion of the *Focal Distance* of the *Object Mirrours* to the *Focal Distance* of the Eye-Glass, as do the other Telescopes; but in this, by Reason of the Reflection of Rays, an Eye-Glass with a much shorter *Focus* may be used, than in the common ones by Refraction; and therefore a *Reflecting Telescope* of six Feet in Length will magnify an Object as much, as a *Refracting* one 100 Feet long; on which Account they are now in much Esteem, though there be many Difficulties in them also.

6. If the Focal Distance of the Object-Glass or Mirrour (in any Telescope) be 50 Inches, and that of the Eye-Glass one Inch; then will the *Diameter* of a distant Object be magnified 50 Times; the Surface 2500 Times; and the Solidity of the whole Body 125000 Times.

V. Of the CAMERA OBSCURA.

1. The *Camera Obscura,* or Dark Chamber, is nothing but a Chamber, Room, or Box darkened, and a Convex Lens fixed in a Hole made in one Side thereof, as at C (*Fig.* XXII. of *Plate* III. fronting *p.* 62.) through this Lens any Object before it without, as AB, a Tree for Instance, will have its Image carried through the Lens between the Rays AC and BC; which proceed to the other Side of the Room (supposed to be at the Focal Distance of the Lens C) where they paint the Image of the Object in the most lively Colours, far beyond the Imitation of the best conducted Pencil, in regard of Colouring, and with respect to the *Motion* of every Part moved in the Object; this is allowed such an inimitable Perfection, as is peculiar to *Nature's Painting* only. Indeed the Image *ab* is *inverted,* and is in Proportion to the Object, as its Distance C*d* from the Glass to the Distance DC of the Object.

2. If the Object be placed at the Distance of twice the Radius of the Convexity of the Lens, the Image shall be exactly as big as the Object. Note, I here suppose the Lens C to be *doubly* and *equally* convex. The only Time for making a dark Chamber, is when the Sun shines; for unless the Objects are strongly enlightened, the Picture will be obscure and little worth. The *Sky Optric Ball,* with its Glasses, is most commonly and conveniently used for this Purpose.

VI. The

B. The Law of Reflection of *Light* is invariable; for the Angle *a*B*c*, of the incident Ray *a*B, is ever equal to the Angle *c*B*d*, of the reflected Ray B*d*, and the Perpendicular *c*B. See *Fig.* IX. of *Plate* IV, fronting *p.* 70.

A. What do you mean by the Refrangibility of *Light*?

B. The Diſpoſition of the Rays of *Light* to be refracted, or broken out of their direct Courſe, in paſſing through one tranſparent Body or *Medium* into another: Thus the Ray *a*B, paſſing through the Medium of Air to B, and there ſtriking on the Surface of Water AC, is refracted or broken out of its direct Courſe BE, into another BF, towards the Perpendicular BG. See *Fig.* X. of *Plate* IV, fronting *p.* 70.

A. Doth the Refrangibility of Rays alſo obſerve any ſtated Law or Order?

B. Yes: for the Line HI, of the Angle of Incident CBH, is always in the ſame Proportion to the Line MK=IK, of the Angle of Re-

VI. The MAGIC LANTHORN.

After all that has been ſaid in this Note, it is eaſy, from a bare Inſpection of *Fig.* XXIII. of *Plate* III, fronting *p.* 62, to underſtand the Reaſon of the Effects of a *Magic Lanthorn.* Let ABDE be a Section thereof, C a Candle placed therein, F a large Convex or Hemiſpheric Lens, which ſtrongly illuminates the inverted Pictures in the Plate GH; the Light coming from any one of theſe, as *ab*, is, in paſſing through the Lens LM, made to ſpread and diverge very much, and conſequently to paint a very large Image AB on the Wall, or any Thing in the Focus of thoſe Rays. If this Image be a *Ghoſt*, the *Devil*, &c. it appears very terrible and ſurpriſing to the Spectators who are unacquainted with the Nature of *dioptric Machines.*

fraction GBF; as 4 to 3 in *Water*; and as 17 to 11 in *Glass*. See *Fig.* X. of *Plate* IV, fronting *p.* 70*.

A. What may we learn by this Doctrine of the Reflection of *Light?*

B. The Reason why Objects appear just as far behind any *Plane Speculum*, or *Looking-Glass*, as they really are before it, and the same Way: Thus, suppose AC the Section of a *Looking-Glass*, it is plain any Object placed before it at *a*, as the *Arrow*, will appear just so far behind the *Glass* AB as E, and directed to the same

* The Proof of this Experiment is easy, and may be as follows. Let ABD be a Semicircle (*Fig* XXIV. of *Plate* III, fronting *p.* 62.) large and duly graduated; C the Centre thereof, before which is to be placed a Prism of Glass, represented by *prs*, the upper Plane or Side of which *pr* must be fixed parallel to the Horizon, or to AD. Suppose the Angle of the Prism *psr* be 60 Degrees, then will the Angle *pst* be 30. Let I*c* be a Ray incident on the Prism in the Point *a*; if this Incidence be such, that the Ray entering the *Medium* of Glass be refracted into the Direction *af*, parallel to the Horizon AD, it shall emerge out of the Glass into the Air in the Direction CR, making the Angle RCD equal to the Angle ICA. Now in order to find this Angle, draw through *a* the Line *hb* perpendicular to the Side of the Prism *pr*, and also *gd* parallel to the Horizon AD, then shall the Angle *had* be the Angle of Refraction in the Prism as required, which is known, as being equal to the Angle *pst*, or 30 Degrees; therefore, if the Ratio of the Sine of Incidence be to that of Refraction as 17 to 11, out of Air into Glass, it will be, as 11 to 17, so is the Sine of $bad = 30°$ to the Sine of Incidence $Iab = 50° 45'$, nearly; from which take $gab = 30$, there will remain *ga*I equal to $ICA = 20° 45'$; and since any Object at I under the Angle $20° 45'$ does actually appear to an Eye at R under the same Angle, it proves the Truth of the said *Ratio*. And this always will be the Case, be the Angle of the Prism what it will.

If the Figure *prs* were an hollow Glass Prism, this filled with various Sorts of pellucid Liquors, would exactly shew the different refractive Powers of those Liquors. Also, a Piece of Looking-Glass placed horizontally at C, shews, that the Angle of Incidence ICA is equal to the Angle of Reflection RCD.

Point

Point in the *Glaſs* B: For all Objects appear in that *Ray* E*d*, that meets the Eye in *d*, be it any how reflected or refracted. See *Fig.* IX. of *Plate* IV, fronting *p.* 70.

A. And are our Eyes thus deceived by the Refraction of *Light*?

B. Beyond your Imagination, I believe.

A. Aye, indeed! Pray oblige me with an Example how, and in what Reſpects?

B. I will; and that by a very vulgar Experiment: Suppoſe AGHB be a *Veſſel*, whoſe Length GH is 56 Inches; let any Object, as a Half-Crown, be placed exactly in the Middle thereof at F; then let the Veſſel be filled with Water to the Height CD, 24 Inches; let FP be a Ray of *Light* paſſing from the Object F to P, but there meeting with the Air, is refracted towards N, and becomes PN. Now it is evident, an Eye placed in N cannot, by any Means, ſee the Object F (for the Sight is interrupted by the Side of the *Veſſel* at *e*) before the Water is poured into the *Veſſel*; after it is poured in, the Eye at N will indeed ſee the Object F, yet not in its true Place at F, but in another, diſtant 15¾ Inches, at E; alſo to an Eye placed perpendicular over the Object F, it will appear to be in O, and the whole Bottom of the *Veſſel* will ſeem elevated to IK, the Height of FO, 11 Inches. See *Fig.* XI. of *Plate* IV, fronting *p.* 70.

A. Well, it is very wonderful, as well as diverting and improving, to ſee and conſider of theſe Things: I could not, indeed, have thought that Things placed ſo far out of Sight could thus be made viſible; and that we ſhould behold them in Places ſo far diſtant and different from the true: It is well we have Reaſon to guide us, for I perceive our moſt exquiſite Senſes are fallible, and often deceived.

B. It is true, our Senſes are liable to Deception, and it is well for us in many Caſes they are; for as I go on, I ſhall often ſhew you the Advantages which accrue to us thereby, and from the Cauſes thereof particularly the Reflection and Refraction of *Light*.

A. How came Bodies firſt of all to be endued with this wonderful Property of *Light?*

B. By the omnipotent *Fiat* of the great Creator; he ſaid יהי אור, *Eſto Lux*, let there be *Light*, and immediately there was *Light*; and the ſtupendous Body of the Sun was created, as it were, a *Repoſitory* or *Store-Houſe* thereof, whence it was to be diſtributed to every Part of the *Planetary Syſtem*, in order to make the Whole viſible, and uſeful to the various Inhabitants thereof.

A. Can you give any Account of the Smallneſs of the Particles of *Light?*

B. Yes: It is computed, that in a Second of a Minute, there flies out of a burning Candle the following Number of Particles of *Light*, 418660000000000000000000000000000000000000000000, which is 10 000 000 000, or ten millions of millions Times a bigger Number than 1000000000000000000000000000000000000; the Number of the Grains of Sand computed to be contained in the whole Earth *.

* See the Calculation in *Niewentyt*'s Relig. Philoſopher.

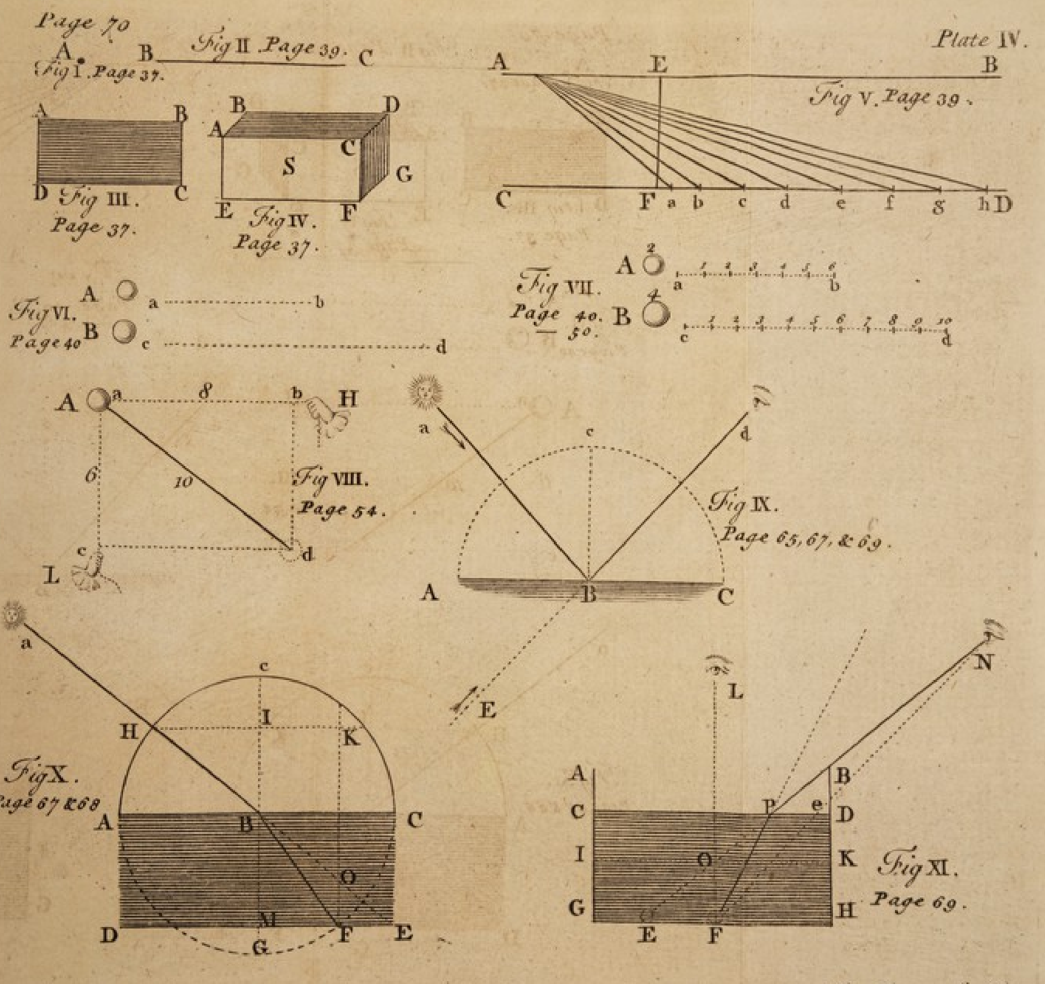


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Fig III. Page 37.
Fig IV. Page 37.
Fig V. Page 39.
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Fig VII. Page 40. — 50.
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Fig IX. Page 65, 67, & 69.
Fig X. Page 67 & 68
Fig XI. Page 69.
Em: Bowen Sculp.

CHAP. VII.

Of the COLOURS *of* LIGHT, *and natural* BODIES.

A. NOW, if you pleaſe, *Sir*, let us turn our Diſcourſe to the *Phænomena* of *Colour:* And firſt, be pleaſed to define what *Colour* is.

B. Colour is that which ariſeth from a certain Quality of Bodies, whereby they are diſpoſed ſo to modify and reflect the Light falling on them, and ſtriking on the Organ of Sight, as thereby to occaſion or produce the Senſation of *Colour* in our Minds: And that Senſation in us is alſo called *Colour*.

A. Whence is the Original of *Colours?*

B. All the *Colouring* in the Univerſe proceeds originally from the *Rays of Light*; for in them are contained all the primary, original, and abſolutely pure and unmixed *Colours* *.

A. Which

* *Des Cartes* pretended, that Colours reſulted from the Relation of the direct and circular Motion of Etherial Globules; if the Direct be ſlower than the other, *Red* is produced; if more rapid, *Violet*; and the others between theſe Extremes accordingly.

Dr. *Hooke* ſuppoſed they conſiſted in the Obliquity of the Pulſes of the Ethereal Matter. *Malbranche* made them the Effect of Vibrations of Light, more or leſs quick. *Regnault* has a particular Hypotheſis on this Head in his *Phil. Converſations*, Vol. II. Page 391, remarkable for nothing but Novelty, and the Preſumption of the Author. The *great Barrow* imagined that Colours

A. Which, and how many, are thoſe primary and original *Colours?*

B. Thoſe which follow: 1. *Red,* 2. *Orange,* 3. *Yellow,* 4. *Green,* 5. *Blue,* 6. *Indigo,* 7. *Violet.*

A. How are thoſe *Colours* diſcerned and diſtinguiſhed in the *Rays of Light?*

B. By Means of the different Degrees of its Refrangibility; for thoſe Rays which are leaſt refrangible, are tinctured with Red, and paint that *Colour* on Bodies; and thoſe which are moſt refrangible, are Violet and Purple, and paint Bodies therewith; and the intermediate Degrees of refrangible Rays are dyed with the intermediate *Colours,* in the Order before mentioned *.

A. By what Experiment do you prove this Doctrine?

B. By this eaſy one following: In a Chamber made dark, make an oblong Hole in the Window-Shutter at F, about $\frac{1}{6}$ of an Inch in Breadth, through which will enter the Sun Beam FH; and a large Priſm ABC, placed at about 20 Feet from the Hole, will refract the Rays of this Beam; after which they will again unite, and become a white Beam at H,

that Colours conſiſted in a conſtipated and rare Light. But Sir *Iſaac Newton* has ſhewn the Errors of Hypotheſes about Colours; and proves the Truth of his own new Doctrine by undeniable Experiments.

* Light is ſuppoſed to be more or leſs *reflexible* or *refrangible,* as the Particles thereof are of a leſſer or greater Magnitude; the Particles of *Red Light* being the greateſt, and thoſe of *Violet* the leaſt, of all others; theſe, therefore, excite the leaſt, and thoſe the largeſt Vibrations in the *Optic Nerve,* which occaſion different Senſations.

where let be applied an opaque Body GHI, at the Diſtance of two or three Feet from the Priſm, in which let there be an oblong Hole made at H, $\frac{1}{10}$ or $\frac{1}{60}$ of an Inch in Breadth, through which the white Part of the Beam being tranſmitted, and made to fall on a Piece of white Paper placed after, will there paint the primitive original *Colours of Light*; ſuppoſe *Red* at *t*, *Yellow* at *s*, *Green* at *r*, *Blue* at *q*, and *Violet* at P. *Fig.* XII. of *Plate* VIII, fronting *p.* 120.

A. Very good; and what is the Conſequence of all this?

B. Why then, with a Piece of Wire R (or any opaque Thing about $\frac{1}{10}$ of an Inch thick) you may, by intercepting the Rays at *k*, *l*, *m*, *n*, *o*, take away any one of the *Colours* at *a*, *s*, *r*, *q*, or P, whilſt the other *Colours* remain as before.

A. What do we learn by this Experiment?

B. *Firſt*, That the *Rays of Light* paint natural Bodies with different *Colours*. *Secondly*, That the leaſt refrangible Rays, as *t*, paint *Red*; and the moſt refrangible ones, as P, paint the deepeſt *Violet Purple*; and that other intermediate refrangible Rays paint the other intermediate *Colours*. *Thirdly*, That thoſe Differences of *Colour* are abſolutely and really exiſting in the *Rays of Light*, and do not ariſe from the different Confines of Shadow, variouſly modifying the *Light*, as has hitherto been the Opinion of Philoſophers.

A. I think it ſeems from hence, as if you would inſinuate, that *Colours* are not *connate* with Bodies, or naturally in them, but painted on them by the *Rays of Light*?

B. It

B. It is very true; *Colours* only are in the *Rays of Light*, not in Bodies; and all Bodies are of the ſame Hue in the Dark, and appear differently *coloured* only by, and in the *Light*.

A. Strange Doctrine this! I am apt to think you'll perſuade very few, that *Colours* are not in Bodies, when they conſtantly ſee all around them tinged with ſuch an agreeable Variety.

B. If they will not be convinced by Reaſon and Experience, they muſt remain ignorant, and ſtill poſſeſs their Prejudices and Errors.

A. But, according to this Notion of *Colours*, how comes it to paſs, that ſome Bodies are all of one *Colour*, ſome all of another, and ſome of ſo many different *Colours*?

B. This is eaſily conceived; for the Matter of ſome Bodies univerſally reflects one Sort of Rays more copiouſly than another; and according to the Refrangibility of thoſe Rays are the Bodies *coloured*: Thus *Minium* reflects the leaſt refrangible Rays moſt copiouſly, and thence appears *Red*: *Violets* reflect the moſt refrangible Rays, and thence have their Colour; and ſo of their intermediate Degrees: Again, the Matter of ſome Bodies is ſuch, as reflects different refrangible Rays; and therefore is in various Parts of various *Colours* *.

A. Pray,

* The Colours of natural Bodies are of two Sorts. (1) *Variable*, which change and differ according to the Situation of the Eye, as in *Silks*, *Satins*, and the Tails of *Peacocks*, &c. (2) *Permanent*, which are always the ſame, and never vary. To underſtand the Reaſon of both which, it is neceſſary to premiſe the following Things.

Firſt,

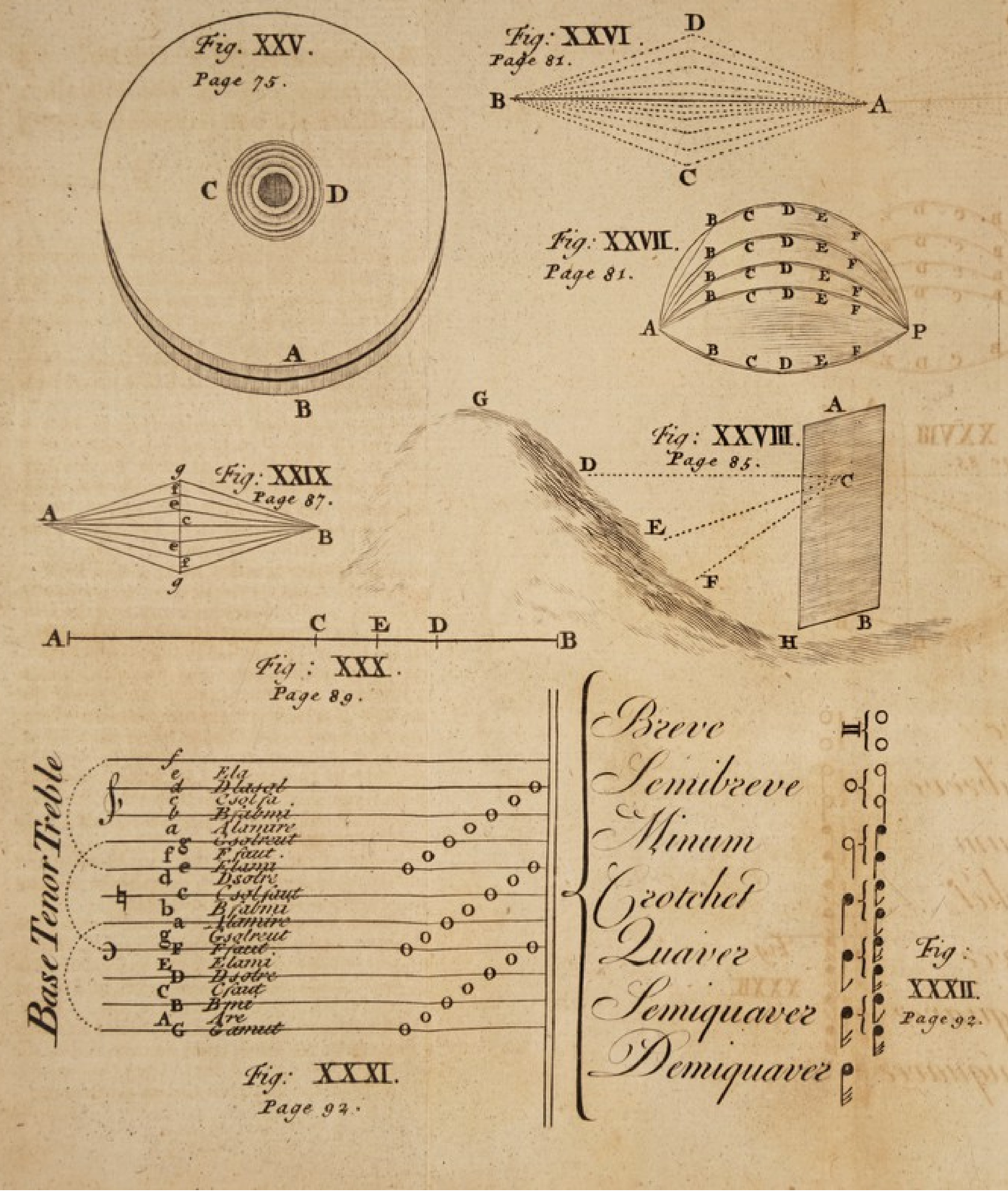
Fig. XXV.
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C
D
A
B
Fig: XXVI.
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D
B
A
C
Fig: XXVII.
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B C D E F
A
P
G
Fig: XXVIII.
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A
D
C
E
F
H
B
Fig: XXIX.
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A
B
g f e c e f g
A C E D B
Fig : XXX.
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Base Tenor Treble
Ela
Dlasol
Csolfa
Bfabmi
Alamire
Gsolreut
Ffaut
Elami
Dsolre
Csolfaut
Bfabmi
Alamire
Gsolreut
Ffaut
Elami
Dsolre
Cfaut
Bmi
Are
Gamut
Fig: XXXI.
Page 92.
Breve
Semibreve
Minum
Crotchet
Quaver
Semiquaver
Demiquaver
Fig:
XXXII.
Page 92.

A. Pray, *Sir*, what can be the Meaning, that *White* and *Black* are not reckoned among the *primary Colours* of *Light?*

B. Because

First, That Rays of Light, by Means of a thin transparent Plate of *Air*, *Water*, or *Glass*, &c. are separated from one another; and according to the different Thickness of the Plate, the Rays of some Colours are transmitted, and those of others are reflected.

Secondly, Such a very thin Plate is of a different Colour when seen by the transmitted Rays, from that which it is tinged with when seen by reflected Rays.

Thirdly, To prove this, the usual Experiment is to take a Plano-convex Glass (whose convex Surface is the Segment of a very large Sphere) as A (*Fig.* XXV. of *Plate* V, fronting *p.* 75.) lay this with its convex Surface on a plain Piece of Glass B, and compressing them together, there will appear, in the Point where they touch, a dark central Spot, and about it various coloured Circles, as represented within CD.

Fourthly, The Glasses thus compressed being placed under a Microscope, the Colours of the several Circles may be clearly and largely viewed, and the Breadth of each, as also the Distances of those Circles, may be accurately measured (by a *Micrometer* fitted to a Microscope) to the 10000th Part of an Inch.

Fifthly, To find the Thickness of the Plate of Air between the Glasses at the Periphery of any coloured Ring, say—As the Diameter of the Glass's Convexity is to the Semidiameter of any Ring, so is that Semidiameter to the Thickness of the Plate of Air at its Periphery. Suppose the Diameter of the Sphere, the Glass was ground to, was 12 Feet, or 144 Inches, and the Semidiameter of the Circle $\frac{1}{10}$ of an Inch; then $144 : \frac{1}{10} :: \frac{1}{10} : \frac{1}{14400}$, therefore the Thickness of the Plate where that Circle is formed is $\frac{1}{14400}$ Part of an Inch.

Sixthly, The Colours of the Circles seen by the reflected Light, are much more vivid and distinct, than those seen by transmitted Light, which are faint and more dilute.

Seventhly, The Rings made by Reflection are differently coloured from those made by the Transmission of Light; *White*, in the latter Case, will be opposed to Black in the former; *Red* to *Blue*, *Yellow to Violet*, and *Green* to a Compound of *Red* and *Green*.

Eighthly, The more obliquely the Rings are viewed in either Case, the larger they appear by much; nor do they follow the simple Proportion of the Obliquity of the View; but as this increases, the Circles swell and dilate themselves much more.

Ninthly,

B. Becauſe *White* is ſo far from being a pure, ſimple, original *Colour*, that, on the contrary,

Ninthly, The farther the Circles are from the Center, the leſſer and fainter their Colours appear; the fifth, or ſixth, is the laſt which appears diſtinct; though I have obſerved a faint Skim of Circles to the Number of 11 or 12 in the light Air.

Tenthly, Water applied to the Edges of the Glaſs, is attracted between them, and filling all the Interſtice, is made to conſtitute as thin a Plate of Water, as before there was of Air.

Eleventhly, The Water approaching the coloured Circles in the Plate of Air, does in a great Meaſure deſtroy the Brightneſs of the Colours, leſſen the Number of the Rings, and contracts their Peripheries in the Proportion of 7 to 8, nearly.

Twelfthly, Bubbles blown up in Soap Water exhibit the like Appearance of coloured Rings, brighter towards the Top where the Bubble is thinner; but towards the Bottom, where the Water running down makes the Bubble thicker, the Rings and Colours gradually become more faint and obſcure, till at laſt they quite diſappear.

Thirteenthly, Thin Plates of *Muſcovy* Glaſs ſhew Rings of Colours alſo, but if they are wetted with Water, the Colours become more faint and languid, though they vary not in their Species.

Fourteenthly, Light incident on thin Plates of Air, Water, or Glaſs, is diſpoſed, according to the different Thickneſſes thereof, to be either tranſmitted or reflected; where the Thickneſſes are as the Numbers 1, 3, 5, 7, 9, *&c.* the Rays are diſpoſed to be *reflected*, and *tranſmitted* at the Thickneſſes expreſſed by the Numbers 0, 2, 4, 6, 8, 10, *&c.* And this Action or Diſpoſition of Rays, in its Propagation, intermitting and returning by equal Intervals (as here ſpecified) for innumerable Viciſſitudes, occaſioned Sir *Iſaac Newton* to ſay—they were then in *Fits of eaſy Reflection*, or in *Fits of eaſy Tranſmiſſion*.

Theſe Obſervations afford the following Concluſions concerning the *Colours of natural Bodies*.

1. The Particles of all Bodies conſiſt of very thin Plates, or Laminæ of Matter, in themſelves clear and pellucid; this in ſome Meaſure is evident, by viewing the Particles of *dry Earth*, or *Sand*, with a Microſcope.

2. Theſe very thin Plates do reflect or tranſmit Light incident upon them, and thereby become coloured.

3. The Colours of Plates depend on their Thickneſs and Denſity, and not on the encompaſſing *Medium*.

4. The

trary, it is a Mixture of all thoſe ſeven original *Colours* together; or a Compoſition of *Colours*, even all the *Colours* in Nature: And, on the other Hand, *Black* is properly no *Colour* at all, being only the Hue of thoſe Bodies whoſe Subſtance abſorbeth all the *Rays of Light*, and therefore, by reflecting none, cannot, of Conſequence, be coloured at all.

A. Then thoſe Bodies which appear *White*, I apprehend, are ſo by reflecting promiſcuouſly all the *Rays of Light* which fall on them * ?

B. Yes, they are ſo. I have one Thing more very curious on this Head of *Colours* to relate to you, and then, if you pleaſe, we will make a Tranſition to another Subject.

4. The thinner the Plate, the more vivid the Colours.

5. The more the Thickneſs of a Plate is increaſed, the more Colours it reflects, and different ones.

6. The Colour of ſome Plates will vary, by changing the Poſition of the Eye, while others remain always the ſame.

7. The thickeſt Plates reflect the *red* Rays, and the thinneſt the Violet-coloured ones.

8. The denſer the Medium encompaſſing the Plates, or which fills the Pores of Bodies, the more obſcure and darker are the Colours.

9. All Bodies appear of ſuch a Colour, as ariſes from the Mixture of reflected Rays.

10. The more ſimple and vivid the Colours, the leſſer and more denſe are the conſtituent Particles or Plates of natural Bodies.

For a larger Account of theſe Things, ſee Sir *Iſaac Newton*'s Optics, Book II. *Graveſande*'s Elements, Vol. II. Book 3. Chap. 22, 23. *Worſter*'s Prin. of Nat. Philoſophy, Page 239 to 252. *Harris*'s Lex. under the Word *Colour*.

* Thus Sir *Iſaac* proved by ſeveral Experiments (beſides bare Reaſoning) in mixing coloured Lights, and coloured Powders, in proper Proportions; for the Compoſition was of as perfect a Whiteneſs as any in Nature: As may be ſeen at large in his Optics, *Book* I. *Part*. II. *Prop*. 5.

A. Pray,

A. Pray, what is that? I long to know, being raviſhed with theſe natural Curioſities.

B. It is this: Sir *Iſaac Newton*, by Experiments, hath found that the *Colours of Light*, with Reſpect to their Quantity, were in Proportion to the *ſeven muſical Notes*, or *Intervals of Sound*, contained in an *Octave*, viz. *Sol, la, fa, Sol, la, mi, fa, Sol.* *Fig.* XIII. of *Plate* VIII, fronting *p.* 120.

A. A Diſcovery indeed! ſure the happieſt Man that ever lived for Experiment. What! muſical Harmony in *Colours!*

B. Yes, he diſcovered it thus: He cauſed a Sun Beam to be largely refracted on the Side of a dark Chamber, which produced the *Spectrum of Colours*, repreſented by ABCDEF; in which he cauſed an Aſſiſtant exactly to mark the Confines of each *Colour*, by drawing parallel Lines betwixt each, as *am*, *bi*, *ck*, *&c.* and Thus the Spaces V, I, B, G, Y, O, R repreſent the Quantity of the reſpective *Colours*, viz. *Violet*, *Indigo*, *Blue*, *Green*, *Yellow*, *Orange*, and *Red:* And upon a nice Examination, he found the parallel Sides of the *Spectrum* AF and CD to be divided in the Points *a*, *b*, *c*, *d*, *&c.* juſt in the Proportion as a muſical Chord is divided for the Concords of an *Octave*, *viz.* as the Intervals of theſe Numbers, $1.\ \frac{8}{9}.\ \frac{5}{6}.\ \frac{3}{4}.\ \frac{2}{3}.\ \frac{3}{5}.\ \frac{9}{16}.\ \frac{1}{2}$ *.

A. This

* See Sir *Iſaac's* Optics, *Book* I. *Part.* II. *Prop.* 3. where you have not only the Original of this excellent Diſcovery, but alſo a Method deduced from thence to determine of the Sines of Refraction proper to each of thoſe Colours. For when the Sine of Incidence was 50, he found the Sine of Refraction for the leaſt

A. This would induce one to think there were ſome Kind of Relation between *Muſic* and *Colours*; ſince it hence appears, that in Nature, the pleaſing Notes of the one, and the Quantities of the other, are in the ſame Proportion, and both deſigned to delight and pleaſe Mankind, and ſooth the Cares of Life.

B. One Thing more I muſt remind you of, and that is this: Some Perſons tell us, *Colours* are tangible Qualities, and may be diſtinguiſhed by *Feeling*, and give an Inſtance of one that could and did do it: But this is certainly impoſſible to do naturally; and therefore if any one ever did do it, he muſt have a miraculous *Gift of Feeling**.

leaſt refangible, or reddeſt Rays, was 77; and for thoſe which were moſt ſo, or deepeſt Violet, was 78; and for the intermediate Colours he found

The Sides of	Red	Rays extended from	77 to $77\frac{1}{8}$
	Orange		$77\frac{1}{8}$ to $77\frac{1}{5}$
	Yellow		$77\frac{1}{5}$ to $77\frac{1}{3}$
	Green		$77\frac{1}{3}$ to $77\frac{1}{2}$
	Blue		$77\frac{1}{2}$ to $77\frac{2}{3}$
	Indigo		$77\frac{2}{3}$ to $77\frac{7}{9}$
	Violet		$77\frac{7}{9}$ to 78.

* Mr. *Derham*, in his *Phyſico-Theology* (Page 144) aſſerts, that Colours may be diſtinguiſhed by the *Touch*, or *Senſe of Feeling*; and to confirm this, relates a Story (from *Grimald. de Lum. & Col.* Pr. 43, § 59.) of one at the Court of the Duke of *Tuſcany*, who on a Piece of Silk uniformly woven, and tinged with many Colours, being offered to him, did truly, by that Senſe only, judge of the Colours of every Part.——But ſince Colours are but *Qualities*, and no *material* Eſſences, I cannot be induced to believe this extraordinary Perſon could diſcern Colours merely as ſuch by Feeling, but rather from ſome ſmall Differences in the Surface of Silks and other Bodies tinged with various Colours, and occaſioned thereby; which is a Thing that not only he, but many, who deal in dyed Commodities, have been able to do alſo.

CHAP. VIII.

Of Sound.

B. LET us next entertain ourſelves with a Conſideration of the Nature and Property of *Sound*; for this is no barren Part of Nature, nor a uſeleſs Speculation, the Curious know.

A. Come on then, *Sir:* If you are not tired, I never ſhall with theſe noble Diſquiſitions and Enquiries; and pray tell me, firſt, wherein *Sound* doth conſiſt?

B. *Sound* is the undulatory or wave-like Motion of the Air, ariſing from the *tremulous* Motion of the Parts of any Body, occaſioned by a Stroke; and thoſe Undulations or Pulſes of the Air beating on the *Tympanum*, or Drum of our Ears, convey, by the Nerves, this Senſation to our Minds *.

How doth it happen that one and the ſame *Sound* may be heard by ſo many at once, and in different Places?

* Let AB be a String ſtrained and fixed at the Ends A and B; and then let it be drawn out of its natural Poſition AB into another ACB; if then it be let go, it will by its Elaſticity not only fly back again to its firſt Poſition AB, but in another ADB, which is ſo far above AB, as ACB was below it; after this, it will return again almoſt to C, and then return almoſt to D; and theſe *Courſes* and *Recourſes* of the String growing leſſer and leſſer above and below AB, it will at laſt ſettle into its firſt and natural Poſition, and be again at reſt. And this is what is called the *Vibration* of a Chord or String drawn tight, and ſtruck, as in muſical Inſtruments. See *Fig.* XXVI. of *Plate* V, fronting *p.* 75.

B. Becauſe the Vibrations and Tremors of the Air, excited by the Percuſſion of any Body, are propagated in concentric Spheres all around the ſaid Body (which is their common Centre) to very great Diſtances; and therefore let a Perſon be any how, or any where ſituated within the Verge of thoſe Motions, he will equally hear the *Sound*, at equal Diſtances from the Body whence it comes: See *Fig.* XIV. of *Plate* VIII, fronting *p.* 120, where DD repreſents a Drum, and D, 1, 2, 3, 4, 5, *&c.* the circular Pulſes of the Air, made by and conveying the *Sound* of the Beats to our Ears*.

A. How is it to be proved, that Air is thus the Medium of *Sound?*

B. By the Experiment of a Bell in the Receiver in an *Air-Pump*, which, before the Air

* As there is a manifeſt Agreement between *Light* and *Sound* in many Particulars, ſo it is moſt of all conſiderable in *Reflection* from hard Bodies. For as Light is rendered more intenſely bright and hot, by being reflected from the concave Surfaces of Mirrours to a certain Point (*viz.* the *Focus*) where the Rays are crouded into a leſſer Space; ſo Sound being uttered within a long and narrow Space, as that of the *Stentorophonic* Tube, or Speaking Trumpet, is continually reflected, and reverberated from the curved Sides into the Axis, whereby it becomes more intenſe and ſtrong at its Exit, is conſequently much louder, and may be heard much farther, than it could be otherwiſe.

Thus alſo, if a ſmall Sound or Whiſper be uttered at one Side of a large *Dome*, or concave Hemiſphere, (as at the Whiſpering Gallery in St. *Paul's*) ſuppoſe at the Point A, (*Fig* XXV. of *Plate* V, fronting *p.* 75) then ſhall all the Sound ſtriking againſt the whole hemiſpheric Concave be reflected to the Points B, B, B, *&c.* and from thence to C, C, C, *&c.* and, after ſeveral ſuch Reflections, will all be united in the oppoſite P; where the Sound will be much more ſtrong, loud, and audible, than at any other Point in the whole Dome or Concave. See *Clare's* Motion of Fluids, *Page* 341.

is exhausted, may be heard to a considerable Distance; but when exhausted, can scarcely be heard at the nearest Distance *.

A. What Velocity of Motion hath *Sound?*

B. Very great, but not near so great as that of Light: Mr. *Derham* has found by Experiment, that the mean *Velocity* of Sounds is at the Rate of 1142 Feet in one Second of Time, or a Mile in $4\frac{1}{2}$ Seconds; and therefore would take up $17\frac{1}{2}$ Years in passing from the Earth to the Sun, which is near double the Velocity of a Bullet, at its first Discharge from the Cannon †.

* This Experiment shews also, that Sounds are augmented or diminished proportionally as the Air is condensed or rarefied. Thus it is known Sounds are weaker on the Tops of high Mountains, where the Air is more *rare*, than in low Vallies, where it is more *condensed* by the Weight of the superincumbent Atmosphere. See *Varen.* Geog. Gen. lib. I. cap. 19. Prop. ult.

† According to	Sir *Isaac Newton*	968	Feet in a Second of Time.
	The Hon. Mr. *Fr. Roberts*	1300	
	Mr. *Boyle*	1200	
	Dr. *Walker*	1338	
	Mersennus	1474	
	The *Florentine* Academy	1148	
	The *French* Royal Academy	1172	
	Flamstead, Halley, Derham	1142	

But the Reader may depend on the last, *viz.* 1142, as very just for a mean Rate of Velocity.

Several good Uses may be made of the Knowledge of the Velocity of Sound. Thus by it we can easily measure the Distance of the Clouds producing *Thunder* and *Lightning*; for suppose from the Moment we observe the Flash to the Moment we hear the Stroke of Thunder, we number four Seconds, then it is plain the Sound has come four Times 1142, *i. e.* 4568 Feet, or somewhat above $\frac{1}{4}$ of a Mile; and so far distant is the Cloud. In like Manner the Distance of Ships on the Sea, &c. is known by *Firing of Guns.*

A. Can

A. Can you certainly tell how far *Sounds* may be heard?

B. Indeed this is a Matter not altogether certain; but there are Reports of *Sounds* (as the Explosions of great Guns, *&c*) which have been heard to the Distance of 180 or 200 Miles *.

A. Doth not the Wind greatly obstruct the Motion of *Sound?*

B. No, not so much as one would imagine; tho' there is some small Difference in the *Velocity of Sound,* with or against the Wind; but *Sound* is greatly augmented or diminished by the Strength or Weakness of the Wind.

A. Is there any Difference in the Motion of great or small *Sounds?*

B. Mr. *Derham* says, none at all; whether they be loud or languid, of Bells, Guns, *&c.* great or small, or any other sonorous Body.

A. How do you estimate the Greatness or Intensity of *Sound?*

* Mr. *Clare* says, a Gentleman of great Veracity, who had lived some Years at *Gibraltar,* affirmed to him, that he has at *Old Gibraltar* heard the Watch-word of the Night (viz. *All's well)* given by the Centinel to the Patroll on the Ramparts of *New Gibraltar,* in a still serene Night, and the Water perfectly smooth, and that as plain and distinctly, he thought, as he should have done had he been on the Rampart himself. The Bay between the two Places he judged to be about three *Spanish* Leagues over, or above 10 Miles and a half. Motion of Fluids, Page 343, 344. *Derham's* Physico-Theol. Book 4. Chap. 3. Note 27. where he tells us from Dr. *Hearn,* that Guns fired at *Stockholm* in 1685 were heard 180 *English* Miles; and in the *Dutch* War, 1672, the Guns were heard above 200 Miles. See also his curious Experiments on Sound, in the Phil. Transactions, No. 300; and *Harris's* Lex. under the Word *Sound.*

B. That, *Sir*, is always as the Space paſſed through by the Particles of undulating Air, in their paſſive Motion backward and forward *.

A. What farther have you to obſerve concerning the Motion of *Sounds?*

B. They fly equal Spaces in equal Times, and nothing but the Wind can accelerate or retard them; not the Differences of *Day* or *Night*, *Summer* or *Winter*, *Heat* or *Cold*, *Weather* cloudy or clear, the *Air* heavy or light, *&c.*

A. Pray, *Sir*, tell me the Reaſon why, after the *Stroke*, the *Sound* of ſome Bodies, as Bells, the Strings of muſical Inſtruments, *&c.* continues ſo long, but weaker and weaker?

B. The *Sound* of Bodies endures in Proportion to the Number of Vibrations made therein by the *Stroke*, each Vibration producing a Wave in the Air, and each Wave repeating the *Sound*; but ſtill more and more faint, as the Vibrations are leſs and leſs, till they entirely ceaſe: This is eaſy to be obſerved by the Ear in Bells, and by the Eye in a String under Tenſion.

A. There is one Thing more I had almoſt forgot to enquire the Reaſon of, tho' I gueſs

* In a warm and rarefied Air, whoſe *Elaſticity* is therefore ſmall, the Strength or Intenſity of Sounds is not near ſo conſiderable as in a cold and denſer Air, when the Elaſticity thereof is much greater.

The Velocity of Sound is 52 Times greater than that of a briſk Wind, or Current of Air; and (as Mr. *Hales* aſſerteth) it is to that of undulating Water as 865 to 1.

how

how it muſt be; but I beg your Thoughts of it, *Sir*; is it an *Echo*?

B. This, *Sir*, is no more than the Repetition of *Sound*, made by a Reflection or Repercuſſion of a Wave of *Sound*, from the Surface of very hard and ſmooth Obſtacles, as Walls, *&c.* whence flying back, it re-ſalutes our Ears with the ſame *Sound* *.

A. This

* 1. The Angles of Incidence and Reflection are equal, as well in the Caſe of Sound as Light; and therefore it is eaſy to underſtand where the *Echo* will be heard moſt diſtinctly, when the Figure of the reflecting Surface and Situation of the Speaker is known.

2. Thus let AB be the plane Side of a Tower (*Fig.* XXVIII. of *Plate* V, fronting *p.* 75.) GH the Declivity of a Hill before it; let a Perſon utter a Voice at D, and ſuppoſing EC perpendicular to the Plane AB, and the Angle DCE equal to the Angle ECF, the Echo of that Voice will be heard at F.

3. The Diſtance of the Object returning, the *Echo* of one Syllable muſt be 24 Paces, or an 120 Feet; and for the *Echo* of two Syllables 28 Paces, or 240 Feet, and ſo on in a direct Proportion; ſo that an Object returning the *Echo* of 10 Syllables muſt be diſtant 240 Paces, or 1200 Feet.

4. The famous *Echo* in *Woodſtock Park*, near *Oxford*, returned 17 Syllables in the Day, when the Wind was a little ſtirring, and 20 in the Night; for then the Air being denſer, the Vibrations became ſlower, and ſo a Repetition of more Syllables were audible; as Dr. *Plot* relates in his *Nat. Hiſtory of Oxfordſhire.*

5. Dr. *Harris* ſays there is a much finer *Echo* from the North Side of *Shipley* Church in *Suſſex*, which in the Night would repeat diſtinctly theſe 21 Syllables:

Os Homini ſublime dedit Cœlumque tueri
Juſſit, & erectos——

See his *Lex. Tech.* under the Word *Echo*.

Note, (1.) That the Object AB, which reflects the Sound, is called the *Phonocamptic* Object; and the Point C, on which the Sound impinges, is called the *Phonocamptic* Centre; from the *Greek* Word φωνὴ a Voice or Sound, and κάμπτω, to bend or inflect.

A. This is juſt as I apprehended it to be: But pray, *Sir*, whence ariſeth the great Variety in the Note or Tone of *Sounds?*

B. The Notes and Tones of *Sound* ariſe from the peculiar Nature of the ſonorous Body, the Manner and Degree of Percuſſion, and the different Make and Configuration of the Organ or Inſtrument of *Sound*; all theſe contribute to make that wonderful Variety and Difference in the Tunes, Notes, or Tones of *Sound* *.

A. Why

Note, (2.) That as the Science of Viſion is called *Optics*, ſo the Science of Sound or Hearing is called either *Acouſtics*, from ἀκέω, to hear; or *Phonics*, from φωνὴ, a Voice or Sound. Alſo *Catacouſtics* is that Part which treats of *reflected* Sounds, Echo's, &c. and *Diacouſtics*, the other Part which explains the Nature of refracted Sounds; and laſtly, thoſe Inſtruments which are uſed to aſſiſt or improve the *Senſe of Hearing*, are called *Otacouſtics*, from ὂς, ὠτὸς, an Ear, and ἀκέω, to hear.

* I ſhall here obſerve a few Things concerning *Sound* conſidered as the Subject of the excellent Science of *Muſic*.

1. Sounds, as they are more *intenſe* or *remiſs*, are ſaid to be *loud* and *low*, or *ſtrong* and *weak*, which depends on the *Nature* of the ſonorous Body, its *Figure*, the *Force* of *Percuſſion*, &c.

2. The ſame *loud* or *low Sound* hath divers Degrees of *Note* or *Tone*, which are in the Extremes called *Acuteneſs* and *Gravity* of the Sound; in the lower Degrees, the Note or Tone is *grave*, *flat* or *low*; in the higher, it is *acute*, *ſharp* or *high*.

3 The Degrees of *Acuteneſs* and *Gravity* make all the different and diſtinguiſhable *Tones* or *Tunes* of a Voice or Sound; which are the component Parts of *Harmony*.

4. Sound is again diſtinguiſhed into *long* and *ſhort*, which relates to the Duration or Continuance thereof.

5. Farther, Sounds are *Simple* or *Compound*: A *Simple* Sound is the Product of *one Voice*, or individual Body, as that of one Wire or Word. A *Compound* Sound conſiſts of ſeveral ſimple ones, all united in the ſame Meaſure of Time, or ſtriking the Ear all together: As the various Notes ſtruck at the ſame Time on different Inſtruments in a Concert.

6. Laſtly,

A. Why is it that ſome Notes, called Concords, are agreeable to the Ear, and others we call Diſcords, diſagree thereto?

B. We

6. Laſtly, Sounds are either *ſmooth* and *even*, or *rough* and *harſh*; alſo *clear* and *diſtinct*, or *hoarſe* and *obtuſe*. To produce a ſmooth, even, and clear Sound, the Body muſt be homogeneous in its Parts, and of an uniform Figure throughout; otherwiſe, rough, obtuſe, and grating Sounds will enſue. The former of theſe are only concerned in *Muſic*, and are therefore called *harmonic*, or *muſical Sounds*.

7. As Sounds are produced by the *Vibrations* of the Parts of Bodies, and *Strings* or *Chords* are the moſt ſimple and proper Subjects to examine theſe Matters in; ſo it has been found that the following Articles, reſpecting *Chords* and their *Vibrations*, are founded in Nature, and confirmed by repeated Experience.

8. The Forces requiſite to draw any Chord or String ACB out of its Place (*Fig*. XXIX. of *Plate* V, fronting *p*. 75.) to the Diſtance of *ce*, *cf*, *cg*, are directly proportional to the Spaces, or Lines, *ce*, *cf*, *cg*.

9. The Vibrations, therefore, of the ſame Chord are all performed in equal Spaces of Time; that is, the Chord will return from the Situation AgB as ſoon as from A*e*B to ACB, becauſe the Force at *g* is as much greater than the Force at *e*, by which it returns, as C*g* is greater than C*e*.

10. If Chords differ only in *Tenſion*, the Times of their Vibrations are inverſely as the Square Roots of the Weights which ſtretch them; that is, if the Weights are as 4 to 9, the Times will be as 3 to 2.

11. The Number of Vibrations in the *ſame Time*, are directly as the Square Roots of the Weights; that is, as 2 to 3, in the preceding Caſe.

12. The Number of Vibrations made in the ſame Time by two Chords differing in Thickneſs, are as the Diameters of their Baſes inverſely.

13. If Chords differ only in *Length*, the Times of their Vibrations are directly proportional to their Lengths; and the Number of Vibrations in the ſame Time are inverſely as the Lengths.

14. Hence Chords of different Tenſions, Diameters, and Lengths, may be ſo adjuſted, by compounding the foregoing Ratios, that the Times of their Vibrations ſhall be in any given Proportion; which is of great Uſe in ſtringing Inſtruments, as the *Spinet*, *Harpſichord*, &c.

 15. As

B. We may ſay, they are ſo from the Agreement or Diſagreement of the different Motions

15. As the *Tune* of a Note or Sound is conſtituted by the Meaſure and Proportion of Vibration, in reſpect of their Velocity, the quicker Vibrations making the *acuter* Tone, and the ſlower the *graver* one; ſo it follows, the Tune of any String's Note will be *acuter* or *graver*, in Proportion as it is *ſmaller* or *greater*, *ſhorter* or *longer*, *tighter* or *ſlacker*.

16. Two or more Notes or Sounds being made together, are called a *Conſonance*; if the Sounds are of the ſame Tune, they are called *Uniſonance*; if of different Degrees of Tune, *i. e.* of *Acuteneſs* or *Gravity*, but yet make an Effect agreeable to the Ear, they are called *Concordance*; otherwiſe *Diſſonance*.

17. A *Concord*, therefore, is the Agreement between two Sounds or Notes of different Times, either in *Conſonance* or *Succeſſion* of Sound; ſuch as is pleaſing and delightful to the Ear.

18. As the Vibrations of Chords are the Cauſe of Sounds in general, ſo the *Coincidences* of the Vibrations of Chords are the Reaſon and Ground of *Concordance*: If there be two Chords, A, B, whoſe Lengths are as 4 to 3, then it is plain (by the 13th hereof) that while the Chord A makes three Vibrations, the Chord B will make 4; and therefore ſuppoſing them to begin together, there will be conſtantly at every three Vibrations in A, and four in B, a *Coincidence* of Vibration; that is, they will then vibrate together, and begin each Period of Vibration ſo long as they continue in Motion. This makes them concord with each other, and produce an agreeable Sound.

19. The more frequent theſe *Coincidences* are, the more agreeable is the Conſonance; and therefore Uniſon is the firſt Degree of *Concord*, becauſe there the Vibrations begin and end together: this is expreſſed by the *Ratio* of one to one, *viz.* 1:1. Next to this the Ratio of 1:2 is the moſt agreeable and perfect *Concord*, and then 2:3; after which, the Concordance becomes leſs perfect and pleaſant in the Ratios 3:4, 4:5, 5:6, beyond which the Conſonance is inſufferable; for in theſe the Coincidences of Vibrations become leſs frequent.

20. Beſides theſe Ratios of Concord found in the natural Order of Numbers, 1:2:3:4:5:6, there are ſome others, *viz.* 3:5, and 5:8, which the Ear adjudgeth Concords, tho' in a lower Degree. And hence, it is plain, there is ſomewhat beſides the Frequency of the Coincidences of Vibrations, that qualifies the Ratio for Concordance or pleaſing Sound; for elſe

Motions in the Air producing them; but a Person

4 : 7, or 5 : 7, both Discords, would be preferable to 5 : 8, a Concord contrary to Experience.

21. If one certain String be struck, in order to compare the Sounds of others with its own, it is called the *Fundamental*; and its Note is called the *Key* or *Key Note*. A Table of all the Concords between the *Ratio* of *Unison* 1 : 1, and the *Octave* 2 : 1, expressing the Lengths, Vibrations, Coincidences, Names, and Perfections thereof, you have here subjoined.

Length.	*Vibrat.*	*Coin.*			*Names.*	*Perfection.*
1 : 1	1 : 1	1	100	1000	Unison.	Most Perfect.
6 : 5	5 : 6	5	120	833	Third Lesser.	Imperfect.
5 : 4	4 : 5	4	125	800	Third Greater.	Imperfect.
4 : 3	3 : 4	3	133	750	Fourth.	Imperfect.
3 : 2	2 : 3	2	150	666	Fifth.	Perfect.
8 : 5	5 : 8	5	160	625	Sixth Lesser.	Imperfect.
5 : 3	3 : 5	3	167	600	Sixth Greater.	Imperfect.
2 : 1	1 : 2	1	200	500	Octave.	Perfect.

22. This Table wants but little Explanation; take an Example of the 5th; the Length of the Chords sounding this Concord must be as 3 to 2; their Vibrations then performed in the same Time, will be as 2 to 3; the Coincidence of these Vibrations will be at every 2d Vibration of the Fundamental; the Chord, which is a 5th, makes 150 Vibrations, while the Fundamental makes 100. The same Chord is 666 of such equal Parts as the Fundamental contains 1000. It is called a *Fifth*, as being the 5th Note from the *Key* inclusive; and is a *perfect* Concord.

23. To divide a Right Line so as to exhibit the seven Concords, is very easy; for let AB be the given Line, (*Fig.* XXX. on *Plate* V, fronting *p.* 75.) divide it into two equal Parts in C; and divide CB into two equal Parts in D; and lastly, divide CB into two equal Parts in E.

Then is	AC to AB	as	1 : 2, An Octave.
	AC to AD		2 : 3, A Fifth.
	AD to AB		3 : 4, A Fourth.
	AC to AE		4 : 5, A Third Greater.
	AE to AD		5 : 6, A Third Lesser.
	EB to AE		3 : 5, A Sixth Greater.
	AE to AB		5 : 8, A Sixth Lesser.

24. Of

Perſon is little the wiſer for that: I therefore
reſolve

24. Of theſe ſeven Concords, three of them are *ſimple*, the reſt *compound*. The ſimple Concords are 5 : 6, a third leſs, 4 : 5, a third greater, and 3 : 4, a fourth; for theſe cannot be parted into any other Concords, by putting any *mean Number* (whether *Arithmetical* or *Harmonical)* between the Terms of the Ratios.

25. But the other four Concords are compoſed of the ſimple ones, as is plain by interpoſing an *Arithmetical* or *Harmonical Mean*, or both, between the Terms of the Ratios of theſe Concords, as in the following Table.

With Arithmetical Means.

A Fifth, or 2 : 3, contains 4 : 5 : 6, a 3d greater and 3d leſs.
A Sixth, G. or 3 : 5, contains 3 : 4 : 5, a 4th and 3d greater.
An Octave, or 1 : 2, contains 2 : 3 : 4, a 5th and 4th.

With Harmonical Means.

A Fifth, 2 : 3, contains 10 : 12 : 15, a 3d leſſer and 3d greater.
A Sixth, G. 3 : 5, contains 12 : 15 : 20, a 3d greater and 4th.
An Octave, 1 : 2, contains 3 : 4 : 6, a 4th and 5th.
Alſo between the Terms of a Sixth leſſer, 5 : 8, you put the Mean 6, it reſolves it into 5 : 6 : 8, a 3d leſſer and 4th.

26. If between the Extremes of the *Octave* 6 : 12, we put an Arithmetical Mean 9, it reſolves it into 6 : 9 : 12, a 5th and 4th. If you put an Harmonical Mean 8, it reſolves it into 6 : 8 : 12, a 4th and 5th. If both the Means are interpoſed, the Series will be Geometrical, *viz.* 6 : 8 : 9 : 12. Thus it appears, that a 4th and 5th are the two Concords that the Octave is immediately reſolvable into.

27. The Relations of a 3d, 4th, 5th, 6th, an Octave, to the *Fundamental*, are called *Primary Relations*, and are Concords therewith, as we have ſeen: But the Relations of Concords to each other, are called *Muſical Relations*, and theſe ought to be all *concord*, to make or ſtand together in Harmony. Thus the 3d greater, 5th and Octave, make perfect Harmony; for the 5th is to the 3d greater, as 5 : 6, a 3d leſſer; the Octave to the 3d greater, as 5 : 8, a Sixth leſſer; the Octave to the 5th, as 3 : 4, a Fourth. But the 4th, 5th, and Octave, cannot make Harmony, becauſe the Ratio of the 5th to the 4th is as 8 : 9, which is a Diſcord.

28. *Har-*

resolve it into the Will, Power, and Goodness
of

28. *Harmony* is a compound Sound, consisting of three or more simple Concords in Consonance, and therefore all *Discords*, in the *primary Relations* especially, and also in the *mutual Relations* of the acute Terms of the Ratios, are absolutely forbidden. Though it is true, Discords are used in *Music*, yet their Use is only to make the *Concords* appear more agreeable by the Opposition.

29. The *Intervals* of Concords are termed *harmonious*; the *Intervals* of *Discords* are of two Sorts; the first are called *Concinnous Intervals*, because they are fit for Music in Combination with those of the *Concords*, being in themselves neitheragreeable nor very disagreeable. They arise from the Differences of the Concords. Thus the Difference between a 4th and a 5th, *viz.* $\frac{3}{4}$ and $\frac{2}{3}$, is $\frac{8}{9}$, or 8 : 9; this constitutes the Note which is called the *Second greater* from the *Fundamental*, and the Difference between a 3d greater and 4th, is 15 : 16, and this makes the *Second lesser*, which is the very next the *Fundamental.*

30. The Ratio 8 : 9 is called a *greater Tone* or Interval, 9 : 10 a *lesser Tone*, and 15 : 16 a *Semitone*, or rather, an Interval greater than half, and less than a whole Tone. Now if from a *lesser Tone* 9 : 10 (the Difference of a 3d lesser and 4th) you take an Octave 1 : 2, there will remain the Ratio 5 : 9, which is the Note above the 6th greater, *viz.* the *Seventh lesser*; and the *Seventh greater* is the Difference between the Semitone 15 : 16 and the Octave 1 : 2, *viz.* the Ratio 8 : 15. And thus you have all the Intervals both *Harmonious* and *Concinnous* which constitute the Notes in present Use; the rest are all inconcinnous, which produce very harsh Notes, or gross Discords, too bad to be used in Music.

31. The First or *Fundamental* Note of any Tune or Song, is called the *Key*, as being that to which all the Notes in the Melody of that Song are referred, and by which they are governed and regulated. In this Key the Melody generally begins, and always closes. The Key is distinguished into two Kinds, *viz.* the *Flat* and *Sharp Key*.

32. The *Flat Key* is that which hath always the 2d greater, 3d lesser, 4th, 5th, 6th lesser, 7th lesser, and Octave; the *Sharp Key* has the 2d greater, 3d greater, 4th, 5th, 6th greater, 7th greater, and Octave. Whence it is plain, that the *Air* or *Tone* of the Melody in the Flat Key is a *half Note lower* than it is in the Sharp Key; and is therefore more suited to, and generally used in the *melancholy* and *mournful*, than *brisk* and *airy* Tunes, which the other Key is adapted to, being half a Note higher.

33. These

of the great Creator, who, doubtless, designed the pleasing Harmony and Melody of *Sounds* to

33. These *seven natural Notes* are generally represented by the seven letters, A, B, C, D, E, F, G, in a single Octave. If the Key be *Sharp*, the 3d, 6th, and 7th above have this Mark (*) affixed to the Characters of these Notes to denote it; as thus, if A be the Key, A, B, C*, D, E, F*, G*; or if the Key be *Flat*, they have this Mark (^{b}), as A, B, C, D, E, F, G^b.

34. This Division of the Octave is most natural, and because it contains three *greater Tones*, two *lesser Tones*, and two *Semitones*, is called the DIATONIC SCALE of Music, but more vulgarly the GAMUT, from the Name of the lowest Note therein.

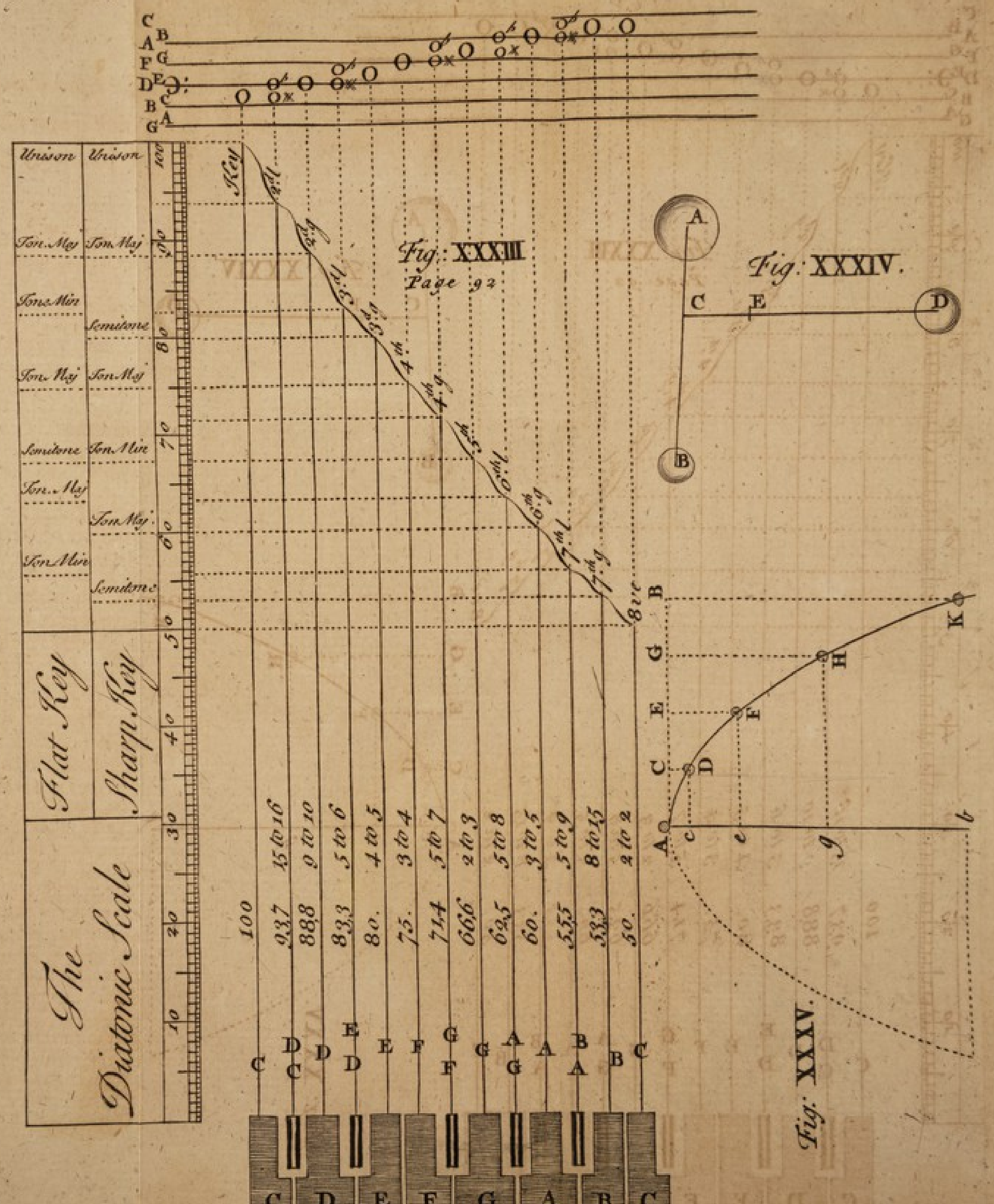
35. The *Gamut* contains three Parts, called *Clifts*, the *Base*, the *Tenor*, and the *Treble Clifts*, as represented in *Fig.* XXXI. of *Plate* V, fronting *p.* 75; each Part singly contains five Lines, on which, and in the Spaces between them, are wrote the Characters of the Notes. The Marks of the Clifts, and Names of each Part, you there see expressed. Part of the Tenor is common to the Base below, and the Treble above.

36. Musicians, in writing Music, use various Characters to express Notes of different Length of Time, as *Breve*, *Semibreve*, &c. any one of which contains two of the next below, in *common Time*; but in what is called *Triple Time*, a Semibreve contains $1\frac{1}{2}$ *Minum*, 3 *Crotchets*, 6 *Quavers*, &c. See *Fig.* XXXII. of *Plate* V, fronting *p.* 75.

37. I have thought it expedient to illustrate the foregoing Rudiments of the Theory of Music, by an Example of an Octave in the Base Clift of a *Spinet* (*Fig.* XXXIII. of *Plate* VI, fronting *p.* 92.) where you observe a Scale divided into an 100 equal Parts; opposite to which are placed the Strings which sound the 12 Notes or Semitones of the Octave; at the lower End, are the Keys of the seven natural Notes, marked with the Letters C, D, E, F, G, A, B, C, between which are the other Keys of the Semitones. The Key Note is C, with respect to which the Strings of the other Keys are proportioned in Length, as they are 2d, 3d, 4th, *&c.* to it. On each String are Numbers, shewing how many equal Parts of the Scale it contains; and others which shew the Ratio of its Length to that of the Key or Scale. From the Ends of the Strings go dotted Lines to the Notes of a Tune wrote in the *Gamut*, in their proper Lines and Spaces. On the left of the Scale of equal Parts is the *Diatonic Scale*, shewing, both in the *Flat* and *Sharp Keys*, the Intervals of the *Tones* and *Semitones*, and their Order in each.

38. Thus

To front Page 92. Plate VI.



to ſweeten and heighten the Pleaſures of human Life, and to alleviate and diſpel its Cares *.

38. Thus much ſhall here ſuffice for a ſhort Sketch of the *Theory of Muſic*; they who would ſee more, may read Dr. *Holder*'s Grounds of Harmony; *Salmon*'s Theory of Muſic, in Philoſ. Tranſ. No. 302; *Malcolm*'s excellent Treatiſe of Muſic; *Jackſon*'s large Scheme of Muſic; and *Harris*'s Lex. Tech. under the Word *Muſic*; beſides various others.

* Among all the wonderful Effects aſcribed to the Power of Muſic, none is more ſurpriſing and important than that of curing the venomous Bite of the *Italian* Spider, called the *Tarantula*. The Part bitten is ſoon affected with a very *acute Pain*, and a few Hours after with a *Numbneſs*; upon which enſues a profound Sadneſs, and a difficult Reſpiration; the Pulſe grows weak, the Sight is diſturbed, and the Perſon loſes Knowledge, Senſe, and Motion. The Doctor is conſulted in vain; the Muſician here alone performs the Cure; he tries a Variety of Airs, and when he chances to hit on that Harmony that accords with the Patient, he begins to move by Degrees, and keeps Time with his Fingers, Arms, Legs, and Body; then he raiſes himſelf up and dances, increaſing in Strength and Activity. This dancing Fit continues ſix Hours, or a Day, or ſometimes two Days. When the Muſic ceaſes, the Perſon gives over dancing, and is put to Bed. This Proceſs is repeated till the Patient has recovered himſelf, which is by little and little; and every ſick Perſon has a particular Air or Tune, and always a very ſprightly one. See Philoſophical Converſation, *Vol.* II. *Conv.* 15. Alſo *Derham*'s Phyſico-Theology, *Book* IV. *Chap.* III. *Malcolm*'s Muſic, *Chap.* XIV. § 3. &c.

C H A P. IX.

Of GRAVITY *and* LEVITY: *Of* ATTRACTION *and* ELECTRICITY.

A. WHAT is meant by the *Gravity* of Bodies?

B. That Property, Power, or Force, whereby all Bodies tend downwards, in right Lines, to the Centre of the Earth.

A. Is not this what is called the *Weight* of Bodies?

B. No; for the *Weight* is properly the Effect of *Gravity*, or the Meaſure or Quality of this Power acting on them.

A. How do you diſtinguiſh the Kinds of this Property?

B. Into abſolute and ſpecific *Gravity*.

A. What is abſolute *Gravity*?

B. All that Power whereby a Body tends towards the Centre of the Earth.

A. And how doth ſpecific *Gravity* differ therefrom?

B. The ſpecific, or relative *Gravity*, is that which is peculiar and appropriate to any diſtinct Species of Bodies, and diſtinguiſheth them from others, when compared with them.

A. What is the Meaſure of *Gravity* in Bodies?

B. Their

B. Their Quantity of Matter; for their *Weight* or *Gravity* is always proportional thereto.

A. Pray what do you call that Point towards which Bodies naturally tend?

B. The Centre of *Gravity*, which is very near the Centre of our Earth, for all Bodies within its Verge or Power: And thus the Centre of *Gravity* of the Planets is ſaid to be near to the Centre of the Sun, about which therefore they all circulate *.

A. In what Manner doth this Power of *Gravity* act on Bodies?

B. Equally and abſolutely on all alike, without regard to their Figure, Size, or Quantity of Matter.

A. If ſo, one would think all Bodies would deſcend with equal Velocity or Swiftneſs.

B. So they would in Reality, were it not for the Reſiſtance of the Air.

* The common Centre of Gravity of two Bodies is a Point ſo ſituated in a right Line joining their Centres, that their Diſtances from it on each Side are reciprocally as the Quantities of Matter in the ſaid Bodies.

Example. Let A be a Body of 12 ℔, and B another of 4 ℔; join their Centres by the Line AB; then ſay, as A+B : A :: AB : BC, that is, As the Sum of the two Bodies 16 ℔ is to the greater 12 ℔, ſo is the whole Diſtance AB to the Diſtance BC, which gives the Point C, the common Centre of Gravity between them. If a third Body D of 6 ℔ be added, to find the common Centre of all the three Bodies A, B, and C; ſay, as A+B+D : D :: CD : CE, which gives E, the common Centre of all their Gravitation. In this Manner you find the common Centre of Gravity for any Number or Syſtem of Planets.

For the Common Centre of Gravity of Lines, Superfices, and Solids, ſee *Wallis*'s Mechanics, and other Writers on the mechanical and experimental Philoſophy, particularly Dr. *Deſaguliers*'s Courſe, Vol. I. Lect. 1ſt and 2d.

A. This

A. This is a ſtrange Aſſertion! Pray how do you prove it?

B. By the *Air-Pump*; for put the lighteſt Feather and a Guinea together in the Receiver, holding them faſt at the Top till the Air be exhauſted, then letting them go, you will perceive them deſcend to the Bottom in the ſame Moment of Time, and with incredible Swiftneſs.

A. This is indeed very curious and wonderful, and almoſt paſt Belief, that the lighteſt Bodies ſhould deſcend as ſoon as the heavieſt *!

B. Yes, they will *in vacuo* indeed; but in the reſiſting Medium of the Air, Bodies gravitate towards their common Centre, and one another, according to their different Quantity of Matter contained in them, as I ſaid before.

A. What, *Sir*, do you ſay that Bodies gravitate towards one another?

B. Yes, they do: The *Moon* gravitates to the *Earth*, and ſo does the *Earth* to the *Moon*;

* This may ſeem wonderful at firſt Thought, but the Wonder will ſoon ceaſe, if we only conſider, that each equal Particle of Matter is acted upon by an equal Force of Gravity, and that therefore every ſuch Particle in one Body muſt needs deſcend with the ſame Velocity that every ſuch Particle does in another. Conſequently, if the Matter of the Feather conſiſt of ten Particles, and that of the Guinea *ten Thouſand*, it is plain, that ſince there is 1000 Times more Particles in the latter Caſe to be moved than in the former, there will be required a thouſand Times greater Force of Attraction to move the Guinea, than to move the Feather, with the ſame Velocity; but this is all the Force that can poſſibly affect the *Guinea*; the Velocity of Motion therefore in both Caſes muſt be the ſame; it is the Quantity of Motion only in the Guinea, which is 1000 Times greater than that of the Feather.

the *Satellites* of *Jupiter* and *Saturn* to them; and *Jupiter* and *Saturn* gravitate to the *Satellites*; yea, the *Earth* gravitates or moves towards the *Stone* that falleth, as well as the *Stone* gravitates or moves towards the *Earth*.

A. Aye, indeed, why then, if the Earth moves towards all Bodies falling on it, how is it that we can never perceive it?

B. By Reason of the vast Disproportion of Matter in each; for suppose a Stone 100 solid Feet in Magnitude, let fall from a Height equal to our *Chichester* Spire, *viz.* 300 Feet; then because the Globe contains about 300000000000000000000000 solid Feet, and suppose the Earth every where to be of the same Density with common Stones, then the Quantity of Matter in the Earth will be to the Quantity of Matter in the aforesaid Stone of 100 Feet, as 3000000000000000000000 to 1; and therefore, while the Stone falls 300 Feet, the Earth will move towards the Stone the $\frac{300}{3000000000000000000000}$ or $\frac{1}{100000000000000000000}$ Part of a Foot; which is so very small a Matter, as to be not only imperceptible to the Senses, but inconceivable by the Imagination.

A. Very small indeed. But, *Sir*, now we are upon the Descent of heavy Bodies, pray at what Rate of Velocity doth a Body descend to any given Distance downright?

B. The perpendicular Descent of Bodies, is at the Rate of 15 Feet in one Second of a Minute; and for all the following Seconds,

 the

the Spaces are as the Squares of the Seconds: Thus, ſuppoſe a Body keeps falling 1, 2, 3, 4, *&c.* Seconds, the Squares of theſe Times will be 1, 4, 9, 16, *&c.* and the Spaces paſſed through at the End of each will be 15, 60, 144, 240, *&c.* and the exact Number of Feet paſſed through in each ſingle Second will be as the odd Numbers, 1, 3, 5, 7, *&c.* that is, 15, 45, 75, 105, *&c.* Feet; all which is diſtinctly and naturally ſeen in the Line AB, *Fig.* XV. of *Plate* VIII, fronting *p.* 140 *:

A. In

* 1. If then a Body were projected or thrown from the Point A in the horizontal Diſtance AB, it would, in an unreſiſting Medium, and without Gravity, proceed with an uniform Motion; and, in equal Times, deſcribe equal Spaces AC, CE, EG, GB, *&c.* But, ſince all Bodies have Gravity, the ſame Body A would with its Gravity alone, in the ſame equal Times aforeſaid, deſcend through the Space A*c*, *cg*, *eg*, *gb*, &c. Draw CD, equal and parallel to A*c*, and *c*D the ſame to AC; then, becauſe the Body A is urged with two Forces, one in AC, the other in A*c*, it will be carried in a Direction between both, and at the End of the firſt Moment will be found in D, the oppoſite Angle of the Parallelogram A*c*DC (according to Note * in Page 54.) Thus in two ſuch Moments, while it would have deſcribed twice the horizontal Space AE, or four Times the Perpendicular Space A*e*, by ſingle Forces, it would by Compoſition of thoſe be found in F. And ſo after three ſuch Moments it will arrive to H; after four to K, *&c.* Now ſince A*c*, A*e*, A*g*, A*b* are as the Numbers 1, 4, 9, 16, they are as the Squares of the Lines *c*D, *e*F, *g*H, *b*K. But this is the common Property of the *Parabola*, as all Writers on Conics demonſtrate. Therefore all *Projectiles*, or Bodies thrown in any Direction, deſcribe the Curve of a *Parabola* in their Deſcent.

2. On this Principle depends the *Art of* Gunnery; let AN be a Cannon (*Fig.* XXXVI. of *Plate* VII, fronting *p.* 99) elevated above the horizontal Level AM, in the Angle BAM; a Bomb diſcharged from the Muzzle A will leave the rectilineal Direction AB, and deſcribe the parabolic Curve AIM. AM is the Amplitude of the Projection, or horizontal Random of the Bomb; I, I, is the Height thereof. Now a ſkilful Engineer knowing the Diſtance of an Object, as the Spire S, can ſo

pro-

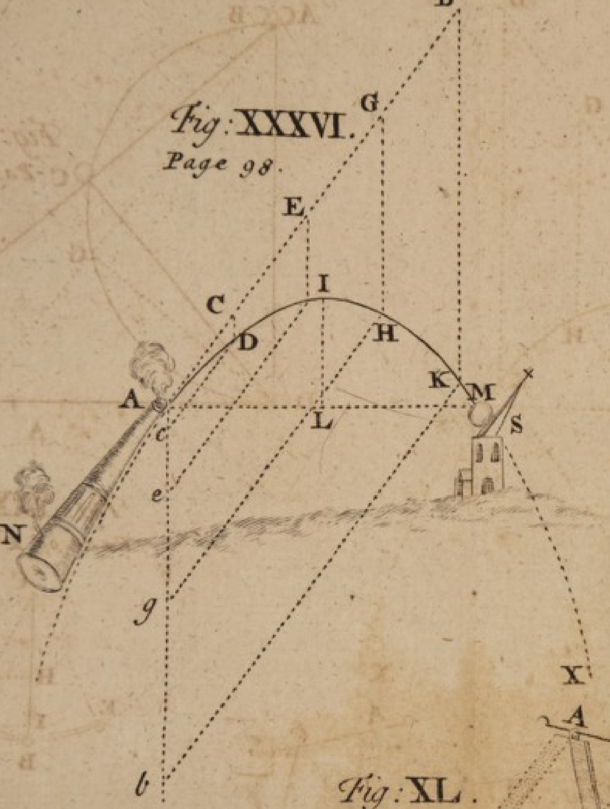


Fig: XXXVI.
Page 98.

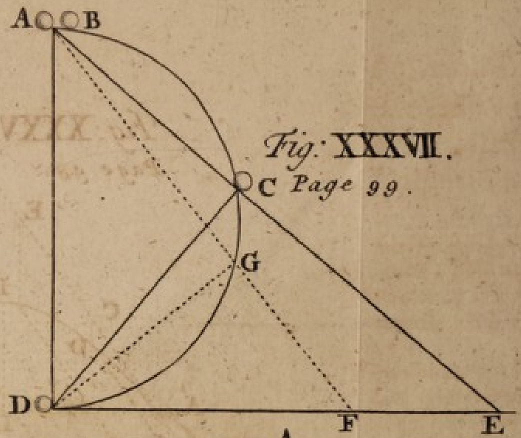


Fig: XXXVII.
Page 99.

Fig: XXXVIII.
Page 99 & 100.

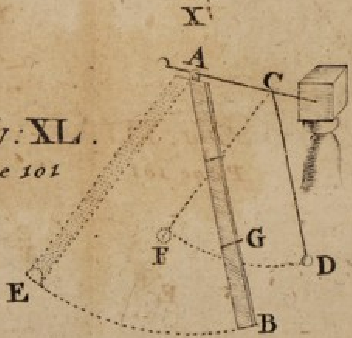


Fig: XL.
Page 101

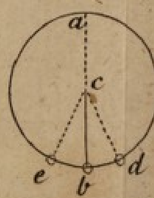


Fig: XXXIX.
Page 100.

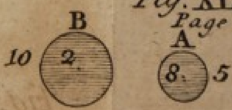


Fig: XLIII.
Page 100.

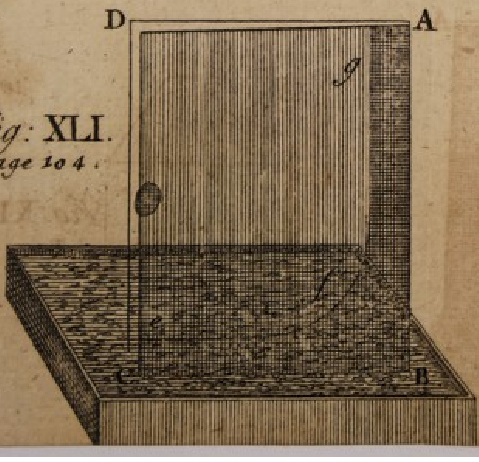


Fig: XLI.
Page 104.

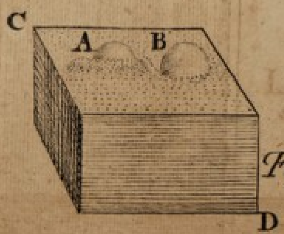


Fig: XLII.
Page 105.

A. In what Manner or Proportion does the *Weight* of Bodies increaſe or decreaſe, with reſpect

proportion the Charge of Powder, and the Elevation of the Mortar, that the projected Bomb M ſhall deſcribe ſuch a Parabola AIX, as ſhall paſs through the propoſed Object S, which therefore muſt be hit by the Bomb in its Courſe through that Curve.

3. Since a Body falling freely, deſcends with a Motion equally accelerated in equal Times, as proved by Experiments, and evident to Reaſon; and alſo ſince the Motion of a Body deſcending upon an inclined Plane is of the ſame Kind, as the Mathematicians prove (ſee *Keill's* Introd. Pag. 207) the Forces by which two Bodies, A, B, deſcend, one of which falls freely, the other B runs down an inclined Plane, if they begin to move in the ſame Moment, are always to one another in the ſame Ratio, as in the Beginning of the Fall, which Ratio is as the Length of the Plane AE to its Height AD (*Fig.* XXXVII. of *Plate* VII, fronting *p.* 99.) See the laſt Article of Note *, in Page 54.

4. The *Effects* of thoſe Forces, therefore, that is, the *Spaces paſſed through* by theſe Bodies in the ſame Time, are in the ſame Ratio of the *Length of the Plane to its Height.* On the Height of the Plane AD deſcribe a Semicircle ACD, this will cut the Plane in C; join CD; then, ſince the Angle at C is a right one, the Triangles AED and ADC are ſimilar, and ſo the Ratio of the Side AD to AC is the ſame as of the Side AE to AD. Conſequently, while the Body A deſcends freely to D, the Body will deſcend on the inclined Plane to C.

5. In the ſame Manner it is ſhewn, with reſpect to any other inclined Plane AFD, that while a Body A falls freely from the perpendicular Height AD, the Body B let go at the ſame Time, will arrive on the inclined Plane to the Point G. But AD is the Diameter of a Circle, and AC, AG, two Chords in the ſame; *therefore a Body falls through the Diameter, or any Chord of a Circle, in the ſame Time.*

6. Let AB be a String with a Weight B at the End, hanging freely from the Point C, (*Fig.* XXXVIII. of *Plate* VII, fronting *p.* 99) this is called a *Pendulum.* Let the Weight B be brought to the Point D, and there let go, it will by its own Gravity deſcend to its firſt Place B, and then with the Velocity acquired in that Deſcent will aſcend to E, ſo that BE will be equal to BD; and this Motion or *Swing* of the Body from D to E is called a *Vibration.*

7. The *Bob* or *Ball* of any *Pendulum,* vibrating freely, deſcribes the Arch of a Circle, as DBE, whoſe Diameter AB is twice the Length of the *Pendulum* CB. If the Arches BD, BE,

reſpect to their Diſtance from the Centre of *Gravity?*

B. The

are very ſmall, they do not ſenſibly differ from the Chords BD, BE; there the Deſcent of a Body through a *ſmall Arch*, and through its Chord, is performed in the ſame Time, as far as Senſe can diſcern. But the Deſcent of Bodies in any Chord is in the ſame Time, and *therefore all Vibrations of the ſame Pendulum, though unequal, are performed in the ſame Time.*

8. The Velocities acquired in the loweſt Point B, by a Body deſcribing different Arches DB, KB, are as the *Subtenſes* or Chords of thoſe Arches. See *Keill*'s Introd. Lect. 15. Theor. 37, and 43.

9. The Times of the Vibrations of two *Pendulums*, CB and *cb*, (*Fig.* XXXVIII. and XXXIX. of *Plate* VII, fronting *p.*99) are in the *ſubduplicate Ratio* (*i.e.* as the Square Roots) of their Lengths, for the Body deſcends from D to B, in the ſame Time it would fall freely through the Diameter of the Circle; *i. e.* twice the Length of the *Pendulum*; therefore it performs one Vibration from D to E in the ſame Time that it would fall by the Force of Gravity through four Times its Length CB. Thus alſo the *Pendulum cb* vibrates from *d* to *e* in the ſame Time it would fall freely through four Times its Length *cb*. But Spaces paſſed through in this Caſe, are as the Squares of the Times, and therefore the Times are as the Square Roots of the Spaces. Conſequently, the Time of a Vibration through DE, is to the Time of a Vibration through *de*, as the Square Root of four Times CB to the Square Root of four Times *cb*, or as the Square Root of CB to the Square Root of *cb*.

10. It has been found that a *Pendulum*, which ſhall vibrate Seconds of Time in our Latitude, muſt be $39\frac{2}{10}$ Inches in Length; if then it be required to find the Length of a *Pendulum*, that ſhall vibrate *half Seconds*; ſay, as the Square of 1 (which is 1) is to the Square of $\frac{1}{2}$ (which is $\frac{1}{4}$) ſo is $39\frac{2}{10}$ to $9\frac{8}{10}$ Inches, the Length of the *Pendulum* required. Thus the Length to vibrate Thirds of Seconds will be found $4\frac{35}{100}$ Inches; and the Length to vibrate quarter Seconds will be $2\frac{45}{100}$ Inches.

11. From hence it appears, that a *Pendulum* is an univerſal *Chronometer*, and that by it a Perſon may meaſure Time very truly when deſtitute of a Clock or Watch. For hang up any String with a Bob to it, and let it vibrate; then having numbered the Vibrations performed in the Time propoſed, ſay, as $39\frac{2}{10}$ is to the Length of the String, ſo is 1 to a Number, whoſe *Square Root* is the Time of one Vibration made by the *Pendulum*, which multiply by the Number of Vibrations, and you have the whole Time required. So that you divide the

Length

B. The *Weight* of Bodies is reciprocally as the Squares of the Diſtances from the Centre of *Gravity*.

A. I ſhould be glad if you could exemplify this to my Apprehenſion.

B. That I can eaſily. Suppoſe ZPNS the Globe of our Earth, and its Centre C, the Centre of *Gravity*; let there be a Body placed on its Surface at Z, whoſe Weight let be 3600 Pounds; then if this Body be removed to the Diſtance CF, two Semi-diameters of the Earth, you have its Weight there by this Analogy,

Length of the *Pendulum* by the conſtant Number $39\frac{2}{10}$, and take the Square Root of the Quotient for the Time of a Vibration.

12. Let AB (*Fig.* XL. of *Plate* VII, fronting *p.* 99) repreſent an uniform Bar of Iron, or any other Thing; let this be made to vibrate; and with it hang up a common *Pendulum* CD that ſhall vibrate in the ſame Time with it; the Length of ſuch a *Pendulum* CD will ever be found equal to AG, which is $\frac{2}{3}$ of AB. This Point G is therefore called the *Centre of Oſcillation*; and has the ſame Effect, as if all the Weight of the Bar was collected into it: Conſequently, if that Point of the Bar be made to ſtrike an Object, the Blow will be greater than from any other Point; for which Reaſon it is alſo called the *Centre of Percuſſion*.

13. It is ſaid, that *Ricciolus* was the firſt who meaſured Time with a *Pendulum*, and that herein he was followed about the ſame Time by *Vendelinus*, *Mercennus*, *Kircherus*, &c. ſome of whom declared they knew nothing of *Ricciolus*'s Attempt. But the firſt who applied it to a Movement, a *Clock*, or *Watch*, was the famous Mr. *Chriſtopher Hugens*, who brought it alſo to a good Degree of Perfection. See *Lex. Tech. Magnum*, under the Word *Pendulum*; and moſt mechanical Writers on this Subject. As to what farther concerns the *Doctrine of Projectiles*, I ſhall leave that to the Chapter of *Hydroſtatics*, in the laſt Part of this Book. And for a compleat *Theory* of the ſaid Doctrine, I refer the Reader to *Keill*'s Introduction to Natural Philoſophy; and for the *Praxis* thereof, or its Application to the *Art of Gunnery*, he may conſult the *Young Trigonometer's Guide*, Vol. I. Part II. Chap. V.

4 : 1 :: 3600 : 900. If the ſaid Body were removed three Semi-diameters to E, the ſame Analogy finds its Weight there, *viz.* 9 : 1 :: 3600 : 400. And at the Diſtance of ſix Semi-diameters, the Weight thereof will be but 100 Pounds; for 36 : 1 :: 3600 : 100. Thus, at the Diſtance of 1, 2, 3, 4, 5, 6 Semi-diameters from the Centre of the Earth, the Diminution of the Weight of ſuch a Body would be as theſe Numbers, 3600, 900, 400, 225, 145, 100. Thus, on the contrary, he who beareth 100 Pounds Weight on the Earth's Surface, would, with equal Eaſe, ſuſtain the Weight of 3600 Pounds, at the Diſtance of 6$\frac{1}{2}$ Diameters, as at A. See *Fig.* XVI. on *Plate* VIII, fronting *p.* 120.

A. After ſo much of the *Gravity* of Bodies, let me know what the Philoſophers ſay of the *Levity* of Bodies?

B. There is no ſuch Thing, philoſophically ſpeaking, as abſolute *Levity* or *Lightneſs*; this is only a comparative Term, and implies no more, than the Difference of the Weight of Bodies compared together, or their ſpecific *Gravity.*

A. Pray, what Diſtinction do you make between *Gravity* and *Attraction?*

B. In the Nature of the Thing there is no Difference, they are both one and the ſame Principle, only in the Manner of conſidering it this Diſtinction ariſeth; if we reſpect it in the Body, containing the Centre of *Gravity*, we call this *Power*, in that Body, *Attraction*; but we call it *Gravity* in Bodies which are

moved

moved toward that Centre, or Body, wherein it is: Thus the Earth is ſaid to attract Bodies on it, or falling on it; and thoſe Bodies are ſaid to gravitate towards the Earth; ſo the *Loadſtone* attracts Steel, and the Steel gravitates to it *.

A. Is

* ATTRACTION is, by the *Modern Philoſophers*, conſidered twofold, *viz.* (1.) *Attraction of Gravitation*, whereby one Body affects another at a Diſtance, and cauſes it to *gravitate* towards itſelf; which is what I have above conſidered; and concerning which the Reader may ſee abundance in *Lex. Tech. Mag.* under this Word. (2.) *Attraction of Coheſion* which we find only among the very ſmall Particles of Matter in Bodies, and of which I ſhall here enumerate the chief Properties.

1. This Force is then greateſt when the Particles are in Contact, or touch each other.

2. In homogeneous Particles, the greater the Surface of Contact, the ſtronger the Force.

3. The Sphere of this Attraction is inconſiderable at any ſenſible Diſtance from the Particle.

4. The ſmaller the Diſtance, the ſtronger the Force, which is very great at very ſmall Diſtances.

5. This Force decreaſes nearly as the *Cubes* of the Diſtances increaſe; and not as the *Squares* thereof, as in the other Sort of Attraction.

6. This Force is proportional to the Quantity of Matter in Particles.

7. Conſequently, the denſeſt Particles, whoſe Surface of Contact is largeſt, hath the greateſt *Attraction* of *Coheſion*.

8. In Particles of the ſame Kind, or equal Denſity, the Attraction is ſtronger between ſmall Particles than the large; becauſe in thoſe there is a greater Quantity of Surface than in theſe, eſpecially if they are of a ſpherical Form

From this Property of Matter proceed many wonderful and curious Phænomena, which are eaſily accountable for on this Principle. As,

1. The ſtrong Coheſion of the Particles which compoſe ſolid or hard Bodies; for without this Power, the hardeſt Adamant would inſtantly diſſolve into an impalpable Powder.

2. The prodigious Coheſion of poliſhed Surfaces, as of Glaſs, Stones, Metals, *&c.* Thus two leaden Balls pared with a ſharp

A. Is this Power of *Attraction* the same in all Bodies, of the same Kind, of equal Density and Magnitude?

B. Yes;

Knife, so as to cut off a Segment about $\frac{1}{4}$ of an Inch Diameter, if they are pressed together (giving them a little Twist) pretty hard, they will require the Weight sometimes of 100lb. to separate them. That this is not owing to the Air is plain, because they are not separated in the *exhausted Receiver*.

3. By this Power, *Liquids* arise into the Substance of *Bread*, *Sugar*, *Sponge*, and all very porous Bodies.

4. On this Account also Liquids rise on the Sides of containing Vessels, and about the Surface of Bodies floating therein, to a small Height above the common Level.

5. Particularly on this Principle, and no other, can we account for the *Ascent* of Liquids in capillary Tubes of Glass to so considerable a Height above the Surface of the Liquor in which they are placed, contrary to the Laws of *Hydraulics*; the Heights to which Water will arise in different Tubes, are reciprocally as the Diameters of the Bores of those Tubes, and the Quantities of Water drawn up, are directly as those Diameters. See *Gravesande*'s and Dr. *Desaguliers*'s Courses. *Webster*'s Principles of Nat. Phil. Page 17. *Rowning*'s Comp. System. *Harris's Lex. Tech.* under the Word *Attraction*.

6. By this Means, the Water in the Vessel BC (*Fig.* XLI. of *Plate* VII, fronting *p.* 99) will arise between the two polished Glass Plates, AC, A*e*, being set therein touching each other on the Sides AB, and open a little on the other Sides; the Figure of the Water between the Plates *e*, *f*, *g*, is that of an *Hyperbola*.

7. When Particles of Matter of different Densities, Quantities of Surface, and, consequently, of different Attractive Powers, are mixed together, they will necessarily attract, agitate, and move each other in various wise, and with incredible Velocities in many Cases; from hence will arise *Fermentations*, *Ebullitions*, *Excalescencies*, *Fusions*, *Dissolutions*, *Crystallizations*, and other such like Effects known in Chymistry.

8. But among the small Particles of Matter, there is not only an *attractive* Power, but also a *repelling* one, whereby they are made to recede and fly from each other; and this Force is called *Repulsion*.

9. REPULSION begins where Attraction ends, and increases as the Distance of Particles decrease.

10. Particles attracted most strongly within the Sphere of its Power are repelled most forcibly when without it.

11. From

B. Yes; but in all ſuch Bodies, the leſs any one is than another, the greater is its attracting Force; ſo the *magnetic Attraction* is ſtronger in a ſmall *Loadſtone*, in Proportion to its Weight, than in a larger one.

A. What is the Conſequence of this?

B. Sir *Iſaac Newton* has found, by Calculation, that, as the Particles of *Light* are the leaſt Bodies we know of, ſo their *Attraction* is 1000000000000000 Million of Millions of Times greater than that of the Earth, on the Earth's Surface; according to the Quantity of Matter in each, and the aforementioned Velocity of *Light*.

A. Pray, *Sir*, what do you underſtand by *Electricity* *?

B. A

11. From the great Degree of this repulſive Power in *Oil*, *Greaſe*, &c. ariſes the great Difficulty of mixing thoſe Bodies with *Water*, ſo as to make their Parts touch and ſtick together.

12. This Power is ſmall between *Glaſs* and *Water*; greater between *Glaſs* and *Quickſilver*; ſtrong between *Quickſilver* and *Copper*; ſtronger between *Quickſilver* and *poliſhed Steel*; but weaker between *Quickſilver* and *Gold*.

13. From this Principle it is that a dry *Needle* ſwims upon the Water; and that Flies, *&c.* walk and run thereon without wetting their Feet.

14. Let there be two Balls of Wood, A and B, the one wetted all over with Water, the other with Oil; let theſe be put into the Veſſel of Water CD, and the different Effects of the *attractive* and *repulſive* Powers of Matter and Oil will become very viſible; the Water in one Caſe riſing by *Attraction* above the common Surface; and in the other it is forced below it by *Repulſion* See *Fig.* XLII. of *Plate* VII, fronting *p.* 99. See more concerning *Attraction* and *Repulſion* of Particles in *Webſter*'s Principles, *Graveſande*'s Elements, and Dr. *Deſaguliers*'s Courſes of Experimental Philoſophy; and alſo the *Lex. Tech.* under the Word *Attraction*.

* Electricity conſiſts of an *Attraction* and *Repulſion*, pretty much of a like Nature with thoſe in the foregoing Note.

B. A certain Kind of attractive Faculty, peculiar to ſome Bodies, as *Amber*, *Jet*, *Sealing-Wax*,

Note. The principal Properties of theſe wonderful Qualities of Bodies are as follow.

1. It exiſts of fine inviſible *Effluvia*, ſuppoſed to be of an unctuous and oily Nature, which are excited by Attrition, or rubbing the electrical Body till it become warm.

2. Such Bodies warmed by the Fire only, do not attract ſo forcibly as when heated by rubbing.

3. If a Glaſs Tube be firſt warmed by the Fire, and then heated by Attrition, it will attract moſt ſpeedily and powerfully.

4. *Terſion*, or Wiping, is alſo neceſſary, as well as Attrition or Rubbing, to procure *Electricity*; for this frees the Pores for the better Emiſſion of the *Effluvia*.

5. This Effect is much weakened if the Weather be thick and cloudy.

6. The Interpoſition of the fineſt Linen or Paper will hinder the Action of *Electricity*; whereas the *magnetic Virtue* pervades all Objects.

7. *Electrical* Bodies attract all Things indifferently, the *Loadſtone* only Iron and Steel.

8. If a Glaſs Tube be rubbed in the Dark, the Effluvia will appear lucid; and if a little Bruſh be held near the Tube, or drawn along it without touching, juſt after it is rubbed, Sparks of Light like Stars will appear upon every Hair of the Bruſh.

9. If when a Tube is juſt rubbed, your Hand be brought along down very near by the Tube, it will prevent its Effect.

10. If the Fingers be moved nimbly by the Tube, as if you went to ſtrike it in a Direction perpendicular to its Axis, the *Effluvia* will be heard to ſnap againſt the Finger (or beat back from it) againſt the Tube, like the Crackling of a green Leaf in the Fire, but not ſo loud.

11. In hot and moiſt Weather, the Tube requires a great deal of rubbing before it will ſnap, and its Virtue will then diffuſe itſelf but a little Way, for what it will when the Weather is dry and cold.

12. In fine dry Weather, the Electrical Virtue will attract at the Diſtance of eight or ten Feet: In cloſe moiſt Weather, not above the Diſtance of two Feet.

13. After the Feather is attracted, and has ſtuck to the Tube ſome Time, it will fly off, or be repelled, and never return to the Tube again till it has touched ſome other Body.

14. If

Wax, *Glaſs*, &c. whoſe Particles are ſuch, that being greatly rarefied and agitated, (by the Heat occaſioned by *Attrition*, or rubbing of them) they fly off to a certain ſmall Diſtance, but not beyond the Sphere of the Body's *Attraction*; and therefore, by this *Attraction*, they are obliged to return again to their old Quarters.

A. Why then, I ſuppoſe, it is by their flying off, that light Bodies, as *Feathers*, *Hairs*, &c. are repelled from the electrical Body; and by the Return of thoſe Particles, they are again inſtantly compelled back, and attached to the ſaid Body.

B. Yes, that is the Caſe, as underſtood at preſent; but for the real Cauſe of *Attraction* or *Gravity* in general, Sir *Iſaac Newton* profeſſeth himſelf entirely ignorant of it; even though he makes this Principle of *Attraction* or *Gravity* the Baſis of all his Philoſophy: Where-

14. If the Finger, &c. he held near the Tube, the Feather will alternately fly from the Finger to the Tube; always ſtretching out its Fibres towards the Object it flies to embrace.

15. Moſt, if not all, theſe Effects ſucceed *in Vacuo*, only the Light excited by Attrition will be of a purple Colour, in a much greater Quantity, and all within the Glaſs.

16. An exhauſted Tube loſes all its Virtue externally, which, in this Caſe, is wholly exerted within the Tube.

See a great Number of curious and ſurprizing Experiments concerning Electricity in Dr. *Prieſtley*'s Hiſtory and Preſent State of Electricity. 4to.

fore

fore let us now diſcourſe of ſome other Properties of natural Bodies *.

CHAP. X.

Of TRANSPARENCY *and* OPACITY, DENSITY *and* RARITY, HARDNESS *and* SOFTNESS, RIGIDITY *and* FLEXIBILITY, *in* BODIES.

A. SIR, I thank you for your Inſtructions concerning *Gravity* and *Attraction*, and ſhall be very glad to hear you farther on the other Qualities of Bodies; and, firſt, what may we underſtand by the *Tranſparency* and *Opacity* of Bodies?

B. Tranſparency is that Quality of certain Bodies, whereby their Subſtance is enlightened, and Objects appear viſible through them, as in *Glaſs*, *Cryſtal*, &c. and therefore thoſe Bodies are called *Tranſparent*, *Pellucid*, or *Diaphanous*, all which Terms imply the ſame Thing. *Opacity* is the Quality oppoſite hereto; and thoſe Bodies are ſaid to be *Opake*, whoſe Matter is not *tranſparent*, or through which Objects are not viſible.

* Sir *Iſaac's* Words are—"Hitherto I have expounded "the *Phænomena* of the Heavens, and of the Ocean, by the "Power of Gravity; but the *Cauſe of Gravity* I have not yet "aſſigned."—Again, ſpeaking of the Laws of Gravity, he ſays,——"But the Reaſon of theſe Properties of Gravity I "have not been able to deduce from *Phænomena*, and I frame "no Hypotheſes. It is enough, that Gravity doth actually "exiſt, and acts according to the Laws I have explained, and "is ſufficient to account for all the Motions of the heavenly "Bodies and Sea." *Princip. Philoſophiæ, Edit.* 3tia. *Pag. ult.*

A. Pray what is the Cause of these Qualities?

B. The Cause of *Transparency* is owing to that Constitution of Bodies which admits the *Rays of Light* to pass through their Pores in right Lines, and in all Directions whatever; and, on the contrary, *Opacity* is the Effect of *Light* obstructed in its Passage through Bodies, or that which is not transmitted in right Lines *.

A. It seems to follow from hence, that the Matter of transparent Bodies must be very little in Proportion to their Pores.

B. Very little indeed; so little, that a celebrated Philosopher questioned whether the Quantity of Matter in *Glass* was more in Proportion to its Bulk, than one Grain of Sand to the Bulk of the whole Earth †.

A. In what Proportion are Bodies *transparent*?

* Sir *Isaac Newton*, in the Propositions of his second Book of Optics, shews,——That the least Parts of almost all natural Bodies are in some Measure transparent, and the Opacity of those Bodies arises from the Multitude of Reflexions caused in their internal Parts. Also, that the Parts of Bodies, and their Interstices, must be of a definite Magnitude, to render them opake and coloured; since the opakest Bodies, if their thin Parts be subtilly divided, (as *Metals* dissolved in acid Menstruums, &c.) become transparent. Again, opake Bodies (he shews) become transparent, by filling their Pores with any Substance of equal or almost equal Density with their Parts. Thus Paper dipped in Water and Oil, the *Oculus Mundi* Stone steeped in Water, Linen Cloth oiled or varnished, and many other Substances soaked in such Liquors as will intimately pervade their little Pores, become by that Means more transparent, than otherwise. See more to the same Purpose in the same Place.

† Dr. *Keill*, in his Introduction, Lect. 5th. Page 67.

B. In

B. In Proportion to the *Rarity* and *Denſity* of Matter.

A. What do you call the *Rarity* and *Denſity* of Matter?

B. By *Rarity* is underſtood the *Thinneſs* of the Particles of Matter; and by *Denſity*, the *Thickneſs* thereof; in reſpect of the Bulk of Bodies.

A. Then the *Denſity* of Bodies hath regard both to their *Matter* and *Magnitude*, I underſtand by this; but what is the Proportion?

B. The *Denſities* of two Bodies are in a Proportion compounded of the direct Proportion of their Quantities of Matter, and a reciprocal Proportion of their Magnitudes.

A. I believe I could better apprehend you, if you would be pleaſed, *Sir*, to exemplify this Matter.

B. I will. Thus ſuppoſe A be a Body which hath eight Parts of Matter, and five Degrees of Magnitude; and B be a Body having two Parts of Matter, and ten Degrees of Magnitude; then the *Denſity* of A will be to the *Denſity* of B, as $\frac{8}{2} \times \frac{10}{5} = \frac{80}{10} = \frac{8}{1}$, that is $= \frac{A}{B} = \frac{8}{1}$, or A : B :: 8 : 1; therefore the Body A's *Denſity* is eight Times greater than the *Denſity* of the Body B*.

A. What

* 1. Let us (*Fig.* LIII. of *Plate* VII, fronting *page* 99) illuſtrate this Example; and ſince the Denſities of A and B are in the compound Ratio of the Quantities of Matter directly, and of their Magnitude reciprocally; it will follow,

2. That their Bulks are as directly as the Quantities of Matter compounded with the Denſities reciprocally.

3. That the Quantities of Matter will be in the compound Ratio of the Bulks into the Denſities directly.

4. If

A. What Means are thoſe Qualities moſt of all increaſed or diminiſhed by?

B. Heat and *Cold*; for *Heat*, by dividing, extending, and expanding the Particles of Bodies, doth attenuate and rarefy them, and this is called *Rarefaction*; on the contrary, *Cold*, by uniting and contracting the Particles of thin Bodies, doth thicken and condenſe them, and this is called *Condenſation*.

A. Do not the Hardneſs and Softneſs of Bodies ariſe from their *Denſity* and *Rarity*?

B. No, *Sir*: The Hardneſs of Bodies ariſeth from the mutual *Attraction* of the moſt minute primogenial Particles of Matter, whereby they firmly cohere, and are, as it were, conglutinated together: When this Firmity or Coheſion of Parts is ſo ſtrong, that the Preſſure of the Finger will not part or diſplace them, then we ſay ſuch Bodies are hard; but, on the contrary, when they give way, or yield to the Touch, we call them ſoft Bodies.

A. What Figure of thoſe primitive Particles of Matter is moſt requiſite to produce Hardneſs or Firmity of Bodies?

B. The nearer the Figures of thoſe Particles approach to the Figures of the five regular Bodies, or the greater their Superficies, by which they touch one another, the ſtronger

4. If the Bulks are equal, the Quantities of Matter in two Bodies, AB, will be directly as their Denſities.

5. If the Denſities are equal, their Bulks and Quantities of Matter are directly proportional.

6. If the Quantities of Matter in each be equal, the Bulks will be in a reciprocal Ratio of the Denſities.

will be their *Attraction*; and conſequently the greater their *Coheſion*, *Firmity*, or *Hardneſs*: But by how much leſs Superficies they touch, and by how much the eaſier they ſlip and ſlide by and over each other, by ſo much the ſofter ſhall we find the Bodies; and this in various Degrees even to *Liquidity* *.

A. Is it not alſo to the Size, Shape, *&c.* of thoſe ſmall Particles of Matter, that the *Rigidity* and *Flexibility* of Bodies are owing?

B. No doubt of it, though it cannot be poſitively defined: But by the Analogy of Reaſon, *Rigidity* or *Stiffneſs* of Bodies ſeems to depend on two Things: *Firſt*, an oblong Square-figured Set of Particles, which are (*ſecondly*) unequally placed or jointed together, as thus () for the Want of *Poroſity* and the mutual *Attraction*, with the Reſiſtance ariſing from the Poſition of Particles, will cauſe *Rigidity*; and by how much leſs Particles are endued with ſuch Modifications, by ſo much the more Bodies are flexible or liable to bend; whence their *Flexibility* †.

* See what has been ſaid of the *Attraction of Coheſion* in Note * in Page 103.

† See further on this Subject, *Boerhave*'s Meth. Deſcend. Medicinam. *C. Bartholine*'s Specim. Nat. Philoſ. Cap. 6. *Muſſchenbroek*'s Elements Phyſico-Math. Part I. Cap. 16. *J. Clerici* Phyſica, Lib. V. Cap. 16, 17. *Chambers*'s Dictionary, and *Harris*'s Lexicon, under theſe Words. *Rohaulti* Phyſica, Cap. 22; and Dr. *Clarke*'s Notes, at Art. 9. *Regnault*'s Phil. Converſ. Vol. I. Conver. 9. with *Dale*'s Notes. And the Authors mentioned in *Johnſon*'s Quæſt. Philoſophicæ, Page 13, 14, 15, 16, 17, 18.

CHAP.

CHAP. XI.

Of CONSISTENCE *and* FLUIDITY, HEAT *and* COLD, HUMIDITY *and* SICCITY, ELASTICITY, ODOURS, *and* SAPOURS *of* BODIES.

A. WHAT do you mean by the *Confiſtence* of Bodies?

B. That State of Bodies whereby the conſtituent Particles do naturally keep the ſame Poſition to each other, and are not to be moved or ſeparated, but by ſome coercive external Force; whence this Quality is alſo called the *Fixity* of Bodies.

A. Whence doth this *Fixity* or *Confiſtence* of Bodies ariſe?

B. Undoubtedly from the Figure, Size, and Attraction of the conſtituent Particles of the ſame Sort with thoſe which produce *Hardneſs* and *Rigidity* of Bodies.

A. Is not *Fluidity* oppoſite to *Confiſtence*? And doth it not ariſe from contrary Cauſes?

B. Yes: *Fluidity* is that State of natural Bodies, whereby their Particles are always in a *Flow*; and are equally diſpoſed to move in any Direction by the leaſt Impreſſion.

A. What may be the Cauſe of *Fluidity*?

B. The exceeding Tenuity or Smallneſs, Sphericity or Roundneſs, Lubricity or ſmooth Slipperineſs, and Similarity or Likeneſs of the primogenial, conſtituent Particles of Matter: For Particles thus modified muſt always produce a fluid Body, or Subſtance, as *Water*, *Fire*, &c.

A. Is there any Difference between *Fluidity* and *Liquidity?*

B. Yes, a great deal: For *Fluidity* is a general Name for all Bodies whoſe Parts yield to any Impreſſion; and thus a Quantity of Sand as well as Water is called a *Fluid:* But what we properly call a *Liquid*, or *Liquor*, is only that Kind or Species of Fluids which *cleaveth to the Touch*, or *ſticketh to the Finger*, &c. which toucheth it, and, as we may ſay, *wetteth* it, as doth Water, or any Kind of Juices.

A. What may be the Reaſon or Cauſe of this Difference?

B. It is owing to the exceeding Smallneſs of the Particles of Liquids above thoſe of fluid Bodies; and alſo to their Weight, or Ponderoſity: For, by theſe Means, the Particles of Liquids enter the Pores of the Body which toucheth them; and by their Weight and Gravity, cohere to, and abide therein; and ſo cauſe Wetneſs *.

A. Pleaſe now to let me know, *Sir*, what your Sentiments are of *Heat* and *Cold* in Bodies, and wherein thoſe Qualities do conſiſt?

B. *Heat* is a Senſation excited in the Mind by a great Agitation of the Particles of the hot Body, which exerteth its Action or Influence on us; ſo that *Heat* in us is only the Idea thereof; and in the hot Body, Activity or Motion, and nothing elſe: No *Heat* is ſenſible to us, unleſs the Motion of the Parts of a Body, which

* The *coheſive Attraction* is herein not a little concerned, as will be eaſy to conceive from Note * in Page 103.

acts

acts on us, be greater than the Motion of the Organ or Part of the Body acted upon. When the Motion of the Parts of the Body is leſs than that of our Organs of Feeling, then it occaſions in us the Senſation or Idea of *Cold*, or *Coldneſs*.

A. Then, if I take you right, *Sir*, the Reaſon or Difference of *Heat* and *Cold*, for Inſtance, in Water, lieth in this: That in the firſt Caſe, the Particles are by the Fire put into a greater Motion and Agitation than is in the Hand that feeleth it; and in the latter Caſe, the Motion of the aqueous Particles is in a leſs Degree than of thoſe in the Hand; and thus we find it to be either *Hot* or *Cold* *.

B. Yes, that is the true Nature of the Caſe, according to modern Philoſophy and manifold Experiments.

A. Pray how do you conceive of *Flame*?

B. As a *Fluid*, whoſe Parts are ever in Mo-

* The Motion here intended is that inteſtine Motion which exiſts among the Particles, and in the Pores of any Body, and in the Spirits, Blood and other Juices in the Organ of Feeling, to which that Body is applied.

The Heat of the Sun may be augmented to a prodigious Degree by means of a *convex* Lens or *concave* Mirrour. Thus ſuppoſe you have a double convex Lens, four Inches Diameter, and whoſe focal Diſtance is 12 Inches; it will be found by Calculation, that the *focal*, or *burning Spot* of this Lens will be $\frac{1}{10}$ of an Inch very nearly. Now ſince Circles are as the Squares of their Diameters, the Denſity of the Sun's Rays falling on the whole Area of the Glaſs, will be to their Denſity when collected into the *focal* Spot, as the Square of 4 to the Square of $\frac{1}{10}$, that is, as 16 to $\frac{1}{100}$, or as 1600 to 1; and conſequently the Heat will in that Spot be ſixteen hundred Times greater than the common Heat of the Sun's Rays. No Wonder, then, they burn with ſuch amazing Violence and *Ardor!* A *concave Mirrour* of the ſame *Diameter*, and *focal Diſtance*, will burn ſtill more intenſely, becauſe many Rays are loſt by Reflection on a *convex Lens*.

tion, inſenſible, and inconceivably great; and which ſeems to depend on the Air, in its natural State; becauſe a *Candle* will not burn in *aduſt*, or burnt Air, as is found by Experiment.

A. Is not *Light* and *Fire* pretty much the ſame Thing, or of the ſame Nature?

B. The Particles of *Light* and *Fire* agree in ſeveral Things, *viz.* 1. In their Smallneſs: 2. Their Luminoſity: 3. Their exceeding Activity: 4. Their Heat or burning Quality: For the Rays of the Sun, collected together by a burning Glaſs, burn more violently than any common Fire; kindle Wood in a Moment; immediately make *Iron* or *Steel* red hot; melt *Silver*, *Gold*, &c. in half a Minute; turn *Stones* into a *black Glaſs*; and *Brick*, *Tiles*, and *Earth* itſelf, to *green Glaſs* in an Inſtant; from whence we muſt infer, the Particles of *Light* and *Fire* are the ſame *.

A. This ſeems a juſt Inference indeed: But becauſe we cannot be large on every Head, pray give me a ſmall Account of the Qualities called the *Humidity* and *Siccity* of Bodies?

B. *Humidity*, or *Moiſture* of Bodies, is only a Mixture of the Particles of Liquor with thoſe of the ſolid Matter of Bodies; thus Particles of

* See concerning the Nature of *Heat*, *Fire*, *Cold*, &c. *Boerhaave*'s Chymiſtry, Part I. Page 220, to 276; and Dr. *Shaw*'s large Notes thereon. Mr. *Boyle*'s Hiſtory of Cold. *Cheyne*'s Phil. Principles, Page 61, 62, 63. *Deſaguliers*'s Courſes, Vol. I. Page 421, to 426. *Clare*'s Mot. of Fluids, Page 225, to 229; alſo 287, 288. *Hales*'s Veg. Statics, Page 278, 279, 280. *Clerici* Phyſica, Lib. V. Cap. 13. *Rohaulti* Phyſica, Part. I. Cap. 23. Part. III. Cap. 9. cum Annot. *Clark.* annexis. *Chambers*'s and *Harris*'s Lexicon, under theſe Words. *Regnault*'s Phil. Conver. Vol. I. Conv. 26; and various Numbers of the Phil. Tranſactions.

Water,

Water, mixed with Earth, make it *humid* and *moist*; thus the Juices of Vegetables make their Substance moist; and the Want or Defect of this Moisture, or Liquid Substance in Bodies, is what we call *Siccity* or *Dryness*; and which, in moist Bodies, is occasioned by the Sun, Fire, Wind, *&c.* by attenuating and rarefying the liquid Particles, and thereby causing them to fly off in *Steam*, or insensible *Vapour*.

A. In the next Place, pray, *Sir*, tell me what that Property is in Bodies which you call *Elasticity?*

B. It is that Disposition of some Bodies, whereby, when the Parts of the Body by Pressure are put out of their Place and Form, they immediately again return to, or recover their first Position and Figure.

A. Whence doth this Property proceed?

B. It is hard to say what are the particular Circumstances of the Cause of *Elasticity*; however, it is certainly owing to the special Figure, Surfaces, and Attraction of the Parts of elastic Bodies.

A. Are all Bodies elastic?

B. Yes, in a greater or lesser Degree; but none are perfectly elastic.

A. Pray what do you call perfect *Elasticity?*

B. That, whereby a Body recovers its Figure by the same Force it lost it.

A. Is there any Thing remarkable in the otion of Bodies derived from their *Elasticity?*

B. Yes: If an elastic Body A strikes against the firm Bottom CD, obliquely in the Direction AF, it will always rebound again in the same Obliquity FE, or so, that the Angle

EFD ſhall always be equal to the Angle AFC. See *Fig.* XVII. of *Plate* VIII, fronting *p.* 120. Beſides this, there are many other Properties of the Motion of ſpringy or elaſtic Bodies, ariſing from their *Spring* or *Elaſticity*; for which larger Volumes muſt be conſulted *.

A. Well

* In the Percuſſion or Striking of Bodies not elaſtic, there are four Caſes, *viz.*

1. If one Body ſtrikes againſt another at Reſt, they will both move together in the Direction of the firſt Motion; and the Quantity of Motion in the two Bodies will be the ſame as in the ſingle one before the Stroke.

2. If one Body ſtrikes another moving the ſame Way, but ſlower, they will both continue their Motion in the ſame Direction as before; and the Quantity of Motion in both will ſtill be the ſame.

3. When two Bodies with equal Quantities of Motion tend both directly towards, and ſtrike each other, the whole Motion will be deſtroyed by their Meeting, and the Bodies will be at Reſt.

4. Two Bodies moving both directly towards each other with different Velocities, after the Stroke, will both continue their Motion in the Direction of that Motion which had the greateſt Velocity; and the Quantity or Motion after the Stroke is equal to the *Difference* of their Motions before it.

In *elaſtic Bodies*, other Rules obtain: Suppoſe two ſuch Bodies A and B; let A have three Parts of Matter, and eight Degrees of Velocity; and B have nine Parts of Matter, and two Degrees of Velocity: Then, the Quantity of Motion in A will be 24, and that of B 18. Now ſuppoſing theſe Bodies to impinge on each other, the *Velocity* of each after Impact, and the *Direction* of their Motions, may be known as follows:

1. Let the Body A impinge on B at Reſt; then from A take B, and multiply the Remainder by the Velocity of A; divide this Product by the Sum of the Bodies A and B, the Quotient will expreſs the Velocity of A after the Stroke. As the Body A is leſs, equal to, or greater than B; ſo it will be retrograde, or direct in Motion after Impact. Thus, in the preſent Caſe, the Difference of A and B is 6, which multiply by A's Velocity 8, the Product is 48; this divided by the Sum of the Bodies 12, quotes 4, the Degrees of Velocity with which A will return back after Impact.

2. Again, divide twice A's Motion by the Sum of the Bodies, the Quotient will be the Velocity of B after Impact. Thus 48 divided by 12 quotes 4, the Velocity of B after the Stroke. So that, tho'

A. Well then, leaving that, let us proceed to what you call the *Odours* of Bodies; pray what are they, or wherein do they consist?

B. The *Odours* of Bodies, by affecting the Organ of Smelling, *viz.* the Nose, do raise and excite in us the Sensation we call *Smell*, or *Scent*:

tho' the Velocity be the same, the Motion in both Bodies is double to what it was at first in A.

3. Let the Bodies both tend one Way, and A follow B; then, to the Motion of A add twice the Motion of B, from that Sum subduct the Product of A's Velocity multiplied into the Matter B; divide the Remainder by the Sum of the Bodies, the Quotient will be the Velocity of A after Impact. As the *Product* is *lesser*, *equal* to, or *greater* than the *Sum* (above mentioned) so the Motion of A will be *direct*, *none at all*, or *backward* after the Stroke.

4. Again, to twice the Motion of A add the Motion of B, from that Sum subtract the Product of B's Velocity into A; divide the Remainder by the Sum of the Bodies, the Quotient will be the Velocity of B after the Impact.

5. An Example of each, in our present Case, is as follows. To 24 add 36, the Sum is 60, which I take from 72, (as being greatest) the Remainder is 12, which I divide by 12, the Quotient is 1; so that A returns back with *one* Degree of Velocity, having lost *seven*.

6 Again, to 8 add 58, the Sum is 66, from which I take 6; the Remainder 60 I divide by 12, which quotes 5 for the Velocity of B's Motion.

7. If the Bodies tend the contrary Way, or meet; then, from the Sum of twice B's Motion, and the Product of A's Velocity into B, take the Motion of A, and divide the Remainder by the Sum of the Bodies, the Quotient is A's Velocity after meeting; and as that Sum is greater, equal to, or less than the said Motion of A, the Motion of A will be backward, none at all, or forward.

8. Again, to the Difference of B's Motion and twice A's, add the Product of B's Velocity into A; divide the Sum by the Sum of the Bodies, the Quotient will be the Velocity of B after Reflection.

9. To illustrate both these Cases by our present Example. The Sum of 72 and 36 is 108, from which I take 24; the Remainder 84 I divide by 12, which quotes 7 for A's Velocity backward. 2*dly*. To the Difference of 48 and 18, which is 30, I add 6, and divide the Sum 36 by 12, the Quotient is 3 for B's Velocity the contrary Way.

10. These Rules are applicable to all Bodies, and Celerities; and whosoever will, may see their Investigation in *Keill*'s Introduction, *Lecture* 14. *Theor.* 29. *Prob.* 3.

These *Odours* of Bodies are nothing but *Effluvia*, or exceeding fine and insensible Particles, flying off the *odoriferous* Bodies in all Directions; and as they float in the Air, strike against, and cause in our Nostrils the aforesaid Sensation of Smell.

A. In what Degree or Proportion are those *Effluvia*, or *Odours*, sensible to us?

B. The Sensation which they excite in us, or the Degree or Intensity of Smell, is always in Proportion to their *Density* or *Thickness* where we are; and this *Density* always decreases in Proportion to the Squares of the Distance from the *odorous* Bodies.

A. Pray, *Sir*, can you not make this somewhat more evident and plain by Example?

B. Yes: Let R represent a Rose, and the Dots about it the Emanations of numberless *Effluvia* of *Odours*; now suppose the Nose in three several Distances at A, B, and C, which let be 1, 2, and 3 Feet from the Centre of the Rose: Now, I say, the Degree or Intensity of Smell, at those Distances, will decrease in Proportion to the Squares thereof, 1, 4, 9, *i. e.* it will be four Times less at B than at A; and nine Times less at C than at A. Do you apprehend it now? See *Fig.* XVIII. of *Plate* VIII, fronting *p.* 120.

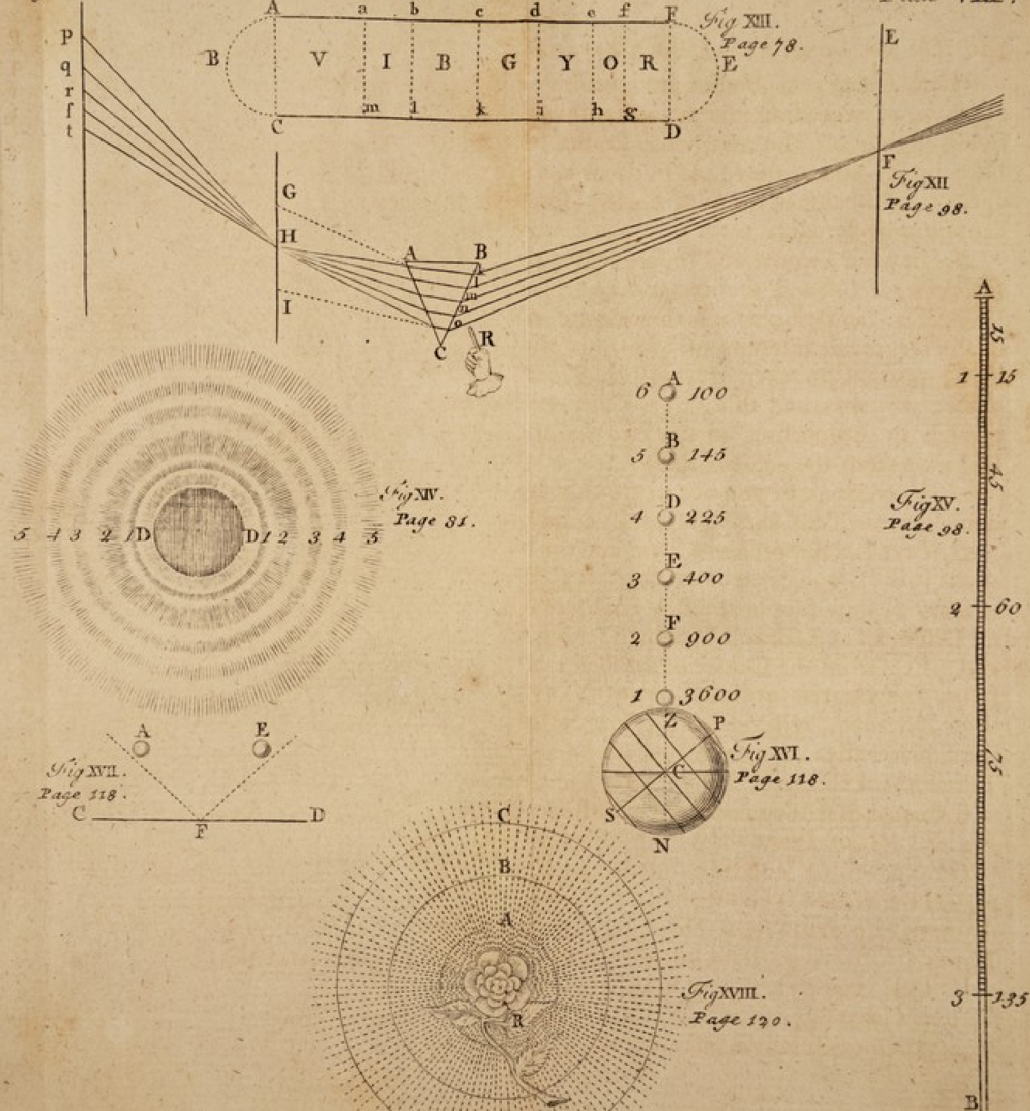
A. Very well, *Sir*, and I am obliged to you: But, pray, how comes it about that some irrational Animals, especially some Dogs, can smell any Thing at so much greater Distance than we can?

B. This is entirely owing to the greater Perfection of that Organ in those Creatures than in Man, as being on many Accounts more necessary

in

Page 120

Plate VIII.



in them than in us; for in them, God has made it *one Means to preserve Life*; in us he seems to have designed little more than *Gratification* and *Pleasure* thereby.

A. Whence do *Sapours* or *Tastes* of Bodies arise?

B. From a certain determinate Magnitude and Figure of the Particles of the *saporific* Body, which, in the Make of the Tongue, do thereby occasion the Sense of *Taste* in all Varieties, according to the different Modification and Configuration of those *saporiferous* Particles.

A. But what are those Sizes and Figures of Particles necessary to qualify them to exert this *saporific* Virtue, which you speak of?

B. No Man knows that; we should be contented to have a general Knowledge, when Particulars are denied us; we had better confess our Ignorance in Naturals, and adore the superlative Wisdom of God, who hath made it his own Prerogative to know all Things; than feign vain or absurd Hypotheses, with an ambitious and impious View of being thought omniscient, or able to account for all Things *.

A. I think so too indeed, *Sir*, and ask Pardon for being sometimes too curiously inquisitive about the *Arcana* of Nature.

B. Sir, we are allowed, yea, it is our Duty, to improve our Knowledge, and communicate

* For a more particular Account of *Odoriferous Effluvia*, and the wonderful Sagacity of Dogs, &c. in respect of this Sense, see *Boyle* on *Effluvia*, Chap. 4. Also for *Taste*, and the Causes and vast Diversity of *Tastes*, read Dr. *Grew*'s Anat. of Plants, and the Treatises referred to in Note † in Page 112, and Note * in Page 116.

the

the ſame to each other ſo far as we are capable: And having taken this particular Survey of the Properties and Qualities of Bodies, let us proceed to a general View of the Univerſe compoſed thereof.

CHAP. XII.

Of Sir ISAAC NEWTON'*s Laws of Nature.*

B. BUT before we launch out into the boundleſs Extenſion of the Univerſe, where we ſhall ſee every Thing in Motion all about us, it will be proper previouſly to conſider that (though we have already ſeen the general Properties and *Phænomena* of Motion, yet) there are ſome ſtated certain *Rules*, or *Laws*, by which all the Motions of all natural Bodies are conſtantly governed and determined, and by which every Thing relating to Motion may be explained.

A. How many are thoſe *Laws?*

B. Sir *Iſaac Newton* has laid down three.

A. But, pray, if you pleaſe, tell me why they are called Sir *Iſaac Newton's Laws of Nature?*

B. That is more than I can do: Sir *Iſaac* was not the firſt Inventor of them, ſince, if you pleaſe, you may ſee them in Monſieur *Des Cartes*'s Philoſophy, which was known before Sir *Iſaac*'s appeared *.

A. Pray what are thoſe *Laws?*

B. The *Firſt* is this:

* See *Des Cartes Principia Philoſophiæ*, Part II. Pag. 38, 39, 40.

LAW I.

All Bodies continue in their State of Reſt, or Motion, uniformly in a right Line, excepting they are obliged to change that Eſtate by Forces impreſſed.

A. What is the Foundation of this *Law?*

B. We ſee all Bodies, by their Nature, are inactive and incapable of moving themſelves; wherefore, unleſs they be moved by ſome external Agent, they muſt neceſſarily remain for ever at Reſt.

A. But why muſt a Body in Motion, if left to itſelf, for ever ſo continue in a right-lined Courſe?

B. We know this by daily Experience; for when any Body is put into Motion, it continues to move in the ſame rectilineal Direction, and with the ſame Velocity; until the Reſiſtance of the Air, the Power of its own Gravity, the Make of the Body, or ſome other external Cauſe, determines it from a right-lined Direction, diminiſhes its Velocity, and brings it at laſt to a State of Reſt *.

A. If this be the Caſe, pray how comes it to paſs that the *Sun, Moon, Comets,* &c. continue their Motion ſo long; have the Regions, thro' which they move, no Reſiſtance?

* Motion, when once produced in any Body, can never be impeded, diminiſhed, or deſtroyed, but from ſomething within or without the Body. Now all Experience teſtifies, that Matter is in itſelf inert, and powerleſs, and ſo abſolutely ſo, that it can in no wiſe be conſidered as the Cauſe of any Thing either within or without itſelf; conſequently, whatever retards or deſtroys Motion muſt be ſomething external to the Body moved; but in a perfect *Vacuum* there is nothing of any Kind, therefore in ſuch a Caſe Motion muſt of Neceſſity be *perpetual.*

B. The

B. The Bodies of the *Planets* and *Comets* are vaſtly great; and the Spaces, thro' which they move, have ſmall Reſiſtance, by which Means they conſerve their Motions the longer.

A. Pray what is the next *Law* of *Nature?*

B. The *Second Law* is this:

LAW II.

All Change of Motion is proportional to the Power of the moving Force impreſſed; and is always made according to the Right Line in which that Force is impreſſed.

A. What do you obſerve from thence?

B. That if any Power produceth any Motion; another Power, which is double, triple, *&c.* will produce a double, triple, *&c.* Quantity of Motion; whether it be impreſſed together, and at once, or ſucceſſively by Degrees: And this Motion (becauſe it is ever determined towards the ſame Part with the generating Force) is added to the Motion of a Body in the ſame Direction by Impact, and it will move ſo much the quicker; but it is ſubtracted from the Motion of a Body in contrary Direction, and therefore that Body will move ſo much the ſlower. It is alſo obliquely joined to the Motion of a Body obliquely moving; and will be compounded with it according to the Determination of both. Hence a very conſiderable Conſequence will follow.

A. Pray what is that?

B. Why, according to the preſent Conſtitution of Things, it follows from this *Law*, there can be no perpetual Motion; for by this *Law*, the

the Motion produced is but proportional to the generating Force; and all Motions on this Globe being performed in a reſiſting Medium, *viz.* the Air, a conſiderable Quantity of the Motion muſt, in the Communication, be ſpent on this Medium; and conſequently it is impoſſible the ſame Quantity ſhould return undiminiſhed upon the firſt Mover, which yet is neceſſary towards a perpetual Motion: Beſides, that ſuch a Diminution of Motion will be greatly increaſed by the conſtant Friction of the Parts of the Machine; for there will be more or leſs of that, be the Inſtrument ever ſo well contrived, there being no ſuch thing as abſolute Smoothneſs or perfect Congruity, in Nature; at leaſt, not in any of the Works of Man *.

A. Pray what is the *third Law?*

B. This:

LAW III.

Repulſe, or Re-action, is always equal, and in contrary Direction to Impulſe or Action; i.e. *the Action of two Bodies upon each other is always equal, and in contrary Directions.*

A. Can you illuſtrate this Matter a little by a familiar Inſtance or two?

B. Yes: Thus, if you preſs a Stone with your Finger downward, the Stone equally preſſes your Finger again upward: If a Horſe draw

* Concerning a perpetual Motion, the Machine contrived for that Purpoſe, and the Reaſons and Arguments which evince the Impoſſibility thereof, ſee *Deſaguliers*'s Courſe, Vol. I. Page 175, to 178. *Cheyne's* Philoſ. Principles, Page 16, 17: and *Chambers*'s Dictionary at the Word, with ſeveral other Authors.

for-

forward a Stone tied to a Rope, the Stone equally draws back the Horſe; for the Rope being equally diſtended both Ways, acts on both Horſe and Stone equally. The Anvil ſtrikes the Sledge with the ſame Force the Sledge ſtrikes it, which therefore rebounds or flies back. The Steel draws the Magnet, as much as the Magnet draws the Steel; as is evident by making both ſwim in Water. When a Barge is pulled to the Bank by a Rope, the Bank pulls the Barge as much as the Bargeman pulls the Bank: And in the Deſcent of heavy Bodies, the Stone that falls attracts the Earth as much as the Earth attracts it; that is, the Motion of the Earth is equal and contrary to that of the Stone.

A. Why theſe are all *Paradoxes* ſurely; I cannot conceive how it can be, nor believe that the Earth moves as much towards the Stone, as the Stone does towards it in falling.

B. But it is true, and is what I proved to you, if you remember, when we diſcourſed of the *Gravitation* of Bodies towards each other. I there ſhewed, the Reaſon we cannot ſee ſuch a Motion of the Earth, is becauſe of the incomprehenſible Diſparity of the Velocities of the Stone and the Earth: For, as I ſhewed you on the Subject of the Motion of Bodies, the *Motions of any two Bodies may be equal to each other, when the Velocities of their Motions are infinitely different.*

A. It is true, I remember you did ſo; and I find what creates the Wonder, is only a Miſtaking of *Velocity* for *Motion,* which is an entire different Thing.

B. Yes, it is so; and in most Cases, were the true Nature and Differences of Things well attended to, we should not be so liable to inglorious Wonder and Astonishment (the constant Effect of Ignorance) as we too commonly are. On this third *Law* depends all the Doctrine of the Loss and Gain of Motion in Bodies impinging on each other, according to Note * in Page 118. But now let us extend our View over the *universal Space* †.

† See the Laws of Nature explained more abundantly at large in Sir *I. Newton*'s Princip. Page 13, & seqq. *Graves.* Elem. Matth. Book I. Chap. 12. *Keill's* Introd. to Nat. Philos. Lect. XI, XII. *Desaguliers's* Course of Exp. Philos. Lect. V. and Annot. thereon. *Domkii* Philos. *Newton* Tom. II. Page 15. *&c.* *Cheyne's* Philosoph. Principles, Page 7 to 24. *Worster's* Philos. Page 45. *Webster's* Prin. of Nat. Phil. from Page 45 to 110; and various Writers on *Mechanics*.

THE

THE

Philosophical Grammar:

Or, VIEW of

Modern Philosophy.

PART II.

COSMOLOGY:

CONTAINING,

I. A general View of the *Universe*.
II. The Philosophy of the *Sun*.
III. The Philosophy of the *Moon*.
IV. The Philosophy of the *Planets*.
V. The Philosophy of the *Comets*.
VI. The Philosophy of the *fixed Stars*.

Explaining their *Nature*, *Properties*, and *Affections*, so far as they are at present known and understood.

CHAP. I.

Of Cosmology in general, of the mundane Space, of a Vacuum, of Duration or Time.

A. WHY do you call the second grand Division of the Science of Nature *Cosmology*?

B. On Account of the Propriety of the original Sense of the Word, and its Congruity with the Things which are the Subjects of the Science intended thereby.

A. What

A. What is originally imported by the Word *Cosmology*?

B. It is composed of the two *Greek* Words, κόσμος, the *World*, and λόγος, a *Discourse*; and therefore, by *Cosmology*, is implied a philosophical or physiological *Discourse* of the *World*, or *Universe* in general.

A. In what Manner, or Order, then, do you design to proceed in taking this general View, or Survey of the *Universe*?

B. In the *first* Place, to observe the Order and Constitution of it, so far as it is known, with the several Parts thereof great and small. *Secondly*, we will take some Notice of the Mundane Space; in which the various Parts or Bodies of the *Universe* do consist, and are posited here and there. *Thirdly*, we shall discourse a little of the Nature of *Duration* or *Time*, whereby the Motions of all the Bodies in the *Universe* are measured.

A. This will be very delightful indeed; pray make a Beginning. What do you first observe in the general Constitution or Frame?

B. The first great *Phænomenon* of the *Universe*, which more eminently strikes our Senses, is that glorious Luminary we call the *Sun*, the Source of *Light*, and Centre of our *Planetary System*, or about which the *Chorus* of all the *Planets* move.

A. What, do you suppose the *Sun* to be the Centre of the *Planets* Motion, and not a moving *Planet* itself?

B. Yes; the *Sun* is in the Centre of our System, round which the primary *Planets* move. See *Fig.* XIX. of *Plate* X, fronting *p.* 134.

A. Pray which, and how many are thoſe you call primary *Planets?*

B. They are in Number ſix; and their Names are, *Mercury*, *Venus*, the *Earth*, *Mars*, *Jupiter*, and *Saturn*; theſe, in different ſtated Periods of Time, all revolve about the *Sun*, in the Order I have rehearſed their Names.

A. But, pray, what becomes of the *Moon*, that you mention her not amongſt the *Planets?* And how came you to make a *Planet* of this *Earth* in her ſtead?

B. I am taught by the modern *Phyſiology* ſo to do; it is very certain the *Earth* is a *Planet*, and moves about the *Sun* with the reſt: And as to the *Moon*, I do not ſay ſhe is not a *Planet*, but not a primary or principal one.

A. Why, *Sir*, what Difference do you make in the Kind of *Planets?*

B. There is diſcovered a two-fold Kind of *Planets*, viz. There are ſome very great and large ones, which regard the *Sun* as the Centre of their Motions; theſe are called *primary Planets*, and are thoſe before named: Again, there are other leſſer ones, called *Satellites*, or *Attendants*, which circulate round ſome *primary Planet*, as their Centre; and theſe are termed *ſecondary Planets*, and ſuch a one is the *Moon* *.

* The Word *Satelles* is *Latin*, and with the *Romans* ſignified an *Officer*, *Serjeant*, or *Yeoman* of the Guard of a Prince, whoſe Office was to attend and defend his Perſon; whence the Aſtronomers, by an eaſy Metaphor, call a Moon (which conſtantly attends its proper Planet in all his Revolutions about the Sun) a *Satelles*, and if there be more than one, *Satellites*, which is a four-ſyllable Word, viz. *Sa-tel-li-tes*, and not a three-ſyllable one, as it is vulgarly, though viciouſly pronounced.

A. Sure

A. Sure it will be thought very ſtrange, that the *Moon* (which, next to the *Sun*, is the greateſt Luminary in the Heavens) ſhould be eſteemed only as a ſmall ſecondary *Planet*; the *Moon* is little obliged to your new Philoſophy, being thus degraded from her ancient ſhining Poſt among the primary ones!

B. What I ſay on this Head is founded on Reaſon, Obſervations, and Experiments; and therefore claims Belief before thoſe Notions which depend only on vulgar Senſe, and were the Products of a moſt rude and barbarous Age, though ever ſo glaring: Remember, *all is not Gold that gliſters.*

A. Well, I am glad to meet with Truth, whatever I exchange for it: But what do you next obſerve in this wonderous *Frame?*

B. The amazing Bodies we call *Comets*; which make ſuch prodigious Excurſions into the unknown diſtant Regions of the *Univerſe*, as to take up (ſome of them) ſeveral hundred Years in making one Revolution about the *Sun*.

A. I ſuppoſe, by *Comets* you mean blazing *Stars*; and do they likewiſe move about the *Sun?*

B. Yes; but in Orbits vaſtly eccentric, and approaching nearer to the Form of a *Parabola*, than an *Ellipſis* or *Circle*.

A. Well, what next to theſe offer for the Subject of our Contemplation, in this univerſal Scene?

B. The fixed Stars, which enamel and beſpangle the concave Expanſe, or Canopy of Heaven; which, by their Numbers and Luſtre, make the Night beauteous and delightful, which would be otherwiſe dark and horrible: And thus I have rehearſed to you all the great Parts of which the World doth conſiſt, ſo far as we know any thing of it *.

* The *Syſtem of the World* now deſcribed, is not a late Invention, but was known and taught by the wiſe *Samian Pythagoras*, and others among the Ancients, which in after Times was loſt; till in the 15th Century it was again revived by the famous *Poliſh* Philoſopher, *Nicholas Copernicus*, who was born at *Thorn* in the Year 1473. In this he was followed by the greateſt *Mathematicians* and *Philoſophers* that have ſince lived, as *Kepler*, *Galileo*, *Deſcartes*, *Gaſſendus*, and Sir *Iſaac Newton*, who has eſtabliſhed this Syſtem on ſuch an everlaſting Foundation of Mathematical and Phyſical Demonſtration, that neither the Gates of Ignorance, nor the Power of Popiſh *Anathema*'s, ſhall ever prevail againſt it.

The moſt famous of the antiquated Syſtems are two, *viz.* One taught by *Ptolemy*, the *Egyptian* Aſtronomer, ſaid to have lived 138 Years before Chriſt. The other by the noble *Dane*, *Tycho-Brahe*, born in *Schonen*, A.D. 1546.

The PTOLEMEAN SYSTEM (*Fig.* XLIV. on *Plate* IX, fronting *p.* 132.) ſuppoſed the Earth immoveably fixed in the Centre of the World, about which moved ſeven Planets, *viz.* the *Moon*, *Mercury*, *Venus*, the *Sun*, *Mars*, *Jupiter*, and *Saturn*; above theſe is placed the *Firmament* of the fixed Stars, then the two *Cryſtalline Spheres*; all which were included in, and received Motion from, the *Primum Mobile*, which conſtantly revolved about the Earth in 24 Hours from Eaſt to Weſt. But this *rude Scheme* was too much accommodated to *Senſe*, to ſtand the Teſt of *Art*; the *Mathematicians* ſoon perceived it a Medley of the groſſeſt Errors and Abſurdities, which they rejecting (as fit only for the ignorant, and zealous Bigot) choſe other more rational Methods to purſue the grand Diſcovery.

The TYCHONIAN SYSTEM ſucceeded the *Ptolemean*, but was never ſo univerſal. This ſuppoſed the Earth in the Centre of the World, (ſee *Fig.* XLV. on *Plate* IV, fronting *p.* 132.) or Firmament of fixed Stars, as alſo of the two Luminaries, the Moon and the Sun. But then he ſuppoſes the Sun the Centre of the Planetary Motions, *viz.* of *Mercury*, *Venus*, *Mars*, *Jupiter*, and *Saturn*; theſe, with the Sun, all revolved about the Earth in the Space of a Year, to account for the *annual Motion*; and the Earth he made to revolve about the Axis every 24 Hours from Weſt to Eaſt, to ſolve the *diurnal Motion* of the Heavenly Bodies from Eaſt to Weſt. This *Hypotheſis* being partly true, and partly falſe, and embarraſſed with many Difficulties and Abſurdities, was embraced by few, and ſoon gave way to the only true and rational *Solar Syſtem*, reſtored by *Copernicus*, as aforeſaid.

A. Pray

Fig. XLIV
Page 132.

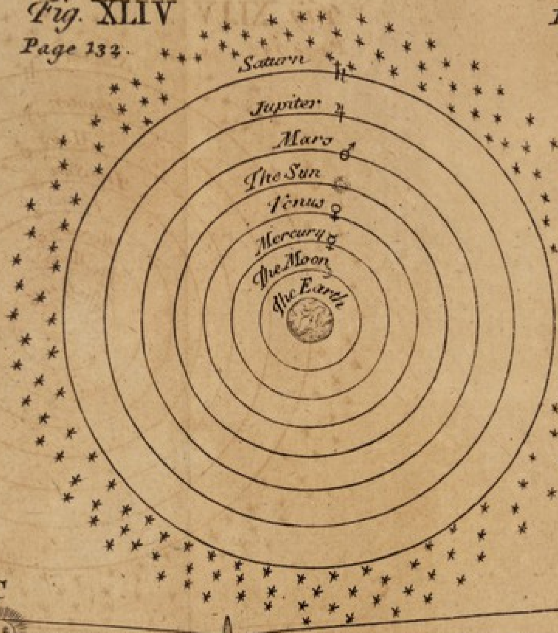


Fig: XLV.
Page 132.

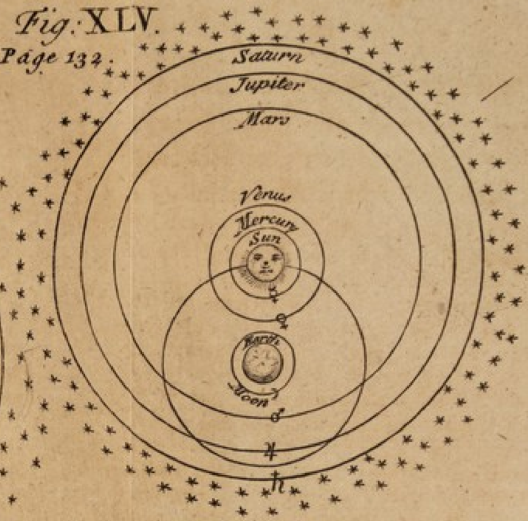


Fig: XLVI.
Page 136.

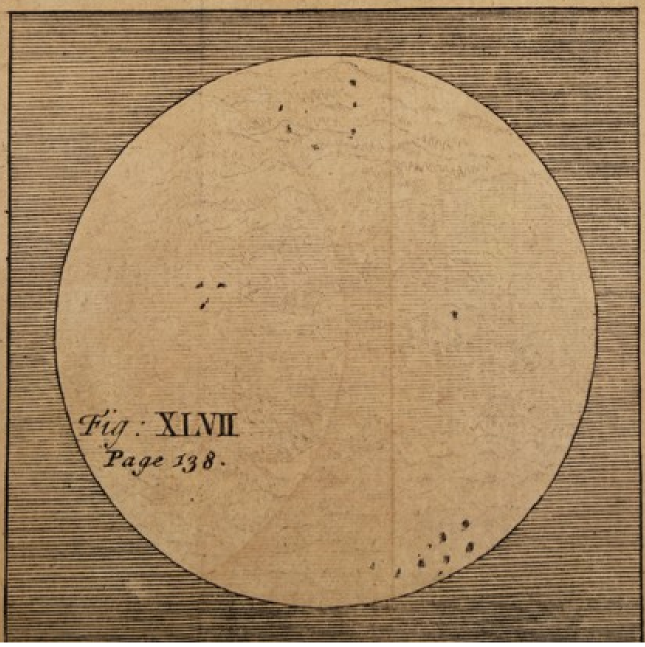
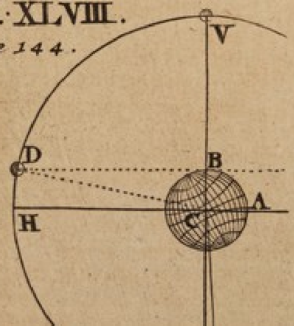


Fig: XLVII
Page 138.

Fig: XLVIII.
Page 144.



A. Pray what is the Form or Figure of the *Universe?*

B. It hath no determinate Form or Figure at all; forasmuch as it is every Way infinite and unlimited.

A. What do you call the *mundane Space?*

B. The infinite *Space,* in which all Bodies of the *Universe* have their Place and Being.

A. Pray what do you properly call *Space?*

B. Extension without Matter; or, in plain *English,* a *perfect Void,* or *Vacuity;* which is better conceived than defined *.

A. What is that the Philosophers call a *Vacuum?*

B. A *Vacuum* is a perfect Void, or Space absolutely devoid of all Body or Matter; as, on the contrary, they call that a *Plenum,* when any Part of *Space* is so absolutely filled with Matter, as to have no Vacuities therein.

A. Is there any such Thing as a *Vacuum* in Nature?

B. Yes; only those who denied their Reason, have denied this.

A. How do you prove a *Vacuum?*

B. A thousand Ways almost; but Motion evinceth it most plainly; for can any one suppose a Body to move in the Midst of *Solidity?*

* See Dr. *Watts's Enquiry concerning Space,* Phil. Essay I. Mr. *Locke,* in his *Human Understanding,* confesses he does not know what it is, nor to what Class of Beings to refer it, *Hum Und.* Book II. Chap. 13. § 17. Sir *I. Newton* considers Space as the *Sensorium* of the Divine Mind, *Prin. Math. Philos.* Page 528. *Optics,* 2d Edit. Page 379. The *Cartesians* absurdly pretend it is a Body or Substance. And others deny that it has any real Existence. See the Authors mentioned in *Johnson's Quæst. Philos. p.* 169, 170.

They who affirm this, may as rationally affirm, that a Bird may fly through a Mountain of *Adamant*, as easily as through the open *Air*: And who so blind as not to see the most monstrous Absurdity thereof by this one Argument*?

A. I think none can deny it indeed, who would be thought rational: But, pray, what have you to say of *Duration* or *Time*?

B. Duration is the Idea we have of the Continuance of the Existence, or Being of Things; and in order to estimate and measure the Parts thereof, we use the Motions of moving Bodies, as the Sun, Stars, a Clock, &c. and the Parts of *Duration* thus compared and measured, we call Time, Times, Seasons, Ages †, &c.

CHAP. II.

Of Uranology, or the Doctrine of the heavenly Bodies; and first of Heliography, or the Philosophy of the Sun.

A. WHAT is the Meaning of the Word *Uranology*?

* It is an old Maxim, that nothing is more difficult than to prove the Truth of a self-evident *Axiom*, or that which is obvious to the common Sense of all Mankind. This is sufficiently confirmed by the numerous Controversies on the Subjects of *Space* and *a Vacuum*; for though nothing is more evident than the Nature of the one, and the Certainty of the other, yet nothing has more distracted and perplexed the Minds of Philosophers, as may be easily seen by perusing the Authors on these Subjects referred to in *Johnson's Phil. Questions*, Page 9.

† The Doctrine of *Time* is the Subject of *Chronology*; an Abstract of which excellent Science the Reader may find in my *Philological Library of Literary Arts and Sciences*.

B. It

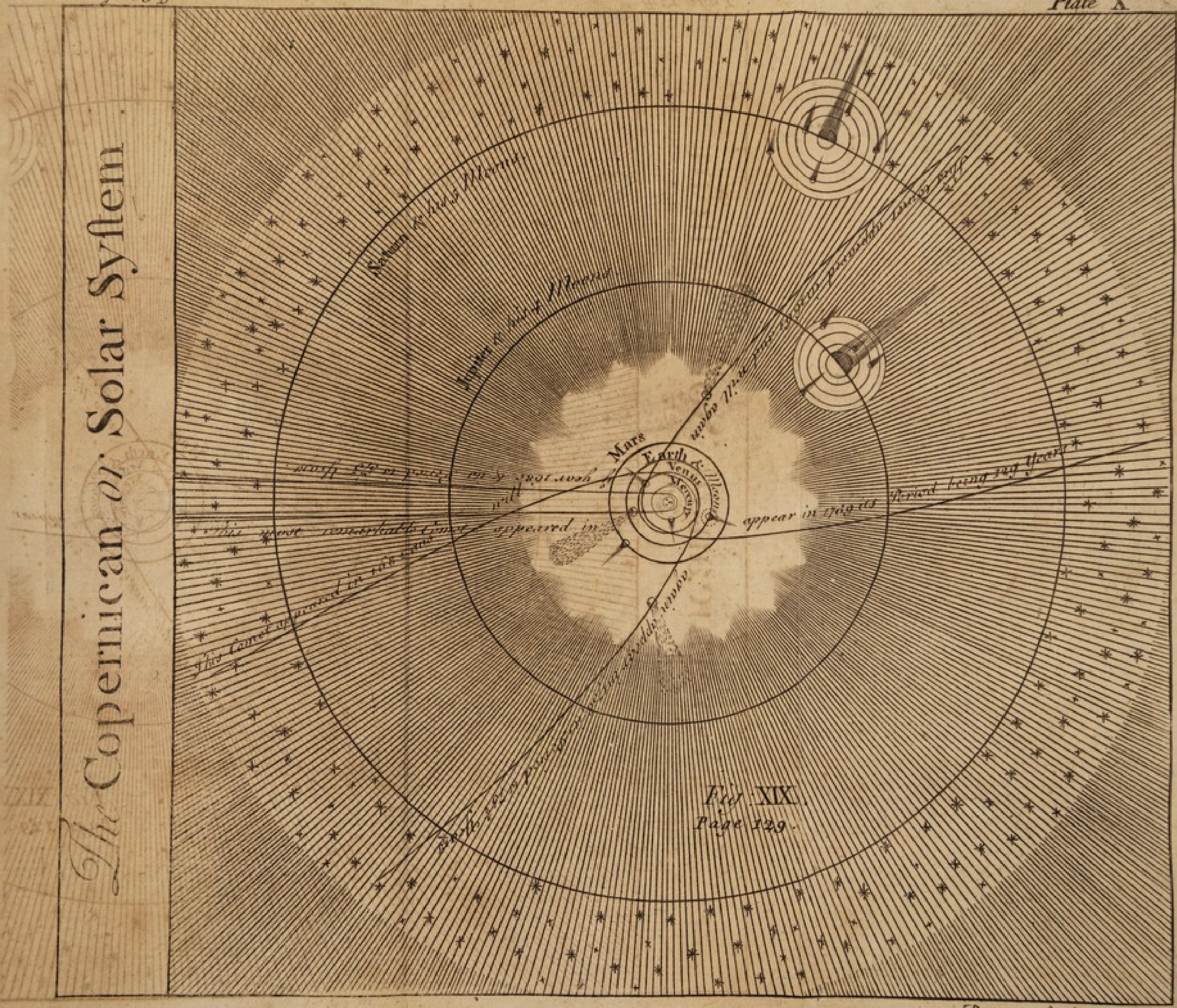


Fig XIX.
Page 129.

Bowen Sculp.

B. It is of *Greek* Original, and is compoſed of οὐρανὸς, *Heaven*, and λόγος, a *Diſcourſe*; therefore it ſignifies a *Diſcourſe* or *Treatiſe* of the *Heavens*, or *heavenly Regions*, and Bodies therein.

A. Pray what do you call the *Heavens*, or *heavenly Regions*?

B. Thoſe Regions, or Fields, of *Æther*, which lie all around us above the *Atmoſphere*; in which are ſituated all the ſhining Bodies, the *Sun*, *Planets*, *Comets*, and *Stars*, and wherein they perform all their Motions.

A. Where will it be proper for us to begin our Converſations on theſe celeſtial Subjects?

B. We will firſt begin with *Heliography*, if you pleaſe.

A. I do not underſtand the proper Meaning of that Word, pleaſe therefore to unfold it.

B. By *Heliography* (as being compoſed of ἥλιος, the *Sun*, and γραφὴ, a *Deſcription*) is to be underſtood, a *philoſophical Deſcription of the* Sun.

A. Well, it ſeems very congruous to begin with what you make the Centre of our Syſtem as you call it; and pray what do you firſt obſerve of the *Sun*?

B. The *Sun* is a huge Body of Light, or Fire, whence all the other *Planets* receive their Light; and by whoſe Emanations of Rays, and Beams of Light, the whole Syſtem of Beings about us is illuminated and made viſible.

A. Can you tell any Thing of the *Sun's* Bulk?

B. Yes: The Diameter of the *Sun* is computed at 822148 *Engliſh* Miles; and its Bulk, or ſolid Content, at 290971000000000000

Miles; which is about 1000000, or a Million of Times greater than the Globe of our Earth *.

A. Stupendous Magnitude! And what, do you suppose it to be all Fire?

B. Yes; and therefore some have thought it to be the Place of Hell †: However, its Quantity of Matter is well known; and the Density thereof is very considerable.

* 1. To compute the Diameter of the Sun, his Distance from the Earth must first be known, which supposing his *horizontal Parallax* 10 Seconds, I have found to be 82136014 Miles, in my *Young Trigonometer*'s *Guide,* Vol. I. Part 2. Chap. 3. § 14.

2. Suppose then you have a double convex Lens, as L, (*Fig.* XLVI, on *Plate* IX, fronting *p.* 132) whose Focus of parallel Rays is at CD, 12 Feet, or 144 Inches distant from itself; let this Lens be fixed in the Window-shutter of a darkened Chamber to receive the Sun's Rays AL, BL, which coming from the extreme Parts of the Sun's Body, and intersecting each other in the Centre of the Lens, will determine the Diameter of the Sun's Image at CD, which, when you have nicely measured, you will find to be $1\frac{34}{100}$ of an Inch. The Half of which is $Ce = \frac{67}{100}$ of an Inch. Then say,

As the focal Distance	CL = 144	=	2.158362
Is to $\frac{1}{2}$ the Diameter of the Image	Ce = 0.67	=	9.826074
So is Radius ———	90° 0′	=	10.000000
To the Line of the Angle	CLe = 0° 16′	=	7.667712

Therefore the whole Angle CLD or ALB is 32 Minutes, and this is called his *Apparent Diameter*, because its Diameter appears under such an Angle to the Eye.

3. Now since the Diameter of any *Object* and its Image are proportional to their Distances from the Lens, the Diameter of the Sun will easily be had by the following Analogy.

As the Distance of the Image	CL = 144	= 2.158362
To its Diameter ———	CD = 1.34	= 0.127105
So is the Distance of the Sun	LA = 82136014	= 7.914533
To his Diameter ———	AB = 764320	= 5.883276

4. Thus his Diameter is found to be *seven Hundred sixty four Thousand three Hundred and twenty English Miles*; which is less, but perhaps truer, than the above assigned——*Ten Thousand Miles* is a trifling Distance, and not to be regarded in the Measurement of such immense Distances.

† See *Swinden*'s Book on the Nature and Place of *Hell.*

A. The

A. The Quantity of Matter; pray, in what Proportion is that to the ſame in other *Planets?*

B. The Quantity of Matter in the *Sun* is to that in *Saturn*, as 100000 to 33; to that in *Jupiter*, as 100000 to 92; to that in our *Earth*, as 10000000 to 59.

A. In what Proportion is the Weight of Bodies on the *Sun*'s Surface?

B. The Weight of equal Bodies on the Surface of the *Sun* is to their Weight on the Surface of *Saturn*, as 10000 to 529; to their Weight on *Jupiter*, as 10000 to 943; and to their Weight on the Surface of our *Earth*, as 10000 to 435.

A. What is the comparative Denſity of the *Sun?*

B. The Denſity of the *Sun* is to the Denſity of *Saturn*, as 100 to 67; to the Denſity of *Jupiter*, as 100 to $94\frac{1}{2}$; and to the Denſity of our *Earth*, as 100 to 400, or as 1 to 4; and therefore the Fire of the *Sun* muſt be prodigious intenſe, yea, almoſt ſolid, as being one Quarter of the Denſity of our Earth *.

A. Why, then the Light and Heat muſt be inconceivably great near the *Sun*'s Surface?

B. Yes, great indeed: Sir *Iſaac Newton* ſaith, the *Sun*'s Light and Heat, at the Diſtance of *Mercury*, is ſeven Times as great as the greateſt with us; and therefore our Water there would

* Theſe Proportions of the *Matter*, *Weights* of Bodies, and *Denſities* in the *Sun*, *Saturn*, *Jupiter*, and the *Earth*, are taken from Sir *I. Newton*'s *Principia*, Pag. 405. Where the Diameters of theſe Bodies are determined to be in the Proportion of 10000, 791, 997, and 109.

be

be for ever boiling-hot, till it was all evaporated, and boiled away *.

A. Is the *Sun*'s Body one pure unmixed Subſtance of Fire?

B. That none can certainly tell; there hath ſeemed Reaſon to doubt it, ſince the Diſcovery of the *Maculæ Solares,* or *Solar Spots.*

A Pray, *Sir,* what are they?

B. The Aſtronomers of late, by proper Glaſſes, have diſcovered many black Spots in the apparent Face of the *Sun*; ſome ſuppoſe they are a heterogeneous Mixture of opake Matter in the Body of the *Sun,* which therefore in thoſe Parts will always appear dark or black. Some of thoſe Spots ſeem to be generated in the very Middle of the *Sun*'s Diſk; and others ſeem to be diſſolved and vaniſh there; ſometimes ſeveral ſmall ones gather together, and make a large Spot; and ſometimes a large Spot is obſerved to be divided, and cut into many leſſer ones. Some Philoſophers have thought they were ſmall *Planets* circulating round the *Sun*'s Body very near it; and others have other Conjectures about them. They were firſt diſcovered by *Galileo,* the *Italian* Philoſopher, in the Year 1610 †.

A. Do

* Since the Intenſity of *Light* and *Heat* are as the Squares of the Diſtances reciprocally, and ſince the Proportion of the Diſtances of all the Planets from the Sun is known, the Proportion of Light and Heat at each is alſo eaſily known, as is expreſſed in the following *Synopſis.*

† 1. That they who have not had an Opportunity of viewing the Spots in the Sun, with a Teleſcope or otherwiſe, may have ſome proper Idea of them, I have carefully delineated ſuch as appeared in the Sun's Face on *Aug.* the 25th, 1737, at Seven in the Morning, (in *Fig.*XLVII. on *Plate* IX, fronting *p.* 213.) where

A. Do theſe Spots appear fixed, or in Motion, on the *Sun*'s Body?

B. They

where the whole circular Area repreſents the Suns Face; on which you ſee the Spots in their proper Magnitudes, and Situations, as they then had.

2. The Number of theſe Spots is always uncertain and variable; it is ſaid when *Galileo, Schinerus, Hevelius,* &c. firſt obſerved them, that the Sun would frequently wear *one* or more of theſe Spots: But now (ſays Mr. *Molyneux,* who wrote about 40 or 50 Years ago) he ſeldom wears any of thoſe *Patches,* as if they were grown out of Faſhion, *one* in *five* or *ſeven* Years hardly appearing. Yet, about the Year 1700, it was not uncommon to obſerve 10, 16, or 20, and ſometimes more Spots on the Sun's Diſk. And now as the Sun is ſcarce ever to be obſerved without ſome, ſo they are generally very numerous, it not being difficult to enumerate 20, 30, or 40 Spots pretty diſtinctly on the Sun's Face, beſides many others which appear duſky and obſcure.

3. As to their *Magnitude,* that likewiſe is very variable, ſome being ſcarcely viſible, and others are ſo large even at his Limb, as to take up an 100th Part of his Diameter, and more; and which therefore will be found by Calculation to contain a far greater Number of ſquare Miles than the whole Superficies of our terraqueous Globe.

4. The *Motion* of theſe Spots is very irregular, ſo far as I could ever yet obſerve; I could never find that the ſame Spots in the ſame Figure, Number, and Order, ever returned in any regular periodical Manner; and therefore what is here ſaid concerning the Motion of the Sun, is wholly on Credit from others.

5. The *Mutability* of the *Form* or *Shape* of theſe Spots is very conſiderable, as is alſo the Variety thereof; being ſometimes long, broad, oval, ſeldom round, often angular, and pointed in ſeveral Parts, and will often vary their Shape while you are obſerving them.

6. Sometimes thoſe Spots decay, and become ſhady, nebulous, and of a miſty Appearance, and are at laſt inviſible before they go off the Diſk. And thoſe Spots and *Nebulæ* or Miſts do ſometimes ſuddenly ariſe, and as ſuddenly decay and become extinct.

7. Spots which continue long on the Diſk of the Sun, are ſaid often to turn to *Feculæ,* or exceeding *bright and flaming Parts,* which do not continue long on the Sun's Face, before they are extinguiſhed or diſappear. But theſe *Feculæ,* or flaming Spots, are very rare of late, ſince I have never had the deſirable Sight of one of them.

8. The ſagacious Mr. *Derham* very rationally ſuppoſes, that —*The Spots in the Sun are cauſed by the Eruption of Vulcano's therein, the prodigious Quantity of Smoke, and other opacous Matter,*

making

B. They all appear to move from the *Eaſtern* to the *Weſtern* Limb of the Sun, in about 12 or 13 Days.

A. Pray what do you infer from thence?

B. Why, was it certainly known (as it is the general Opinion) that thoſe Spots were really in the *Sun*'s Body; then, from their apparent Motion, we could be aſſured of the *Sun*'s real Motion about its own Axis, in ſomewhat above 25 Days and 6 Hours: But if theſe Spots are only ſome diſtinct Bodies actually moving round the *Sun*, then we have no certain Knowledge that the *Sun* hath any real and proper Motion at all.

A. How, *Sir*, do you ſay no Motion at all; pray do we not ſee him move every Day from *Eaſt* to *Weſt*?

B. He ſeemeth, indeed, to us ſo to move; but that is one of the Fallacies of Sight, and indeed the greateſt.

A. What! *Sir*, will you pretend to ſay he doth not move?

making the dark Spots, which gradually decaying and ſpending itſelf, makes the Spots degenerate to Umbræ and Nebulæ; that is, to Shadows and Miſts; laſtly, the fuliginous Matter being quite diſſipated, and ſpent, the horrid Flames of the Vulcano appear, and make the Feculæ before deſcribed.

9. In obſerving the Spots, &c. of the Sun, the beſt Way is to uſe a Teleſcope of about 6, 8, or 10 Feet Length, with a *ſmoked Glaſs* placed before the Eye-Glaſs next the Eye; if in this Caſe the Teleſcope be, and a Micrometer fitted thereto, the Spots may with Eaſe be meaſured, and their Appearances obſerved from Day to Day. Alſo the Sun's Image may be received into a dark Chamber (through a Teleſcope with an Object-Glaſs and one Eye-Glaſs only) on a Piece of white Paper, which may be magnified or diminiſhed as Occaſion requires; this is an eaſy and innocent Way, and that which I generally uſe.

See much more concerning this curious Subject in the *Phil. Tranſactions*, N° 288, 294, 330; or the ſame abridged by Mr. *Jones*, Vol. IV. Page 228 to 245. As alſo in *Harris*'s *Lexicon*, under the Word *Maculæ*.

B. Yes,

B. Yes, *Sir,* there is no Reaſon to think he doth move; and there are phyſical Demonſtrations that he doth not move.

A. Pray what are they?

B. One of them is this: *That ſince the* Sun, *the* Earth, *and all the* Planets *gravitate mutually towards each other, they muſt all have one common Centre of Gravity, about which they muſt all move; but Sir* Iſaac Newton *hath ſhewn and demonſtrated, that this Point, or Centre of Gravity, is not quite a Diameter of the* Sun *diſtant from the* Sun's *Centre; therefore the* Earth, *and all the* Planets, *move round a Point not half the Diameter of the* Sun *diſtant from the* Sun's *Surface; and this is the ſame Thing to us, as if the* Earth, *&c. moved about the* Sun *itſelf*.*

A. Well, I cannot confute Sir *Iſaac,* it is true; but I can chooſe whether I will believe him: Should not I ſooner believe the *Word of God,* and my *own Senſes?*

B. No: A Demonſtration at once commands Aſſent, notwithſtanding the *literal Meaning* of Scripture, and the *Evidence of all* our *Senſes* to the contrary. No one needs be convinced of the Fallacy of Sight, who hath ever been in a Ship under Sail; nor was the Scripture intended for a Syſtem of *Phyſiology*†.

CHAP.

* *Principia Math. Philoſ.* Lib. III. Prop. 12. & Corol. The other Phyſical Demonſtration of the Earth's Motion about the Sun, ſee in *Keill's Aſtronom. Lectures,* Page 34, 35; or in the *Philolog. Library of Literary Arts and Sciences,* Page 300.

† I am ſorry any one ſhould take from hence an Occaſion to ſay that I ſpake irreverently or ludicrouſly of the *ſacred Scriptures*; I think it would be very diſhonourable and ridiculous to urge them in any Senſe againſt a *known and demonſtrated Truth* of any

CHAP. III.

SELENOGRAPHY, *or the* PHILOSOPHY *of the* MOON.

A. WHAT is the Etymology of the Word *Selenography?*

B. It is compounded of σελήνη, the *Moon*, and γραφὴ, a *Deſcription*; wherefore it means a *phyſiological Deſcription of the* Moon.

A. You ſpeak of the *Moon* in the *ſingular*, as if there was but one; whereas juſt now you numbered our *Moon* with ſeveral others.

B. Yes, there are ſeveral other *Moons*, as *Jupiter* hath four *Moons*, and *Saturn* hath five *Moons*; but becauſe we know little more of them than their Number, Motions, and Diſtance from their *primary Planets*, we ſhall omit them here, and ſpeak of them together with their *Primaries* by and by.

A. Well, ſince the *Moon* is favoured with the Preheminence to be conſidered alone; pray what do you firſt obſerve in her?

any Kind. I eſteem the Bible not only a juſt Hiſtory of Facts, but a divine Revelation, and the beſt Syſtem of natural Religion in being; but I am ſo far from thinking that we are to be directed in our Sentiments of natural Science, eſpecially *Philoſophy* and *Aſtronomy*, by the Scriptures, that I am apt to believe thoſe Sciences, as they are now and truly underſtood, were entirely unknown to the Writers of thoſe Books.

But if any one gives himſelf the Trouble, he may ſee the Arguments for the Sun's Motion fairly ſtated, and fully confuted, in *Varenius*'s *Geog. General.* Par. 1. Lib. I. Cap. 5. *Atlas Geog. Introduction*, § 12. *Joan. Clerici Phyſica*, Lib. I. Cap. 2. & 3. *Galilæi Syſtem. Coſmic.* Pag. 354, 356, 457, 492, 644. *Epiſtola Paul. Anton. Foſcarini*, wholly on the Subject.

B. It is found that the Body of the *Moon* is a large, dark, opake, ſpherical Body, alike to our Earth in Matter and Form.

A. What Proportion doth the *Moon* bear to the Earth in its *Magnitude* and *Denſity* of Matter?

B. The Bulk of the *Moon* is to that of the *Earth*, as 586333000 to 258445900000, or as 5 to 258; that is, the *Earth* is about 50 Times (at leaſt) bigger than the *Moon*; the Denſity of the *Moon* is to the Denſity of the *Earth*, as 4891 to 4000, or as 11 to 9; the Quantity of Matter in the *Moon* is to that of the *Earth*, as 1 to 40, or as 1000 to 39788, more nearly; and the Weight of Bodies on the *Moon*'s Surface, is to their Weight on the *Earth*'s Surface, as 34 to 100 *.

A. Can you tell the particular Dimenſions of the *Moon*'s Body in *Engliſh* Meaſure?

B. Yes; the Diameter of the *Moon* is 2175 *Engliſh* Miles, her Circumference therefore muſt be 6829 Miles; whence the Superficies of the *Moon* will contain 1415440 ſquare Miles, and her ſolid Content will be 5386333000 cubick Miles, as before.

A. On what do theſe Meaſures depend?

B. On the Diſtance of the *Moon* from the *Earth*; which ſome Aſtronomers make 59, ſome 60, ſome 61, Semi-diameters of the *Earth*, that is, about 238920 *Engliſh* Miles; whence the Diameter of the *Moon*'s Orb will be 477840 Miles, and Circumference thereof 1500418 Miles; which therefore is the Journey the *Moon* performs every Revolution †.

A. Then

* See *Newton. Princip, Philoſ.* Pag. 468, 469.

† The Diſtance of the Moon from the Earth is thus found. (See

A. Then you do allow the *Moon* to move about the *Earth* every Day from *East* to *West*, though you deny this to the *Sun*?

(See *Fig*, XLVIII. on *Plate* IX, fronting *p.* 132.) Let ABC be the Earth, V the Moon in the Zenith, and D the Moon in the Horizon: BD is the *sensible Horizon*, and CH the *true* or *rational Horizon*. Suppose the Moon in that Part of her Orbit nearest the Earth; an Observer at B would see the Moon in the Line BD, but to an Eye placed in the Centre of the Earth C, she would appear in the Line CD; the former is her *apparent Place* known by Observation with exact Instruments; the latter, her *true Place*, and is known from the *Theory*, or Table: The Difference of these two Places is found to be $1^\circ\ 2'\ 10''$, and is the Measure of the Angle BDC, which is called the Moon's *Horizontal Parallax*; the Angle at B is a Right one, and BC is the Semi-diameter of the Earth. Wherefore, in the Triangle BDC we can easily find the Side BD, the Distance of the Moon from the Observer B, by the following Analogy:

As the Sine of the Angle	D	$=1^\circ\ 2'\ 10''$	$=$	8.257419
To the Side —	BC	$=$ 1	$=$	0.000000
So is the Sine of the Angle	BCD	$=88^\circ 57'\ 50''$	$=$	9.999929
To the Side —	DB	$=$ 55.27	$=$	1.742510

That is, the Moon (when nearest the Earth) is $55\frac{27}{100}$ Semi-diameters of the Earth distant from the Point B. But a Semi-diameter of the Earth is 3982 Miles, which multiplied by $55\frac{27}{100}$, gives $220085\frac{5}{10}$ Miles, her nearest Distance from the Observer at B. In the same Manner you find the Side CD$=220344\frac{78}{100}$ Miles, her nearest Distance from the Centre of the Earth. But her *mean* and *greatest Distance* is variously determined, as above hinted.

Again, to find the Diameter of the Moon in Miles, let P be the Moon, and O her Centre, join CO and PC; then is the Angle OCP equal to the apparent Semi-diameter of the Moon at the Centre of the Earth, which, for the abovementioned *Horizontal Parallax*, is $16'\ 52''$ (see Note * in Page 136) and CO is equal to CD$=220344\frac{78}{100}$, and the Angle at O is a *Right* one, whence the Side PO is thus found:

As the Sine of the Angle	CPO	$=89^\circ\ 43'\ 8''$	$=$	9.999995
To the Side —	CO	$=220344\frac{78}{100}$	$=$	5.342611
So is the Sine of the Angle	OCP	$=16'\ 52''$	$=$	7.690663
To the Side —	OP	$=1079\frac{6}{10}$	$=$	3.033269

Which is the Number of Miles in the Semidiameter of the Moon, the Double whereof, *viz.* $2159\frac{2}{10}$ is the Number of Miles in the Moon's true Diameter. This indeed is 16 Miles less than that assigned in the Text, but the Difference is too small to be regarded.

B. The *Moon* doth, indeed, move about the *Earth*, and that in about 27 Days, 7 Hours, and 43 Minutes, at a mean Rate: But this Motion is not from *East* to *West*, but, on the contrary, from *West* to *East*, every Day about 13 Degrees and 10 Minutes.

A. How comes it then to appear to do thus?

B. By reason of the daily Motion of the *Earth* about its own Axis from *West* to *East* once in 24 Hours; which maketh the *Sun*, *Moon*, and all the *heavenly Bodies*, appear to move the contrary Way from *East* to *West* in the same Time.

A. Pray why do we see the *Moon* rise and set above an Hour later every Day than another?

B. I shall make this easy to conceive. Thus, suppose T be the Globe of the Earth, WSEN the Orb of the *Moon*; let AD represent the *Horizon*, in which let the *Moon* ☽ be, on any Day at her rising and setting, in E and W: Now, because the *Moon* moves every day about 13° 10′ from *West* to *East*, let that Distance be represented in the *Moon*'s Orb by WF and EH; therefore at the same Time, on the following Day, the *Moon* will be under the *Horizon* at H at her rising, and above the *Horizon* at F, at her setting the Day before; where the Surface of the *Earth* must turn from A to B, and from D to C, before the *Moon* will be again in the Horizon at rising or setting; which Motion from A to B, or from D to C, takes up about an Hour's Time, more or less, every Day. See *Fig.* XXI. on *Plate* XIII, fronting *p.* 155 *.

A. Sir,

* In an oblique Sphere, all great Circles intersecting the *Equinoctial* will, in the Revolution of the Sphere, intersect the Horizon

A. Sir, I thank you; I perfectly underſtand you, and the Meaning of this *Phænomenon:* Pray hath the *Moon* any other Motion?

B. Yes: She revolves about her own Axis juſt in the ſame Time ſhe performs one Revolution about the *Earth*, viz. in 27 Days, 7 Hours, 43 Minutes *.

A. How are you ſure of that?

B. Becauſe at the ſame Times we always ſee the ſame Face or Side of the *Moon*; but this could not happen, unleſs a proper Motion about her Axis turned every Day juſt ſo much of the *Moon*'s Body to the *Earth* as her periodical Motions turn from it.

Horizon with different Angles at every different Part thereof. Thus with reſpect to the Ecliptic, when the Beginning of *Libra* is *orient*, or riſing in the Eaſt, it then makes the greateſt Angle with the Horizon; when *Capricorn* is *orient*, the Angle is mean, and when *Aries* is *orient*, the Angle is leaſt of all; and therefore when the Moon is full in the Beginning of *Libra*, one Day's Motion depreſſes her fartheſt below the Horizon, and leaſt when in the Beginning of *Aries*; conſequently, the Difference of her riſing each Day at the *vernal Equinox* will be greateſt, and leaſt of all in the *autumnal Equinox*.

Now ſince the Moon's Orb interſects the Ecliptic in an Angle of about five Degrees, when theſe Points of Interſection ſhall happen to be in the *Equinoxes*, a full Moon in the Beginning of *Libra* will riſe later the next Day after by one Hour and about 20 Minutes; and in the Beginning of *Aries*, by the Difference only of about 20 Minutes. And if the Moon be in *Perigeum* at ſuch Times, the Intervals of her riſing will ſtill be greater in the former Caſe, and leſſer in the latter. Thus the *Autumnal full Moon* riſes near an *Hour ſooner*, the next Day, than the *Vernal* one; whence, by Way of Diſtinction, it is vulgarly called the *Harveſt Moon*.

* The Revolution of the Moon through the *Zodiac* is called a *Lunation*, and 12 of theſe Lunations or Revolutions is a *Lunar Year*; and which takes up the Space of 354 Days, 8 Hours, 48′ 38″. The Difference between this and the *ſolar* Year, which contains 365 D. 5 H. 48′ 57″, is almoſt 11 Days, which Chronologers call the *Epact*. See my *Philolog. Library*, Page 338, 350, *&c.*

And becauſe the Moon's Motion about her Axis is performed in the ſame Time as about the Earth, the *Lunarians* have their *Nycthemeron* or *Natural Day* equal to their Month.

A. This

A. This muſt be a wonderful Harmony and Correſpondence of Motions, indeed! But what is the Form of the *Moon*'s Orbit?

B. The *Moon*'s Orbit is elliptical, but is perpetually changing, and never continueth the ſame Species, or of the ſame Figure.

A. How ſo?

B. The Cauſes of Inequalities of the Motions of the *Moon*, and the Form of her Orbit, are the different Attractions of the *Sun* and *Earth*, the Eccentricity of her Orb, and the Obliquity of the Axis of her daily Motion *.

A. I think you agree, the *Moon* receives all the Light ſhe ſhines with from the *Sun*?

B. Yes, ſhe does ſo; and by Reflection conveys it to us in the *Sun*'s Abſence †.

A. Pray, *Sir*, give me Leave to aſk what is the Reaſon why ſome Parts of the *Moon*'s Face look dark, and others light?

B. The bright Parts of the *Moon*'s Body are the more eminent Parts of Land, which reflect the Light of the *Sun*, as Hills, Mountains, Promontories, Iſlands, *&c.* and the dark Parts of the *Moon* are thought to be Seas, Lakes, Rivers, Fens, *&c.* by ſome; and by others, they are ſaid to be ſhaded Vallies, Caverns, Pits, *&c.* But in Truth they repreſent both Water and ſhaded Places; for neither of theſe reflecting Light, muſt appear dark, and not bright.

* Concerning the *Irregularities* of the Moon's Motion, and her compleat Theory, ſee *Newton*, Princip. Lib. III. *Gregory*'s, *Whiſton*'s, and *Keill*'s Aſtronomy; alſo Mr. *Leadbetter*'s Books of Aſtronomy.

† The Sun's Light by Reflection from the Moon is ſo very weak and effœtè, that it cannot be made to produce any ſenſible Heat by the beſt of *Burning-Glaſſes* yet made.

A. Then you ſuppoſe the *Moon* to be inhabited, I find? I have heard there be ſome of that Opinion.

B. Yes, undoubtedly; to what End elſe can ſerve the Diſtribution of Land and Water, Mountains and Vallies, Caverns, Pits, *&c.*? Beſides an *Atmoſphere* of Air (and thereby Winds, Clouds, Rain, and other Meteors of Conſequence) has been lately diſcovered about it: No doubt but they ſerve the Purpoſes there, as here, to nouriſh and ſuſtain Men, Beaſts, and Vegetables *.

A. Indeed, if it be ſo, your Reaſoning and Inferences are very juſt: I wiſh I could have the Happineſs of viewing the Face of the *Moon* through a good *Teleſcope*, for my own Satisfaction.

B. It is a very great Curioſity indeed; I can tell, becauſe I have thus viewed it many Times; I ſhould be glad if the Weather would permit me now to gratify you in this Particular; however, to make amends for that, I can ſhew you the Face of the *Moon* curiouſly engraven, and juſt as it appears through ſuch a Glaſs, with the Names which ſeveral *Sele-*

* That the Moon is inhabited, few have doubted; but it is a great Queſtion with ſome whether there be an *Atmoſphere* about her, and others flatly deny it. See *Hugens*'s Coſmoth. Book II. and *Keill*'s Aſtron. Lect. X.

The Moon through a good Teleſcope not only appears *perfectly globular* when at full, but at other Times to have all the Varieties of *Mountains*, *Vales*, and *Seas*, as we may ſuppoſe a Lunarian can behold in our Earth.

They who would ſee the Manner of meaſuring a *Lunar Mountain*, may conſult Mr. *Derham*'s Aſtro-Theol. Book V. Chap. 2. in the Notes, and the Authors there referred to. As alſo my Young Trig. Guide, Vol. I. Part II. Chap. 3. Sect. 20. and *Keill*'s Aſtr. Lect. X. Page 107.

To front Page 149.

Plate XI.

Fig: XX.

Em: Bowen Sculp.

nographists have given to the several light and dark Parts thereof. See *Fig*. XX. on *Plate* XI, fronting *p*. 149.

CHAP. IV.

Of PLANETOGRAPHY, *or the* PHILOSOPHY *of the* PLANETS.

A. PRAY what is the original Meaning of the Word *Planet* ?

B. It is a *Greek* Word, and derived from the Verb πλανάομαι, to *wander* or *stray* ; whence the *English* of this Word is, a *wandering Star*.

A. I think I remember, you told me there were two Sorts of those *Planets*, or *wandering Stars*; the first you called *primary Planets*, the other *Secondaries*, or *Moons*, or *Satellites* ?

B. It is true I did : And the *primary Planets*, viz. *Mercury*, *Venus*, the *Earth*, *Mars*, *Jupiter*, and *Saturn*, are principally here intended, as the Subject of our present Discourse ; and the *Secondaries* we will only consider amongst the Accidents of the *Primaries*.

A. Well, since a *Planet* hath its Name from its Motion, we will first begin with the Motions of the *Planets* if you please: And, pray, in what Order, Form, or Manner, do the *Planets* move ?

B. I have already said, that the *Sun* is the Centre of our System ; about which the *Planets* all revolve in different Distances ; 1. *Mercury*, 2. *Venus*, 3. *Earth*, 4. *Mars*, 5. *Jupiter*, and 6. *Saturn*, as you see them in the Solar System ; the Form of their Motion is elliptical more or less, and not perfectly circular ; and they all move round the *Sun*, in ſuch Manner, as *to deſcribe equal Areas of Space in equal Times.*

A. Pray, *Sir*, if you can, illuſtrate this Matter by a Scheme.

B. *Sir*, that may be done very eaſily, Thus, let S be the *Sun*, ABPCD the elliptical Orb of a *Planet* P; then the Part of the Orb P is called the *Perihelium*, being the neareſt Diſtance from the *Sun*; and the Part A is called the *Aphelium*, as being the fartheſt Diſtance from the *Sun*; and SE is called the *Eccentricity* of the *Planet*; and as this *Eccentricity* is leſs or greater, ſo the Orb of the *Planet* is leſs or more elliptical. See *Fig.* XXII. on *Plate* XIII, fronting *p.* 155.

A. But you have not yet ſhewed what is meant by a *Planet*'s deſcribing equal Areas in equal Times.

B. This is no more than to ſay, if the Times, in which the *Planet* moves in his Orb from P to C, and from C to D, and from D to A, be equal to each other, then the Areas or Spaces PSC, CSD, and DSA (deſcribed in thoſe equal Times, by Lines drawn from the *Planet* to the *Sun*) will alſo be equal among themſelves, and *the contrary* *.

A. But, pray, do you aſſign ſuch very unequal Portions of the Orbit to be paſſed over in equal Times? Do not the *Planets* move equal Diſtances in their Orbs in equal Times?

B. No, very far from it; for the Velocity of a *Planet*'s Motion is different in every Part of its Orb, being ſometimes greater, and ſometimes leſs.

* By *the contrary* is meant only, *that if the* Areas deſcribed be equal among themſelves, the Times in which they were deſcribed will alſo be equal. See *Newton*, Princip. Lib. III. Prop. XIII.

A. How

A. How happens that?

B. By Gravity, or the *Sun*'s Attraction: For, when the *Planet* is in P, the *Sun* attracteth it most strongly; and therefore the Motion there, and thereabouts, is greater than any where else. Again, when the *Planet* is in its *Aphelium* at A, at its greatest Distance from the *Sun*, it is then least affected by the Power of Gravity, and consequently the Motion there, and thereby, is the least or slowest of any Place in the Orb. But, when the Motion is so unequal, the Arches PC, CD, DA, must needs be so too, though described in equal Times.

A. Sir, I conceive it must be so now; I did not think of the *Sun*'s Attraction: Since therefore those Areas are always proportional to the Times, pray, what Proportion of Gravity or Attraction will produce this?

B. The Power of Gravity is always reciprocally as the Squares of the Distances of the *Planet* from the *Sun*: Thus, suppose the Distances SP, SC, SD, SA, were as the Numbers 5, 6, 9, 10, then the Power of Attraction in those Distances would be reciprocally as their Squares, *viz.* 100, 81, 36, 25; so that it would be four Times greater in the *Perihelium* P, than in the *Aphelium* A; and this is the constant Law of all the *Planets* both primary and secondary.

A. Pray what other Affections are observable of the planetary Motions?

B. The *Planets*, as I told you, all move about the *Sun* in reality from *West* to *East*, and yet they sometimes appear to move the contrary Way from *East* to *West*, and sometimes not to move at all for ſome Time; and thus they are ſaid to be *direct*, *ſtationary*, or *retrograde*.

A. I ſhould be glad if you could explain this to my Apprehenſion by a clear and eaſy Scheme.

B. That I will endeavour to do: Therefore let S be the *Sun*, ACE the Orb of the *Earth*, and FGI a Part of the Orb of any one of the ſuperior *Planets*, ſuppoſe *Jupiter*; alſo let QR repreſent the Arch of the ſtarry Heavens, wherein we ſee and determine the Places and Motions of all the *Planets*, (ſee *Fig*. XXIII, on *Plate* XIII, fronting *p*. 155.) Now, ſuppoſe the angular Motion of the *Earth* be ſo much greater than that of *Jupiter*, that while the *Earth* deſcribes the Arch ECA, *Jupiter* ſhall only deſcribe the Arch HGF; then it is eaſy to conceive, that, when the *Earth* is in E, the *Planet* at H will be ſeen amongſt the fixed Stars at M, and ſo he will alſo, when the *Earth* is arrived at D; therefore all the Time the *Earth* is paſſing from E to D, the *Planet* will ſeem to ſtand ſtill about M, and is ſaid to be Stationary: Again, when the *Earth* is arrived to C, the *Planet* will really be moved forwards to G, but will be ſeen from the *Earth* at C, amongſt the Stars at N; wherefore, while the *Earth* paſſeth *Eaſtward* from D to C, the *Planet* will appear to move *Weſtward* from M to N in the Heavens, which is backward; alſo, while the *Earth* moves from C to B, the *Planet* will ſtill ſeem to move backwards from N to O, where it will again be Stationary till the *Earth* comes to A. Do you underſtand me?

A. I believe I do: You mean, that while the *Earth* paſſeth from E to D, and from B to A,

the

Fig: XLIX
Page 155.

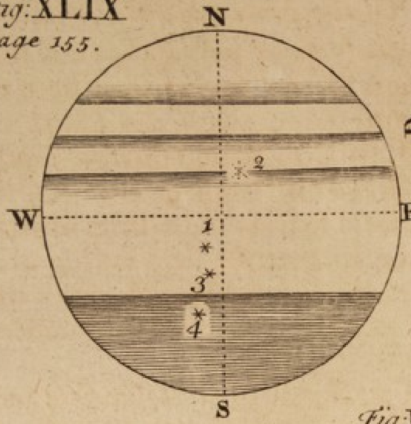


Fig: L.
Page 155.

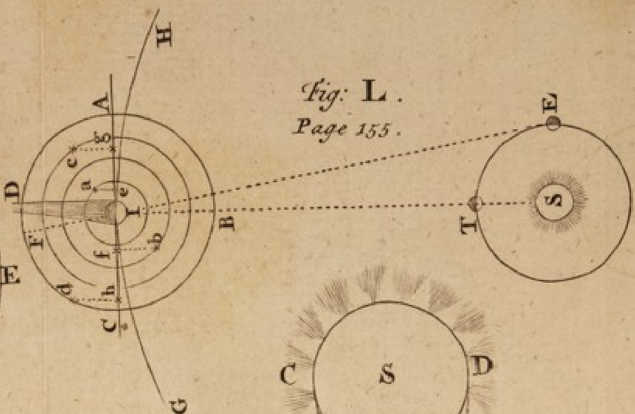


Fig: LII.
Page 155.

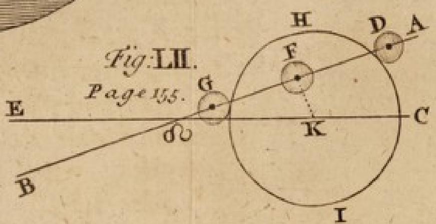


Fig: LIV.
Page 177.

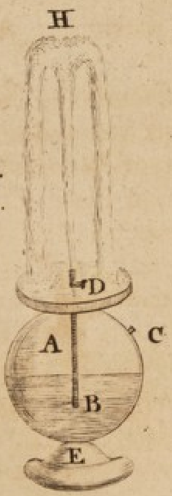


Fig: LIII.
Page 157.

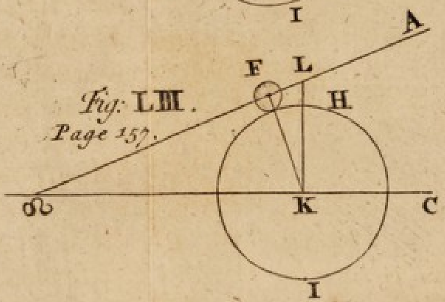


Fig: LV. Page 178.

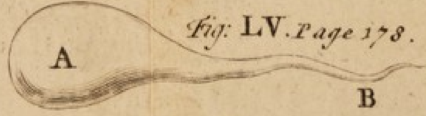
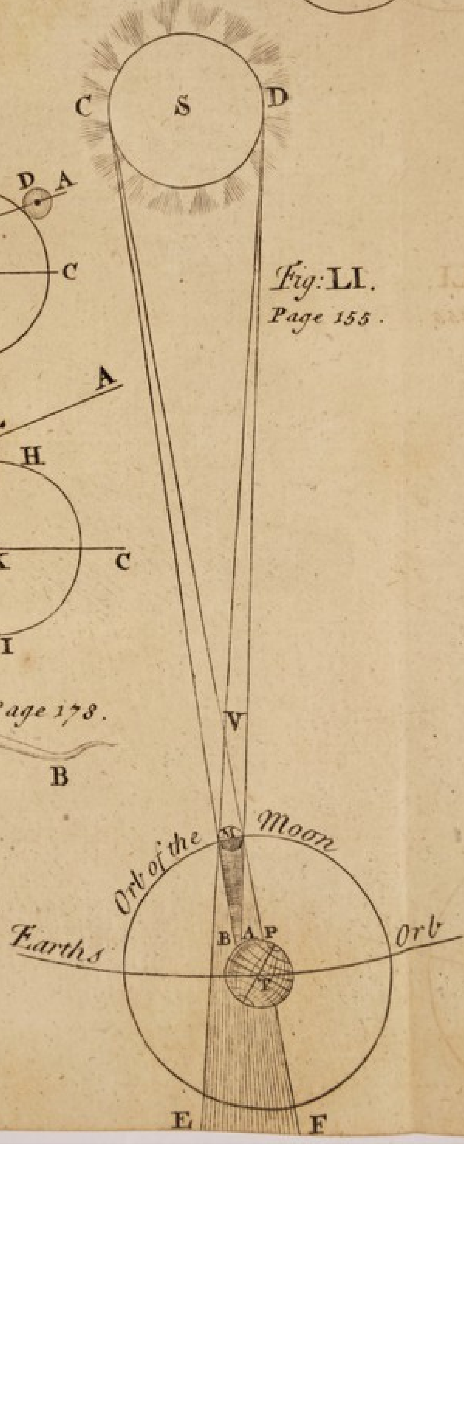


Fig: LI.
Page 155.



the Planet *Jupiter* will appear not to move in the Points M and O; and then he is ſaid to be Stationary: Alſo, while the *Earth* is paſſing from D, by C to B, and though *Jupiter* really moves in his Orb from H to F *Eaſtward*, yet he will ſeem to us to move from M to O *Weſtward*, or *backwards*; and during that Time is ſaid to be Retrograde: I think this is the Matter as you intended I ſhould underſtand it; is it not?

B. Yes, I am glad to ſee you underſtand this intricate Phænomenon ſo well; and in a like Way you may underſtand the ſame of the inferior *Planets*.

A. Pray what particular Affections hath each *Planet*?

B. *Eclipſes* are peculiar to the *Earth*, *Jupiter*, and *Saturn*, becauſe thoſe *Planets* in particular have *Moons* or *Satellites* moving round them, which occaſion thoſe *Eclipſes*; alſo one Thing is particular or peculiar to *Saturn* alone; and that is a ſurpriſing Kind of a Ring, encircling the Body of this *Planet* at a great Diſtance. *Laſtly*, *Jupiter* hath the Appearance of Belts girding his Body; and *Jupiter*, *Mars*, and *Venus*, are found to have dark Spots on their Diſks.

A. Well, that we may have ſome regular Account of thoſe wonderful Particulars, let me know firſt concerning the Nature, Number, and Diſtances of the *Moons* or *Satellites* pertaining to the primary *Planets*.

B. The *Earth* hath one *Moon*, of which already: *Jupiter* hath four *Moons*, and *Saturn* five *Moons*: The Times in which they ſeverally revolve about their Primaries, and their Diſtance in

Semi-

Semi-diameters of the Bodies of *Jupiter* and *Saturn*, are as here follow:

In *Jupiter*.

	D.	H.	M.			
1 *Satellite*	1	18	27	Diſtance from *Jupiter*'s Centre	$5\frac{6}{10}$	Semid. of *Jupiter*.
2 ———	3	13	13		9	
3 ———	7	3	42		$14\frac{3}{10}$	
4 ———	16	16	32		$25\frac{29}{100}$	

In *Saturn*.

	D.	H.	M.			
1 *Satellite*	1	21	18	Diſtance from *Saturn*'s Centre	$1\frac{9}{10}$	Semid. of *Saturn*'s Ring.
2 ———	2	17	41		$2\frac{2}{5}$	
3 ———	4	12	25		$3\frac{2}{5}$	
4 ———	15	22	41		8	
5 ———	70	22	4		$23\frac{3}{10}$	

Theſe *Moons*, and their *Affections*, were all diſcovered by Means of the *Teleſcope*; and, before its Uſe, were unknown to the Ancients *.

A. They

* 1. In the Beginning of the Year 1665, the famous *Chriſ. Hugens* diſcovered the biggeſt of *Saturn*'s Satellites with a Teleſcope of 12 Feet, and is the fourth from *Saturn*. The other four Satellites of *Saturn* were all the Diſcovery of Mr. *Caſſini*, the 3d and 5th in the Year 1671, 1672, and 1673; but the 1ſt and 2d were not diſcovered till the Year 1684, by extraordinary Glaſſes of 80, 100, 150, and 200 Feet in Length.

2. All *Jupiter*'s Satellites were diſcovered by *Galileo*, on *Jan.* 7, 1610; and from that Time to this no more than four could ever be ſeen. Theſe Moons are eaſily ſeen with a 2, 3, or 4 Feet Glaſs, eſpecially with ſhort Focus Eye-Glaſſes; but to make exact Obſervations of their Motions, a Glaſs of 10 or 12 Feet is neceſſary; but a good Reflecting Teleſcope of 4 or 6 Feet is ſufficient for viewing or obſerving the Satellites either of *Jupiter* or *Saturn*.

3. M. *Molyneux*, in the Year 1681, *Nov.* 2, at 10 at Night, obſerved a *total Diſappearance* of all *Jupiter*'s *Satellites*, at once; *Ju-*

To front Page 155.

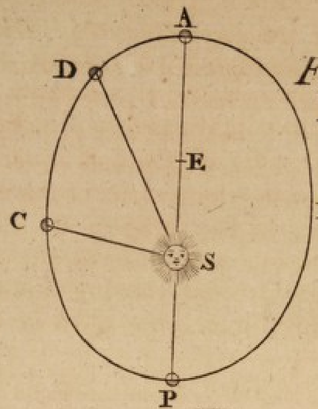


Fig: XXII.
Page 150.

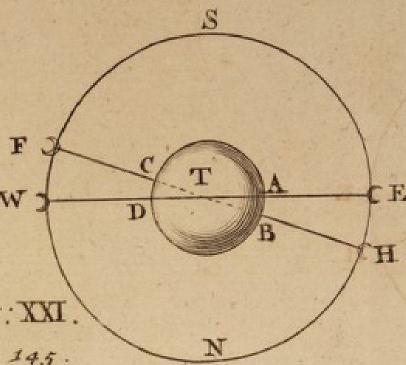


Fig: XXI.
Page 145.

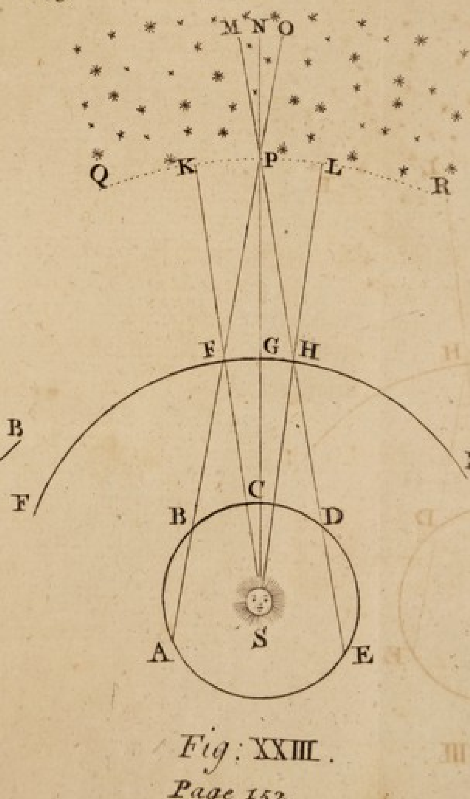


Fig: XXIII.
Page 152.

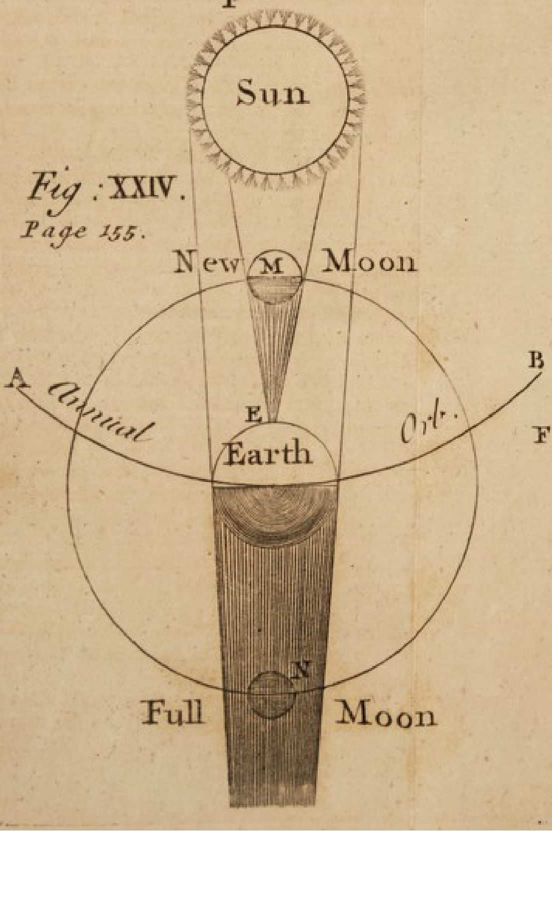


Fig: XXIV.
Page 155.

A. They are certainly noble Discoveries; but you say they are the Cause of *Eclipses* to their Primaries; how, I pray you?

B. This, both in the primary, and also in the secondary *Planets*, will be best understood by a Scheme, shewing the *Eclipses* of the *Earth* and *Moon*: For, in *Fig.* XXIV. on *Plate* XIII, fronting *p.* 155, you observe the *Earth* E, in her annual Orb AB, moving about the *Sun*; at the same Time, you observe the *Moon*

Jupiter then appearing solitary, as it were deserted by his Guards; and a bold *Lucian* might have pulled him from his Throne without Resistance, says the jocose Author. But they were the 1st, 3d, and 4th on his Face, and the 2d behind his Body, in the Manner as represented in *Fig.* XLIX. on *Plate* XII, fronting *p.* 153. See *Molyn.* Diopt. Page 271, &c.

4. For the *Satellites* of *Jupiter* or *Saturn* may be rendered invisible to us four different Ways, (see *Fig.* L. on *Plate* XII, fronting *p.* 153.) Let S be the Sun, E the Earth, I *Jupiter* in his Orbit GH, and *a*, *b*, *c*, *d*, his four Satellites about him. Then, (1.) A Satellite may be eclipsed by *Jupiter's* Shadow ID. (2.) It may be hid behind the Body of *Jupiter*, in the Line IF. (3.) It may pass over the Face of *Jupiter*, whose greater Light will render that of the Satellite insensible. (4.) Lastly, One Satellite may pass before and intercept the Light of another; though this is a Case that very rarely happens.

5. Notwithstanding the Satellites have all a circular Motion about their *Primary*, yet when they are viewed, they appear *to be*, and *to move* in a *straight Line* situated *East* and *West*. The Reason whereof is, that since the Planes of the Orbits of the Satellites do nearly pass through the Eye of the Spectator, either half of any of their circular Orbits, as ABC or ADC, will be projected into its Diameter AC, and consequently its Satellite with it; and thus the Satellites, if situated in the Orbit in *a*, *b*, *c*, *d*, will appear to a Spectator on the Earth at T, in the Right Line AC in the Points *e*, *f*, *g*, *h*.

6. Also, while the Satellite is in the nearest Semi-circle CBA, he appears to move from East to West in the Line CA; but while he passes the remote Semi-circle ADC, he will then appear to return from the West to East along the same Line AC; so that in one Revolution he appears to move twice through the Right Line AC.

7. From hence also it appears, that the most distant Satellite may appear nearer the Body of *Jupiter* than the nearest; and the contrary; which is so easy to conceive, that I need not perplex the Scheme for an Example.

moving

moving about the *Earth* in her Orb: Now when the *Moon* is in Conjunction with the *Sun*, *i. e.* when she is just between the *Earth* and *Sun*, and is what we call the *New Moon*, as at M; then it is evident her Shadow will fall on the *Earth* at E, and consequently will hide some Part of the *Sun*'s Body from those who dwell on that Spot; and this is what they call an *Eclipse* of the *Sun*, but is properly an *Eclipse* of the Earth; for you see it is the *Earth* that is really darkened, and not the *Sun*: Also it is evident, when the *Moon* is in the opposite Part of her Orb at N, in direct Opposition to the *Sun*, that then the *Earth* being exactly between the *Sun* and the *Moon*, will cast her Shadow on the *Moon*; and the *Moon* being thus overwhelmed in the Shadow of the *Earth*, will appear dark or dusky, and is properly said to be then eclipsed.

A. This, indeed, is so plain and evident, I believe none can look on it, and not apprehend the Manner and Cause of *Eclipses*. Pray, can you tell the Quantity of *Eclipses*?

B. Yes; the dark Shadow of the *Moon* covers a Part of the *Earth*'s Surface about 180 Miles in Diameter, and moveth at the Rate of 2104 Miles an Hour: But the *partial* or *penumbral* Shadow extends to the Width of 4900 Miles: And as to Lunar *Eclipses*, the Diameter of the *Earth*'s Shadow at the *Moon*, is near three Times greater than the Diameter of the *Moon*; and therefore the *Moon**, in central *Eclipses* of her

*The Nature of a *Solar Eclipse* will be further evident from *Fig*. LI. on *Plate* XII, fronting *Page* 153, where S is the Sun, T the Earth, and M the Moon. From the Extremities of the Sun her Disk, is totally darkened, or eclipsed, for some Time. *A.* So,

Sun draw CF and CB on one Side, and DE and DA on the other, touching and including the Moon's Diameter. Then it is manifest, there will be two Kinds of Shadows produced from the Moon; one determined by the Rays CB and DA, and is properly called the *dark Shadow*, because an Eye placed with that cannot possibly see any Part of the Sun's Disk. The other is determined by the Rays CF and DE, and is called the *Penumbra*, or *partial Shadow*, because to an Eye placed therein, the Sun will be in *part visible*, and *partly obscured*; and as the dark Shadow is a *Cone*, whose Base is the Moon, so the *penumbral* Shadow is also a Cone in a contrary Situation, its *Vertex* being above the Moon at V, and its Base at an infinite Distance; though the Part of this Cone above the Moon be only *imaginary*, and is equal the Cone of the dark Shadow below the Moon.

From a View of the Figure, then, it must be plain, that the Inhabitants of the Earth between P and A will be within the *partial Shadow*, and will perceive only a Part of the Sun eclipsed, which *partial Eclipse* will be so much the greater, by how much the Spectator is near to A. At A the Sun begins to be wholly obscured, and all within the Section of the dark Shadow AB will perceive a total Eclipse of the Sun, which ends at B, where it again becomes *partial*. And this is the *dark* and *penumbral Shadow*, whose Dimensions were above given. In some *New Moons*, the Latitude of the Moon from the Ecliptic is such, that only the *penumbral Shadow* can fall on the Surface of the Earth, in which Case there will be only a *partial Eclipse*; and sometimes the Latitude will be so great, as to give the Earth Room to pass by the *Penumbra* without touching it, and then there will be no Eclipse at all.

The Manner of representing a *Solar Eclipse* in this Way, is purely *physical*, or according to *Nature*; but the more *Astronomical* Way, is that according to *Fig.* LII. on *Plate* XII, fronting *Page* 153, where the Moon's visible Way AB is represented intersecting the Ecliptic or Path of the Earth (at the Time of the *Eclipse*) in the Point ☊, called the Node. The Circle HCI is the Surface of the Earth, and D, F, and G the Section of the *penumbral* and *dark Shadow* of the Moon, as seen from the Moon on the Earth in the Time of the Eclipse. At D the Shadows are just entering on the Disk of the Earth, and the Eclipse begins; the Middle whereof is at F, and at G the Shadow is got clear off the Disk, and the Eclipse ends.

In *Fig.* LIII. on *Plate* XII, fronting *Page* 153, the Latitude of the Moon KL is such, that the Shadow only touches the Disk, but does not enter or obscure any Part thereof. In this Case, *A.* So, I ſuppoſe, *Eclipſes* happen to *Saturn* and *Jupiter*, on Account of their *Moons*; and likewiſe to the *Moons* themſelves, as well as to our *Moon*?

B. Yes; but the *Eclipſes* of thoſe *Planets* are much more frequent than of our *Earth*, the Number of *Moons*, and their quick Circulations, neceſſarily making them ſo; alſo the *Eclipſes* of thoſe *Moons* or *Satellites* are very frequent, one or the other being continually paſſing thro' the Shadow of their Primary.

A. Well, leaving the *Moon* and their *Eclipſes*, pray let me hear a Word or two about the wonderful Ring of *Saturn*, that you mentioned juſt now.

B. This moſt ſurpriſing *Phænomenon* of all the viſible World, was firſt diſcovered about 100 Years ſince: It is of a prodigious Size, great Breadth, and vaſt Compaſs; it is ſaid the Diſtance of the inner Border of the Ring, from the Body of *Saturn*, is equal to the Breadth of the Ring itſelf, each being computed to be at leaſt 21000 Miles; though others make the Interval between the Ring and *Saturn*'s Body to

Caſe, the Diſtance Kδ is the Limit of the Eclipſe, becauſe the Earth within that Limit will receive the Shadow in Part or Whole, and beyond it it will not. Now the Angle AδC is variable, and when leaſt, the Ecliptic Limit δK is greateſt; and when that Angle is greateſt, the ſaid Limit is leaſt. The Limit, when leaſt, is $14^\circ 6' 36''$, and when greateſt, $16^\circ 18' 3''$.

After a like Manner you conſider an *Eclipſe* of the *Moon*, whoſe *Ecliptical Limits* or Boundaries are, the greateſt $12^\circ 3' 24''$, and the leaſt $9^\circ 31' 24''$.

See more concerning theſe Affairs in Mr. *Whiſton*'s and *Keill*'s Aſtron. Lectures, and my Young Trigon. Guide, Vol. I. Part II. Chap. 3.

be

be 210265, and the Breadth of the Ring to be 29200 Miles; its Thickneſs is unknown, as being too little for Obſervation; it hath a Variety of Aſpects, ſometimes appearing a large *Ellipſis*, then a ſmaller; ſometimes only as a ſtraight Line, and ſometimes not viſible at all: Theſe are the moſt remarkable Particulars of this Prodigy of Nature known by us; as to the Matter of which it doth conſiſt, that is not known by any. I have given you a Repreſentation thereof in *Fig.* XXV. on *Plate* XV, fronting *p.* 187 *.

A. This is aſtoniſhing, and full of Wonder and Amazement indeed! But did not you ſay ſomewhat of a like Nature pertained alſo to *Jupiter?* pray what are thoſe *Belts* of his you mentioned but now?

B. Thoſe *Belt-like* Appearances of *Jupiter* are ſuppoſed to adhere to, or be in the Surface of his Body, and not at a Diſtance from it, as the Ring of *Saturn* is from him; they are four or five in Number, and appear as repreſented on *Jupiter*'s Body in *Fig.* XXV. on *Plate* XV, fronting *p.* 187.

A. And, pray, what are thoſe Belts ſuppoſed to be?

B. Some have imagined they are long Canals of ſome fluid Matter, or Water; and, becauſe they have alſo obſerved ſeveral dark Spots on the Diſk of *Jupiter*, they conclude his Surface

* The celebrated *Galileo* was the firſt who diſcovered any thing extraordinary in the Phaſis of *Saturn*, *An. Dom.* 1610, *October*. But Mr. *Hugens* firſt diſcovered it to be a *Ring* encompaſſing his Body at a Diſtance, and publiſhed it to the World, *An.* 1659, in his Book called the *Saturnian Syſtem*. See more concerning this *Phænomenon*, in Dr. *Gregory*'s, Dr. *Keill*'s, and other Books of Aſtronomy; as alſo Mr. *Derham*'s *Aſtro-Theology*.

is divided into Land and Water, as that of our Globe is, and is therefore inhabited; as they alſo ſuppoſe all other *Planets* are*.

A. Then they imagine the *Planets* to be ſo many Earths, or peopled Worlds? But do not the different Diſtances of the *Planets* render that impoſſible, by occaſioning too great Light and Heat in ſome, and too great Cold and Darkneſs in others?

B. Their Bodies, with their ſeveral Organs of Senſe, are undoubtedly ſuited and adapted to the different Conſtitutions and Temperaments of the *Planets,* which are the Extremes, by the ſame almighty Power, and all-wiſe Providence, which hath ſuited our Bodies, *&c.* to the State of this *Planet* we live on, which is the mean.

A. What are the different Dimenſions, Revolutions, Denſities, Quantities of Matter, Light, Heat, *&c.* of the ſix primary *Planets,* we are diſcourſing of?

B. Theſe will be all ſeen to the beſt Advantage and compared in one general View; to that End, I have drawn up a Synopſis of them all together, as you here ſee, all grounded on Mr. *Whiſton*'s Calculations, which are the moſt moderate of any: I have moreover drawn the ſix primary *Planets* in their true Proportions of Magnitude, on *Plate* XV, fronting *p.* 187.

A. Sir, It is very good; I take it as a great Favour, and humbly thank you.

* I never yet could be ſo lucky as to obtain a Sight of theſe Belts and Spots in Jupiter, tho' I have often endeavoured it with a Tube 12 and 16 Feet. The remarkable Spot diſcovered by Mr. *Hook,* in 1665, *May* 9th, at 9 at Night, is that by which the Motion of *Jupiter* about its Axis is determined to be in 9 Hours 56'.

CHAP.

A SYNOPSIS of divers AFFECTIONS of the *PLANETS*.

TITLES.	SATURN.	JUPITER.	MARS.	EARTH.	VENUS.	MERCURY.
Their *Diameters* in *English* Miles - - -	67870	81155	4444	7964	7906	2460
The *Circumference* of their Bodies - - -	213112	254908	13960	25020	24823	7724
Their *Superficies* in *square* Miles - - - -	14468430000	20688000000	62032000	199250205	196238000	1900804
Their *Solidity*, or *Magnitude*, in *cubic* Miles -	163637000000000	281042300000000	45966600000	264466789070	258445900000	7793273000
Their *mean Distances* from the *Sun* in Miles -	777000000	424000000	123000000	81000000	59000000	32000000
The *Diameter* of their *Orbits* in Miles - -	1554000000	848000000	246000000	162000000	118000000	64000000
The *Circumference* of their *Orbits* in Miles -	4881891000	2662280000	773686000	508939200	370636000	201024000
Their *periodical* Times - - - -	$10759^{d}\ 6^{h}\ 36'$	$433^{d}\ 12^{h}\ 20'$	$686^{d}\ 23^{h}\ 27'$	$365^{d}\ 6^{h}\ 9'$	$224^{d}\ 16^{h}\ 49'$	$87^{d}\ 23^{h}\ 16'$
The Times of their *diurnal* Motions - -	— — — —	09 09 56	01 00 40	00 23 56	00 23 00	* * *
Their *daily mean Motions* in the *Ecliptic* - -	00° 2′ 00″	00° 04′ 59″	00° 31′ 27″	00° 59′ 08″	01° 36′ 08″	04° 05′ 32″
The *Inclination* of their *Orbits* to the *Ecliptic* -	02 30 00	01 20 00	01 52 00	00 00 00	03 24 00	06 54 00
The *Excentricities* of their Orbits - -	54700	25050	141000	1490	517	7970
The *Proportion* of *Weight* on their Surface -	529	943	* * *	435	* * *	* * *
The *Proportion* of their *Bulks* - -	621350	1064500	170	1000	985	30
The *Densities* of their *Masses* - - -	67	$94\frac{1}{2}$	* * *	400	* * *	* * *
The *Quantity* of *Matter* in each - -	33	92	* * *	$\frac{59}{100}$	* * *	* * *
Their *Proportion* of *Light* and *Heat* - -	$1\frac{1}{10}$	$31\frac{1}{12}$	43	100	200	700
Their *Moons* or *Satellites* - - -	5	4	* * *	1	* * *	* * *
Proportion of *Diameters* to that of the *Sun* 1000	137	181	6	12	12	4
Proportional *mean Distances* - - -	953800	520110	152369	100000	72333	38710
Greatest *apparent Diameters* - - -	00′ 19″ 40‴	00′ 24″ 12‴	00′ 20″ 50‴	32′ 47″ Sun	01° 05′ 58″	00′ 11″ 48‴
Least *apparent Diameters* - -	00′ 14″ 11‴	00′ 14″ 36‴	00′ 2″ 46‴	31′ 30″ Sun	00′ 09″ 34‴	00′ 04″ 04‴
Place of the *Aphelion* - - -	♐ 27° 49′ 45″	♎ 9° 9′ 54″	♍ 0° 31′ 54″	♑ 8° 1′ 10″	♒ 4° 19′ 54″	♐ 13° 7′ 54″
Place of the *Node* - - -	♋ 21° 49′ 54″	♋ 7° 19′ 54″	♉ 18° 29′ 54″	* * *	♊ 14° 25′ 54″	♉ 15° 1′ 54″
The greatest Elongation of the inferior, and Parallax of the superior Planets - -	6° 0′ 00″	11° 5′ 00″	14° 0′ 00″	* * *	46° 41′ 00″	22° 46′ 00″

CHAP. V.

Of COMETOGRAPHY, *or the* PHILOSOPHY *of the* COMETS.

A. HAVING thus pretty largely converſed with the *Planets*, and viewed their various Natures, Numbers, and Affections; let us next, if you pleaſe, diſcourſe of the *Comets:* And, in the firſt Place, pray tell me what the proper Meaning of the Word *Comet* is?

B. COMET is a *Greek* Word, derived of the Verb κομάω, to have long Locks, or wear long diſhevelled Hair; becauſe a *Comet* ſeems to have as it were a long hairy Tail.

A. Pray what is the Matter or Subſtance of a *Comet?*

B. Sir *Iſaac Newton* ſaith, the Bodies of *Comets*, or blazing *Stars*, are ſolid, compact, fixed, and durable Subſtances; and are, indeed, but a different Kind of *Planets*, which move about the Sun, and ſhine by the Light of the Sun-Beams reflected from them *.

A. How many Sorts of *Comets* are there?

B. COMETS receive a Diviſion or Diſtinction on Account of the different Form of their Tails: Thus,

Cometa Crinitus, which caſts forth Beams like *Hair* around it.

Cometa Barbatus, having a Tail reſembling a *Beard*.

Cometa Enſiformis, having a Tail like a *Sword*.

* *Principia Philoſ.* 508.

 A. Why,

A. Why, *Sir*, do the *Comets* appear with blazing Tails, and no other Planet or Star do ſo?

B. This ſeems owing to ſome peculiar unctuous Matter in the Bodies of the *Comets*; which, by their Approach to the *Sun*'s Body, is prodigiouſly heated, rarefied, and made to fly off in a fiery Vapour, on that Side oppoſite to the Sun, in the Form of a long Tail, growing wider and thinner (as all fumy Vapours do) the farther it proceeds from the *Comet*'s Body.

A. Then you ſuppoſe, I find, that the *Comets* revolve about the Sun, as well as the Planets; but, pray, in what Kind of Orbs do they move?

B. They move, indeed, in ſtated Periods of Time about the Sun, in Orbs vaſtly eccentric and elliptical, but ſome more, and ſome leſs ſo, as there Periods are longer or ſhorter. The Forms of their remarkable cometary Orbs are deſcribed in the Solar Syſtem before-going *.

A. In what Parts or Regions of the Heavens do they move?

B. Far above our Atmoſphere, or Region of Air: Yet when they come neareſt the Sun, they all deſcend within the Orb of *Saturn*; and thoſe which come neareſt to the Sun, are nearer than even *Mercury* itſelf: Then from the Sun, they make amazing long Excurſions through the vaſtly diſtant Regions of the Universe all Manner of Ways, and acroſs the Orbs of the Planets.

A. How far do you think ſome of the moſt erratic *Comets* may rove from the Sun?

* See the parabolic Orbs of 21 Comets deſcribed in Mr. *Whiſton*'s *Solar Syſtem*, or the ſame epitomized in Dr. *Dejaguliers's Courſes*, Vol. I.

B. Dr.

B. Dr. *Halley* has determined the longer Axis of the Orb of that *Comet*, which appeared in 1680, and whose Period is 575 Years, to be 1382957 Parts, of which the mean Distance of the Earth from the Sun is 10000; wherefore supposing this mean Distance to be 81000000 *English* Miles, then the Length of that *Comet's* Orb will be 11201951700, *i. e.* above eleven thousand and two hundred Millions of *English* Miles; which may be esteemed as so far beyond the Sun, the Sun being, as it were, in the very Orb itself at the hither most End.

A. The *Comets* approaching thus near the Sun, must surely be very hot; and receding again to such a prodigious Distance, must there be again very cold: Is it not thus, *Sir?*

B. Yes, most certainly: Sir *Isaac Newton* has computed the Heat of the aforesaid *Comet*, when nearest the Sun, to be 2000 Times hotter than red-hot Iron: But Bodies thus heated preserve their Heat a long Time; it is computed that a Ball of Iron, as big as the Globe of our Earth, would, if red-hot, require 50000 or fifty thousand Years to grow cold in; but the Bodies of *Comets* being vastly greater than our Earth, can therefore never be cold, at their greatest Distance from the Sun*.

A. And,

* Since the Distance of the Comet *Ann.* 1680, *Decem.* 8, when it was in its *Perihelion*, from the Sun, was to the Distance of the Earth at that Time from the Sun, as about 60 to 1000, the Heat of the Sun at that Time at the Comet was to the Heat of our Summer Sun, as 1000000 to 36, or 28000 to 1. But the Heat of boiling Water is about three Times as great as the Earth conceives from the Summer's Sun; and the Heat of red-hot Iron

A. And, pray, can the Places of the *Comets* be found in the *Zodiac,* as thoſe of the *Planets,* by Calculation?

B. Yes: That indefatigable Improver of all Arts, Dr. *Edmund Halley,* has, by the Labour of many Years, compiled a Set of Tables, whereby the Places of above 20 *Comets* are to be determined for any given Time: A Work which will endure for ever; and for which all future Aſtronomers muſt acknowledge themſelves indebted to this great Man *.

A. Pray what do you farther obſerve concerning thoſe Bodies?

B. We may obſerve, that as they are diſcovered of late Years to be hard ſolid Bodies, encompaſſed with an Atmoſphere, and revolve about the Sun in ſtated Periods of Time; therefore they are a Part of the *Moſaic* Creation, as well as other Planets, and are not to be reckoned Meteors, caſually kindled and fleeting in the Air, as the ancient Philoſophers dreamed.

A. Well, to end the Diſcourſe of *Comets,* pray tell me, in the laſt Place, to what Uſe or Purpoſe they may ſerve?

B. Some conjecture they are appointed to demoliſh planetary old Worlds, and to ſupply

is three or four Times as much as that of boiling Water; and therefore the Heat which dry Earth would conceive from the ſolar Rays at the Comet *in Perihelio* is near 2000 Times greater than red-hot Iron. And therefore with ſo great a Heat *Vapours, Exhalations,* and all *volatile Matter,* muſt needs be immediately conſumed and diſſipated. *Newton's Princip.* in Loco citato.

* This *Synopſis* of *Cometary Aſtronomy* by Dr. *E. Halley* is excellently well explained by Mr. *Whiſton,* at the End of his Geom. Lectures.

Materials again for building them anew; others, that they are ſo many Hells to puniſh the Damned with perpetual Viciſſitudes of intolerable Heat and Cold; but all is uncertain *.

CHAP. VI.

ASTROGRAPHY, *or the* PHILOSOPHY *of the fixed* STARS.

A. DO you not mean by *Aſtrography*, the Science or natural Knowledge of the fixed *Stars?*

B. Yes: It being compoſed of the *Greek* Words, ἄϛρον, a *Star*, and γραφὴ a *Deſcription* (as hath been ſaid often before) whence it ſignifies a *philoſophical Deſcription of the fixed* Stars.

A. Pleaſe to tell me why they are called fixed *Stars?*

B. They are ſo called, in Oppoſition to the *Planets*, or moving *Stars*; becauſe theſe always

* The latter is Mr. *Whiſton*'s Opinion, as may be ſeen in his *Aſtronom. Princip. of Religion.*

See much more of Comets in *Newton*'s *Prin. Math. Philoſ.* Lib. III. Prop. 40, 41, 42. Dr. *Gregory's Aſtronomy*, Book V. Dr. *Keill's Aſtron.* Lect. 17. Dr. *Halley's Synop. of the Aſtron. of Comets.* Mr. *Whiſton's Aſtron. Principles of Religion.* Mr. *Derham's Aſtro-Theology. Rohault's Phyſics*, Part II. Chap. 26. with Dr. *Clarke's* Notes thereon. *Joan. Clerici Phyſica*, Lib. I. Cap. 11. *La Bibliotheque des Philoſophes*, Tome prem. Page 362. *L'Hiſtoire Naturelle de l'Univerſe*, Tom. I. Partie I. Chap. 2. *Inſtitutio Philoſ.* Tom. III. § 2. Dr. *Cheney*'s *Philoſ. Princip.* Part I. Chap. 5. § 18. *Regnault's Philoſ. Converſat.* Vol. III. Converſ. 20. Page 283. with Mr *Dale*'s Notes thereon. The Authors cited in *Johnſon's Philoſ. Queſtions*, Page 129, 130, 131. Dr. *Harris's Lexicon*, and *Chamb. Diction.* under the Word *Comet.* Dr. *Deſaguliers's Courſe*, Vol. I. Page 409, 410, 411.

keep the ſame Place in the Heaven, and do not ſeem to move for many Ages together.

A. But by this, I think, you imply they have ſome Motion?

B. The Motion of the fixed *Stars* is very ſmall, not exceeding 50″ of a Degree in a Year, or one Degree in 70 Years; and therefore to compleat one Revolution of a Circle is required 25920 Years; after which Time the *Stars* all return again to their former Places: This Period of Time they call the *Great* or *Platonic Year*, in ancient Times; and imagined, when it was finiſhed, all Things would begin again anew, and return in the ſame Order they do now.

A. I underſtand by what you ſaid of the diurnal Rotation of the Earth, that the Motion of the *Stars* from *Eaſt* to *Weſt* each Night, is only an apparent one; but the Motion you ſpeak of now, I preſume, is a *real* and *proper Motion of the* Stars; is it not?

B. No, *Sir*, even this is not *real*, but *apparent*; being occaſioned by a certain contrary equal Motion of the Earth, ariſing from the *ſpheroidical* Figure thereof, which Figure alſo ariſeth from the Rotation of the Earth about its Axis *.

A. Thus much of the Motion of the fixed *Stars*; pray what do you think of their Number, is it not infinite?

* This is confirmed by Experiment; for if a large Armillary Sphere be made to turn very ſwiftly about an Axis, the ſaid Sphere will very viſibly ſwell out and become more extended in and about the Equatorial Parts, and at the ſame Time be contracted and ſink from the Poles; which will occaſion the Sphere to put on an *oblate or ſpheroidical Form*, ſuch as is here aſcribed to the Earth on Account of its rapid diurnal Motion. See Dr. *Keill's Aſtron.* Lect. VIII. Page 77, 78, 79.

B. If they are not infinite, they are certainly innumerable; for with a good *Teleſcope* they appear Millions beyond Millions, till by their immenſe Diſtance they evade the Sight as aſſiſted with the beſt Inſtruments; but then do not miſtake, thoſe which are viſible to your naked Eye, are (in the moſt ſerene Night) but a few, not above three or four Hundred.

A. No! That is a ſtrange Doctrine! Do not every Man's Eyes declare them innumerable? And doth not the Scripture alſo affirm the ſame?

B. I know People are not eaſily perſuaded to believe this new Notion of the Number of the *Stars* which are viſible, but it is founded on Demonſtration; the Eye is deceived by the vehement Twinkling, and confuſed Appearance of the *Stars:* And as to the Scripture, it ſpeaketh of the *Stars* hyperbolically, or elſe it meaneth the inviſible *Stars,* as well as thoſe that are viſible; and then, indeed, they are numberleſs, as I ſaid before.

A. Pray how do you know the Number of the viſible *Stars* is ſo ſmall?

B. By aſtronomical Obſervations for many hundred Years paſt, and the Catalogues which have been ſeveral Times taken of them.

A Catalogues! what, I pray you, of the *Stars?*

B. Yes, the fixed *Stars* have been long ſince regiſtered in the Records of Aſtronomy: *Hipparchus,* the *Rhodian,* about 120 Years before Chriſt, was the firſt who made a Catalogue of the *Stars*; his contained 1022: After him, *Ptolemy* enlarged this Catalogue to 1026: *Ulug Beighi,* the Grandfather of *Tamerlane the*

Great, made a Catalogue of 1017 *Stars*: *Tycho* determined the Places of 777 fixed *Stars*, and reduced them to a Catalogue: *Kepler*'s Catalogue contained 1163: The Prince of *Hesse*'s Catalogue was of 400 *Stars*: the *Jesuit Ricciolus* enlarged *Kepler*'s Catalogue to 1468: It is said also that one *Bayerus* had described the Places of 1725: After this, *Hevelius* of *Dantzick* composed a new Catalogue of 1888: But the largest and most compleat Catalogue ever yet published of the fixed *Stars*, is that of Mr. *Flamstead*, in his *Celestial History*, which contains near three thousand *Stars*; all whose Places and Situations are far better, and more exactly determined in the Heavens, than the Position of many Cities on Earth through which Travellers daily pass *.

A. Well, considering the many hundred of Years Observation on the *Stars*, and the various Catalogues made thereof which you have now related; and considering the most compleat contains not above 3000 *Stars*, tho' assisted by the longest and best Glasses; I am obliged to acknowledge my erroneous Notion of the great Number of the visible ones; and shall next, if

* What I have here asserted concerning the small Number of the *visible Stars*, and the Catalogues of them, is upon the Authority of no less a Man than that excellent Astronomer Dr. *Keill*. See his *Astronom. Lect.* VI. Page 51, 52, 53, 54, where he has these Words — Of the 3000 Stars in Mr. *Flamstead*'s Catalogue, it is seldom that a *very good Eye* can reckon more than *one Hundred* together. And, if I mistake not greatly, the famous *Flamstead* himself does, in his *Historia Cœlestis*, positively assert, that the naked Eye cannot discover above 384 Stars in the serenest Night in both the Hemispheres. And the Reader, if he thinks fit to take on him the Trouble of counting the visible Stars, will need no other Reason to convince him of his Mistake in this Matter.

you pleaſe, aſk your Opinion concerning their Diſtance from us?

B. Their Diſtance! Alas, you can hardly enquire about a Thing more unknown, or more incredible, than what is but imperfectly known thereof; however, to ſatisfy you, take the following Account. The famous *Hugens* found the brighteſt and largeſt, and, of Courſe, the neareſt of all the fixed *Stars*, viz. *Syrius*, to be in Appearance 27664 Times leſs than the Sun; and ſince their Diſtances are greater, as their Magnitudes are leſſer, therefore this *Star* muſt be at the Rate of 2000000000000, *i. e.* above two Millions of Millions of *Engliſh* Miles; which is ſo very great, that a Cannon-Ball would ſpend almoſt 700000; *i. e.* ſeven hundred Thouſand Years in paſſing through it; and it is very probable, that all fixed *Stars* are equally diſtant from each other, in Proportion to the Diſtance of the neareſt of them from our Sun.

A. What are the Grounds of this your Opinion?

B. By the Smallneſs of their Appearance thro' the beſt Glaſſes, and the different Degrees thereof, I am induced to believe, that they are not only as far diſtant from each other as from our Sun; but alſo, that each fixed *Star* is a Sun, ſurrounded by a Syſtem of *Planets* and *Comets*, and thoſe again furniſhed with different Numbers of Moons, all in the ſame Analogy, Order, and Proportions of Number, Size, and Glory, as we behold in thoſe of our own Solar Syſtem.

A. O! amazing and ſtupendous Scene! Suns without Number, and Worlds turning up upon Worlds!

Worlds! Syſtems of moving Orbs immenſely great, yet inviſible to our Eyes; all inhabited and diſperſed thro' all the diſtant Realms of univerſal Space! I am almoſt loſt, yea, quite confuſed in my Conceptions; but, pray, on what does ſuch a glorious *Hypotheſis* depend?

B. On Ratiocination, and divers aſtronomical Obſervations. We reaſon thus; our Sun ſhineth by its own native Light, ſo do the *Stars*; *ergo*, they are Suns. The Sun at the Diſtance of a fixed *Star* would appear no larger than a *Star*; *ergo*, a fixed Star may be as large as the Sun. None of our Planets at that Diſtance could be ſeen at all; *ergo*, each Star may have a Syſtem of Planets, tho' unſeen. God hath made nothing in vain (*Axiom* I.) but nothing is more vain than to pretend Myriads of unſeen *Stars* were made to twinkle unheeded in the unſeen, unknown Regions of the Univerſe; *ergo*, they ſeverally ſerve the noble Purpoſes of Light and Heat for the Planets of their Syſtems. As to Obſervation, it is well known how *Stars* appear and diſappear after certain Intervals; what can this be but the Almighty's Hand extinguiſhing old, and kindling new Suns? Demoliſhing old, and erecting new Syſtems of Worlds? And ſuch undoubtedly was the Caſe of our World, and planetary Syſtem, in the *Moſaic* Creation. Our Sun juſt made, would have been a new fixed *Star* juſt appearing to an Eye in any of the neareſt *Stars*; ſome of our *Comets* alſo may there appear new *Stars*, when in their *Aphelia*, but in their Return to their *Perihelia*, diſappear again: Thus alſo ſome

of

of our new *Stars* may be, and doubtlefs are *Comets* (belonging to fome Sun) in their utmoft Excurfions, which upon their Return difappear again: Thefe new and extinguifhed *Stars*, are generally in the *Galaxy*, or Milky-way; but why there more than elfewhere, unlefs becaufe thofe Parts, being replenifhed with a far greater Number of Suns, give of Courfe more frequent Occafions of thefe *Phænomena*. Alfo it is well known, that the *Milky-Way* hath its Complexion from the united Luftre of an infinite Number of fixed *Stars*, or *Suns*, in thofe Parts of the Expanfe, which go by that Name: From all this it apppears, that the Hypothefis of a Plurality of Worlds is rational, worthy a Philofopher, and greatly difplays the Wifdom, and redounds to the Glory of the great Creator and Governor *.

A. I

* 1. A new Star is faid to have been obferved by *Hipparchus*, but its Place in the Heavens was not left upon Record.

2. On *November* the 8th, 1572, a new Star was obferved to appear in the *Chair of Caffiopeia*, by *Cornelius Gemma*; it was feen by *Tycho Brahe* the 11th of the fame Month, and in *March* 1574 it became extinct.

3. In *Ann.* 1640, *Sept.* 30, the Scholars of *Kepler* faw a new Star near the right Leg of *Serpentarius*, which gradually difappeared, and was wholly invifible *Jan.* 1641-2. *Note*, Thefe two appeared with the Luftre of *Venus* or *Jupiter*, and not as the following; and are therefore thought to be of a different Species.

4. In the Year 1596, *Aug.* 3, *David Fabricius* gives the firft Account of the *Stella Maria*, or wonderful Star, in the *Neck of the Whale*; which has been fince found to appear and difappear periodically, its Period being feven Revolutions in fix Years, and is never entirely extinguifhed.

5. In the Year 1600, *William Janfonius* difcovered another new Star in the *Neck of the Swan*. This in Time became fo fmall, as to be thought to difappear entirely, till the Years 1657, 58, and 59, when it recovered its former Magnitude; but it foon after decayed, and is now one of the leaft Size.

6. In

A. I now ſee no Reaſon to heſitate about the Truth of this new and noble Doctrine; which ſo enlargeth our View of the wonderful Works of infinite Wiſdom, by putting the Univerſe

6. In the Year 1670, *July* 15, O. S. *Hevelius* diſcovered a new Star, which in *October* was ſo decayed, as to be ſcarce perceptible. In *April* following it regained its Luſtre, but wholly diſappeared about the Middle of *Auguſt*. In *March* 1672, it was ſeen again, but very ſmall; ſince when, it has been no farther viſible.

7. The ſixth and laſt new Star was diſcovered by Mr. *G. Kirch*, in the Year 1686, which returns periodically after the Space of 404½ Days. And theſe are all the remarkable *new Stars* for 160 Years paſt.

8. There are in the Heavens ſeveral *lucid Spots*, called *Nebulæ*, from their *miſty Appearance*; they appear to the naked Eye as a dim fixed Star, but thro' a Teleſcope they appear a broad illuminated Space of *Æther*; in ſome of which there is a ſmall Star, in others more. Of theſe *Nebulæ* there are ſix diſcovered, *viz.*

9. The firſt and moſt conſiderable in *Orion*'s Sword, at preſent, is in ♊ 19° 0'. South Lat. 28° 45'. About the Year 1661, another was diſcovered in *Andromeda*'s Girdle. Its Long. is ♈ 24° 0', and Lat. N. 33° 20'.

10. The 3d was diſcovered in the Year 1665, and is in Long. ♑ 4° 30', and Lat. S. 3° 30'.

11. The 4th was diſcovered by Dr. *Halley*, 1677, in the Southern Hemiſphere, and never riſes in *England*.

12. The 5th was diſcovered by Mr. *Kirch*, in 1681. Its Long. is ♑ 9° 0', Lat. 17° 10' North.

13. The 6th and laſt was diſcovered by Dr. *Halley*, in 1714; its Place is near ♏ 26° 30', with 57° 0' N. Latitude. See the *Phil. Tranſ.* N° 346, 347, and ſeveral other Numbers.

14. The Conſtellation called the *Pleiades*, or ſeven Stars, contains no leſs than 70 or 80 Stars viſible in the Teleſcope; and when I had placed a large Teleſcope againſt one of the *nebulous* Stars, the Glaſs was ſo full of very ſmall Stars, that they could not be numbered. From all this, I think it is perfectly certain, that the whole Univerſe is replete with numberleſs Worlds, and Realms of Light of eternal Day, which are intercepted from our Sight by the duſky Regions of our Planetary Syſtem.

15. See more on this Subject in Biſhop *Wilkins's World in the Moon. Fontenelle's Plurality of Worlds*, Even. V. *Hugens's Planetary Syſtem.* Mr. *Derham's Aſtro-Theology*, Introduction; and various other Writers of Aſtronomy.

4 into

into Signification and Harmony, and peopling the ſame throughout with rational Beings: How will Poſterity bleſs the divine Diſcoveries and Labours of theſe Ages, wherein the dark and barren Wilds and Deſerts of indefinite Space have been enlightened by ſuch Millions of Suns; ſtored and planted with ſuch Myriads of Planets; and cultivated by ſuch endleſs Numbers of Inhabitants of every Kind!

THE

Philosophical Grammar:

Or, VIEW of

Modern Philosophy.

PART III.

AEROLOGY:

CONTAINING,

I. The Philosophy of the *Atmosphere*, or *Air*.
II. The Philosophy of the *Winds*.
III. The Philosophy of the *Meteors*.
IV. The Philosophy of *celestial Appearances*.

Explaining what is hitherto known of their *Nature*, *Causes*, *Properties*, and *Effects*.

CHAP. I.

Of AEROLOGY *in general, or the* PHILOSOPHY *of* AIR, *shewing its wonderful* NATURE, PROPERTIES *and* EFFECTS.

A. PRAY, *Sir*, what is the original Signification of *Aerology*?

B. It is a Word compounded of ἀὴρ, *Air*, and λόγος, a *Discourse*; and therefore imports a philosophical *Discourse* of the *Air*.

A. What are we to understand by *Air*?

B. That invisible fluid Substance which encompasseth the Earth on every Side, which contains

tains the Vapours, Clouds, and other Meteors, and in which all living Creatures breathe; the whole Body of which is called the *Atmoſphere.*

A. Pleaſe, *Sir,* to let me know why it is called the *Atmoſphere?*

B. From the two *Greek* Words, ἀτμὸς a *Vapour,* and σφαῖρα a *Sphere;* ſo that *Atmoſphere,* in native *Engliſh,* is a round Body of *Vapours;* and ſuch is the *Air* ſurrounding the Earth, as being conſtantly replete with *Vapours* exhaled by the Sun's Rays.

A. What are the principal Properties of the *Air?*

B. Theſe which follow: 1. The *Air* is *fluid,* yet cannot be *congealed* like Water. 2. It is *pellucid* or *tranſparent* to that Degree, as to be *inviſible.* 3. It may be *rarefied* and *condenſed.* 4. It is endued with an *elaſtic Power* or *Force.* 5. It hath *Weight* or *Gravity.* 6. It hath proper *Bounds* or *Limits,* and is not *infinite.* 7. It is neceſſary to *Life, Flame, Sound, Light,* &c.

A. How do you know the *Air* is a *Fluid?*

B. It hath all the Properties of a Fluid; is corporeal, heavy; its Parts yield to any Force impreſſed, and are eaſily moved one amongſt another; it preſſeth in Proportion to its Height, and the Preſſure is every Way equal: It is evident, therefore, that it ought to be reckoned a *Fluid.*

A. What is the Reaſon the *Air* is ſo tranſparent, as to be inviſible?

B. Becauſe of the great Poroſity thereof; the Pores and Interſtices of *Air* being ſo very great and large, it admits the Light not only in right Lines, but in ſuch great and plentiful

Rays,

Rays, that the Brightneſs and univerſal Luſtre thereof, not only renders the *Air* diaphanous, but entirely hinders the Opacity of the very ſmall Particles of *Air* from being at all ſeen; and therefore the whole Body of *Air* muſt conſequently be inviſible.

A. You obſerved next, the *Air* hath the Property of being rarefied and condenſed; pray how is this demonſtrated?

B. That *Air* may be rarefied, is proved ſeveral Ways; as thus, if you take a Bladder, entirely empty as you think, and tie its Neck with a Thread, and lay it before the Fire, the Heat will ſo rarefy the little incloſed *Air*, as to make it extend the Bladder to its utmoſt Stretch, and, if continued, will break thro' it with the Report of a Gun: Alſo, that *Air* may be ſo condenſed by Art, as to take up but $\frac{1}{60}$th Part of the Space it poſſeſſed before, is proved by various Experiments *.

* Since the Air is compreſſed by the Weight of the incumbent Atmoſphere, and the Denſity of Air is proportionable to the Force compreſſing it, it follows by Computation, that at the Height of about ſeven Miles from the Earth, the Air is four Times rarer than at the Surface; and at the Height of 14 Miles, it is 16 Times raeer than at the Surface; and at the Height of 21, 28, or 35 Miles, it is reſpectively 64, 256, or 1024 Times rarer; and at the Height of 70, 140, and 210 Miles, it is about 1000000, 1000000000000, or 1000000000000000000; and ſo on in a geometrical Proportion of Rarity, compared with the arithmetical Proportion of its Height. *Newton*'s Optics, Page 342.

Moſt Authors hold Air to be compreſſible *in infinitum*. *Heat* rarefies, and *Cold* condenſes the Air, the moſt of any Agents whatſoever.

It has been found that Air, by the bare Force of its Spring, will dilate itſelf into 13000 Times the Space it poſſeſſes under the Preſſure of the Atmoſphere; and ſince it may be compreſſed into 60 Times a leſs Space than that, it is plain it may poſſeſs a Space of 780000 Times greater at one Time than another; for 13000×60=780000.

A. Pray

A. Pray how do you prove the *Air's* Elaſticity?

B. By various Experiments of the Air-Pump, and otherwiſe: One very plain, is thus; an empty Bladder, whoſe Neck is faſt tied, being put into the Receiver, and the external *Air* therein exhauſted, the ſmall Matter of the incloſed *Air* will, by its own proper *Spring* or *elaſtic Force*, gradually expand itſelf, and at laſt will ſo extend the Bladder as to break it: Thus alſo, the *Air* compreſſed in the *Wind-Gun* will by its *elaſtic Force* (being diſcharged) drive a Bullet through a Board at the Diſtance of ſeveral Yards, in the ſame Manner as with *Gunpowder*: Yea, Mr. *Boyle* hath found that *Air* by its Spring, or Elaſticity, will ſo far dilate or expand itſelf, as to take up 13769 Times a greater Space than before: *This Power of Elaſticity is as the Denſity of the* Air *.

A. Pray

* 1. The artificial Fountain, or *Jet d'Eau*, is not only a ſufficient *Proof*, but a very pretty *Effect* of the Air's *elaſtic Force*; ſee *Fig.* LIV. on *Plate* XII, fronting *p.* 153. Where the Veſſel ABDE has a Tube or Pipe DB fixed therein, and communicates with the internal Part or Body AB; the Part B is filled with Water, and the other Part A with Air, by Means of an injecting Syringe ſcrewed on at C. The Air thus crouded in and condenſed in the Part A, preſſes very hard on the Water B, and forces it up the Tube to D, where the Cock being turned, it ſpouts upright with great Celerity, in a ſmall Stream to the Height H, where being broke and divided by the Reſiſtance of Air, it falls down in a *Miſt*, or Drops, like Rain. Of theſe Fountains divers Sorts may be found deſcribed in Authors, particularly in Mr. *Step. Switzer's* Introd. to Hydroſtatics and Hydraulics.

2. To this Property of Air is owing the *Vacuum* made in a *Receiver* placed on an *Air-Pump*. For when the Air contained in the Barrels *a, a*, is drawn out by the *Emboli e, e*, the Air remaining in the Receiver *o, o*, dilating and expanding itſelf by this Power, ruſhes through the Pipe *h, h*, to fill the *Vacuity* of the

Barrels,

A. Pray how do you become acquainted with the *Air*'s Gravity?

B. By

Barrels, which is again drawn out, and the Air in the Receiver again dilates to replenish the Barrels; and by such a Process the Air is rarefied to such a Degree, as to cause most of the Appearances and Effects of an absolute *Vacuum*; and this is indicated by the *Mercury* rising in the Tube *l* by the Pressure of external Air.

3. I shall here take Notice of that *Parvum Naturæ Miraculum*, (as *Rohault* calls it) or little Miracle of Nature; I mean the *Lachryma* of *Prussia* or *Holland*, sometimes called *Prince Rupert*'s *Drop*, and in common, the *Glass-Tear*. See its Form in *Fig.* LV. on *Plate* XII, fronting *p.* 153. The Manner of making it is thus: With a Tube they take up a little of the melted Matter of Glass, and let it drop thence red hot into a Pail of Water, by which Means it receives its Form, and is solid throughout, except that now and then a few Air-Bubbles may appear therein.

4. This is the *Nodus Philosophorum*, or that which gives Philosophers the greatest Difficulty and Anxiety to account for its peculiar Property, which is, that the biggest Part or Head of the Tear A will sustain the Stroke of an Hammer without breaking; but if the little End or Tail B be broke, the whole Tear will fly into Dust at once, with the greatest Violence, and cause considerable Pain to the Fingers which break it.

5. Some particular Circumstances render the Drop incapable of this surprizing Property. As, (1.) If the Tear be *cooled in the Air*, it will not break. (2.) Those which are *nealed* will not break. (3.) If they are ground away on a Grindstone, nothing extraordinary happens. On the contrary, if it be put into an Air-Pump, and there broke, the Effect will be so great as to produce Light.

6. Some suppose this Effect of the Tear is produced by a *fine Air*, which being pent up in the Body of the Tear, and suddenly passing into the open Pores of the broken Tail, runs rapidly into a thousand small Cells, which grow narrower from the Middle towards the Extremities, which the Irruption of the Air drives asunder violently by the Efficacy of its Spring and accelerated Motion. See *Regnault*'s Phil. Convers. Vol. I. Conv. 24.

7. Dr. *Clarke*'s Opinion is, that Glass being a springy Substance, it is probable the Glass Drop is broke much after the same Manner as a Steel-bow sometimes bursts in Pieces, when it is loosened on a sudden, *viz.* by the too great Celerity and Force of that Motion, which arises from the mutual Attraction of its Parts. For its Parts from the Centre to the Circumference seem to be like so many Bows bent. And thence perhaps it is, that after it is burst to Pieces, its Fissures are disposed like

Fig: LVI. Page 179.

Fig: LVII. Page 180

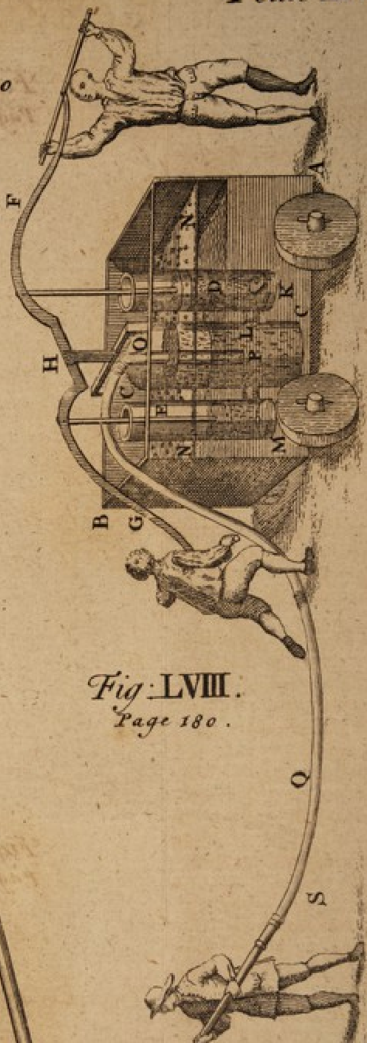


Fig: LVIII. Page 180.

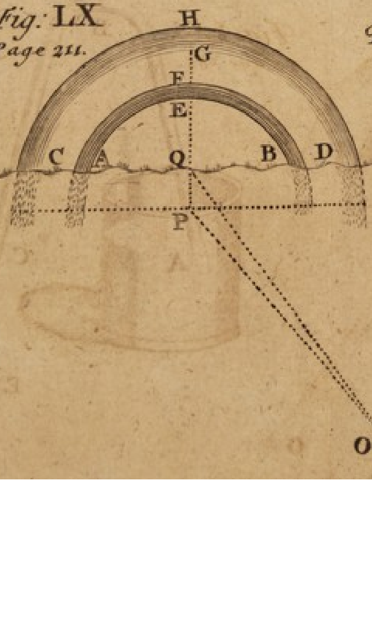


Fig: LX. Page 211.

Fig: LIX. Page 181.

B. By Experiments of the Air-Pump, Barometer, *&c.* The Weight of the Air is greater, the nearer it is to the Earth's Surface: The *Mercury*, by the Preſſure of the *Air*, is raiſed in the Barometer to the Height of 28, 29, 30, or 31 Inches; therefore ſuch a Column of *Mercury* is equal in Weight to a Column of *Air* (of an equal Baſis) which proceeds from the *Mercury* in the Tube to the uppermoſt Part of the *Atmoſphere:* Alſo, becauſe *Mercury* is about 14 Times heavier than Water,

like ſo many Radii drawn from the Axis to the Superficies, as Mr. *Hooke* obſerved in a Glaſs Drop covered over with Glue. Notes on *Rohault*'s Phyſ. Part. I. Cap. 22. ad Art. 52. See *Hooke*'s Microg. Obſerv. 7. and Abundance in *Sturmius's Collegium Curioſum.*

8. The *Phænomenon* of the little *Glaſs-Men,* &c. aſcending and deſcending in a little Glaſs Tube of Water, (as AB, *Fig.* LVI. on *Plate* XIV, fronting *p.* 179) at the Word of Command, which looks like a Piece of *Conjuration* to the Vulgar, is entirely owing to the Elaſticity or Spring of the Air.

9. For theſe Men being blowed hollow, are thereby rendered ſpecifically lighter than Water, and will ſwim in it; and having a ſmall Hole in one Foot, and a Bladder being tied over the Top of the Tube, as C, if this be preſſed with the Fingers, the included Air by its Spring will equally preſs the Water, which will enter and compreſs the Air in the Men, and thereby render them heavier in any Degree. If they are by this Means brought to be of equal Gravity with the Water, they will abide in any Situation therein; if they are rendered heavier by preſſing the Bladder harder, they will deſcend; then the Fingers being taken off, or the Preſſure diminiſhed, the Spring of the included compreſſed Air forces the Water out of the Men, and thus becoming lighter, they aſcend to the Top; all which Motions are to be varied in any Degree of *Quickneſs* or *Slowneſs* the Performer ſhall pleaſe, which renders it the more ſurpriſing.

10. The *Spring of the* Air is of a peculiar Nature, for the Time of its *Exertion* will not alter it, as it does that of *Wood* or *Steel:* For Mr. *de Roberval,* of the Royal Academy of Sciences, having let his *Air-Gun* remain charged with *condenſed Air* ſixteen Years, found, on diſcharging the Gun, that the Air's elaſtic Force was not at all abated, but produced the ſame Effect as at firſt. *Hiſt. de l' Acad.* 1695. Page 368.

therefore Water will riſe in a Tube to 32 or 33 Feet in Height; and therefore every Square Foot in any Superficies ſuſtains the Weight of a Column of Water of 32 or 33 ſolid Feet: Now a Cubic Foot of Water weighs about 63 Pounds, hence the Weight of *Air* on every ſuperficial Square Foot, is above 2000 Pound Weight *. *A.* And,

* 1. By the *Gravity of the Air* we receive ſome of the greateſt Advantages of Life; particularly from thence is deduced the Invention and Conſtruction of the moſt uſeful Inſtruments, Engines and Machines, uſed in all Kind of Fire and Water-works.

2. From thence ariſes the Uſe and Power of that moſt neceſſary Engine the *Antlia*, or Pump, which is ſaid to be the Invention of *Cteſebes*, a Mathematician of *Alexandria*, about 120 Years before *Chriſt*. Of theſe there are many Sorts; the common and moſt uſeful one conſiſts of a Pipe AB (ſee *Fig.* LVII. on *Plate* XIV, fronting *p.* 179) open at both Ends, of which the End B is ſet in Water; toward the lower Part at C is placed a Clack or Valve, opening upwards; in the Part of the Tube above works a Piſton ED juſt as big as the Bore of the Tube or Pipe, in which alſo is a Valve opening upwards; this Part D is called the *Bucket*.

3. Now the Reaſon of the Pump's Performance is plain; for when the Piſton is forced down, ſo as that the Bucket D may touch the Frame of the Valve at C, and Water be poured in to fill the upper Part from A to C; then if the Piſton be raiſed from C to D, it will lift up a Column of Water equal to the Part of the Pipe between C and D, which therefore muſt run out at the Spout of the Ciſtern at A.

4. Alſo at the ſame Time there is a *Vacuum* made between C and D, which is immediately filled by the Water ruſhing through the Hole at C, by the Force of the Preſſure of the Atmoſphere on the Superficies thereof without the Pipe. The Piſton being again thruſt down, the Water between C and D goes through the Hole of its Bucket, and cloſing the Valve with its Weight, is raiſed into the Ciſtern where the Piſton is drawn upwards, and there runs out as before, and thus the Action of the Pump may be continued in raiſing Water as long as you pleaſe.

5. On the *Gravity* and *Elaſticity* of the Air together, depends the Theory of the Fire-Engine in common Uſe. But this has been improved to produce a continual Stream in the Manner as repreſented in *Fig.* LVIII. on *Plate* XIV, fronting *p.* 179, which I ſhall here deſcribe. AB is the Frame or Body of the Engine; CC is a ſtrong metal Veſſel, which is cloſe on the Top, but

A. And, pray, what do you infer from thence?

B. Why thence it appears, that if we allow the whole Surface of a Man's Body (of six Feet Stature) to be about 14 square Feet, then the Weight

but communicates with two forcing Pumps, or Barrels D and E, at the lower Part; whose Pistons are worked with a common double Lever FG moving to the Centre H; the Engine is filled with Water strained through the Grate NN, which by the Pressure of the Atmosphere is forced into the Barrel D and E, when the Pistons are raised up, and a *Vacuum* thereby made in them in working the Engine.

6. In the present Figure, the Sucker in the Barrel D if drawn up, and the Water rushing in through the Valve at K, while in the other Barrel E, the Piston is forced down, and the Water forced through a small Passage against a Valve L, which opens and gives it Admittance into the large Vessel CC.

7. The Water being thus forced into the said Vessel continually by the alternate Action of the Pistons, does violently compress the Air in the upper Part of the Vessel at O, which by its Spring re-acts on the Surface of the contained Water, and forces it to ascend the Orifice of a small Tube P fixed to the Side of the Vessel; the upper End of this Tube communicates with a long *leathern Pipe* Q affixed thereto at O, through the Top of which, at R, the Water spouts with *great Force* in a *continual Stream*, which is directed by a Person at S, to the Fire, or any other Place, as Occasion requires. All which is plain in the Figure which I have taken from Mr. *Clare*'s Plate III. in his Motion of Fluids; though I have seen a much better Construction of this Engine by an Artificer in this City; and wish I had a Draught of that to present instead of this.

8. On this Principle it is, that the *Mercury* or Quicksilver rises to the Height of near 31 Inches in the *Barometer*; for the Pressure of the Atmosphere forces so much Quicksilver into the *Vacuum* of the Tube as will counterbalance its Power, as is evident from the Construction of this Instrument in Note ‡ in Page 23.

9. The *Syphon* or *Crane* has from hence also its Use; see *Fig.* LIX. on *Plate* XIV, fronting *p.* 179. For the End A being immersed in a Vessel of Water, if the Air be exhausted from the *Syphon* at the Pipe D, the Water in the Vessel, by the Pressure of the Air on its Surface, will instantly rise and fill the Cavity of the *Syphon:* Now if the other End of the *Syphon* were at C in an horizontal Level with the End A, then the Pressure of the Air on each End would be equal, and consequently the Water would be sustained in the Tube without running out at C.

 10. But

Weight of *Air* pressing on the Body of such a Man is equal to 28000 Pouuds, or 250 Hundred Weight; that is, 12 Ton and a Half: Also, since the Number of square Miles on the Earth's Superficies is computed 199250205, and in one square Mile are 27878400 square Feet, the square Feet on the Earth's Superficies will be somewhat above 5547800000000000; whence the Weight of

10. But since the Part BE is longer than the Part BA by the Length CE, and the Cylinder of Water CE being far more heavy than the same Cylinder of Air, it is plain the Pressure of the Air, or its Effect at the Point C, is thereby very much weakened and abated, and therefore the *Equilibrium* in the Point B being thus destroyed, the Water will run over and flow towards E.

11. By the *Pressure of the Air* it is that Water in Reservoirs is forced to enter the *Conduit Pipes*, and is thereby carried to any Conduit, House, or other Place, below the horizontal Level of the Surface of the Water in the *Reservoir* or Fountain, be the Distance what it will.

12. The Fire rarefying and attenuating the Air in the Chimnies, causes it to ascend the Funnel, while the Air in the Room, by the *Pressure of the Atmosphere*, is forced to supply the Vacancy, rushes into the Chimney in a constant Torrent, excites the Fire to burn with great Vehemence in Stoves, and buoys up the Smoke aloft in the superior Air.

13. Nor does that common Utensil, the *Bellows*, act on any other Principle than the *Pressure* of the Air; for the upper Part being lifted up, raises the Column of Air off the bottom Part, and thus making a *Vacuum* within, the Air rushes in through the Hole in the lower Part, and being compressed by forcing down the upper, it shuts close the Valve within, is protruded with great Force and Violence through the Pipe or Nose of the Bellows. See a Calculation of this Kind in Mr. *Hales's Statical Essays*, Vol. II. Page 329, 330.

14. The last Effect of the *Air's Gravity* I shall here mention, is the most important of all, as being the immediate Instrument of Life, I mean the Acts of *Inspiration* and *Expiration* in Animals; for in the Dilatation of the *Thorax*, the Air by the *Pressure of the Atmosphere* is forced into the Cavity of the Lungs, which we are then said to *breathe in*, or inspire; but when the Muscles contract, the Air is expelled, and we are then said to *breathe it out*, or expire it. And this alternate Action of the Lungs is maintained by the *Air's Pressure*, and is absolutely necessary to Life.

the whole *Atmoſphere*, or its Preſſure on the Superficies of the whole Earth is more than 11095600000000000000 Pounds, or much about 5000000000000000 Tons; that is, the *Atmoſphere* compreſſeth the Earth with a Force, or Power, nearly equal to that of *Five thouſand Millions of Millions of Tons.*

A. This is extremely wonderful! But, pray, how happens it that Man, Beaſts, Houſes, *&c.* are not cruſhed to Pieces, if they are preſſed with ſuch an intolerable Weight of *Air?*

B. By the *Equilibrium* of the internal *Air*, or the *Air* within all Bodies; which though it be ſmall, and not worth naming, yet can balance, reſiſt, and equiponderate the Force of the external *Air*, (as is proved by various Experiments) how great a Quantity ſoever it be: The Experiments of the Air-Pump which confirm this are very ſurpriſing.

A. I think, Sir, all you have ſaid of the Weight and Gravity of the *Atmoſphere*, or *Air*, is full of Aſtoniſhment; can you tell any Thing of the *Height of it?*

B. Nothing certainly can be determined about that, becauſe the higher you go, the rarer the *Air* is; and there being no certain Means to determine in what Proportion the *Air* becomes rarer and rarer through the whole Extent thereof, there can of Courſe be no preciſe Account of its Altitude: However, they compute the *Air* at the Height of 42 Miles, to be 4096 Times more rare, or thin, than with us; and this being next to nothing, the Height of the *Air* may be reckoned about 40, or 45 Miles.

Agreeably hereto, Dr. *Keill* hath calculated its Height to be 44 Miles by an Obſervation of the Twilight *.

A. Pray what other very remarkable Properties hath the *Air?*

B. It is not only the Means, but as it were the *Matter of Life itſelf*, and therefore abſolutely neceſſary.

A. How do you ſhew it to be the Means of Life?

B. By putting certain Animals into the exhauſted Receiver; where it is ſurpriſing to ſee the Effects of withdrawing the *Air* by the Pump on the Bodies of thoſe Creatures: You will thus ſee *Dogs, Cats, Rats, Mice,* &c. turn up and expire in half a Minute, and look extremely thin and meagre: A *Mole* dieth in one Minute: *Inſects*, as *Waſps, Bees, Hornets, Graſhoppers,* &c. in two Minutes ſeem dead; and will continue a whole Day and Night without *Air*, and afterwards revive in open *Air: Earwigs, Beetles, Snails,* &c. endure the Air-Pump prodigiouſly; and *Frogs* will longer preſerve their Lives *in Vacuo*, than *Toads*; yea, thoſe inviſible *Animalcules* in Pepper-water, will revive in the open *Air*, after having lain 24 Hours in *Vacuo* †.

A. It muſt be curious, indeed, to ſee thoſe artificial Deaths and Reſurrections in mute

* See his Aſtronom. Lect. *Page* 235, 236.

† See Mr. *Derham's Phyſico-Theology*, Book I. Chap. I. in the Notes. Mr. *Davenport's* Deſcription of his *Table Air-Pump*, Mr. *Hawkſbee's*, *Graveſande's*, &c. Experiments. *Sturmius's Collegium Curioſum. Stairii Phyſiol. Exper.* Explor. 14. Sect. 11, 12, 13, 14, *&c.*

Animals! But how do you underſtand Air to be the *Matter* of Life?

B. It is certain *Air* is impregnated with a *vivifying Spirit*, or Matter, which is immediately neceſſary to Life; and that this *vivifying* Spirit is *inflammable*, or proper to feed Fire, and capable of being burnt or conſumed thereby; for it is known by Experiment, that no Creature will live, nor a Candle burn, in *Air* which hath paſſed through the Fire, and may be called *aduſt*, or *burnt* Air.

A. Is the *Air* alſo of Service to Vegetables and Plants?

B. Yes, in as much as there is a manifeſt Reſpiration in Plants and Trees, on which their vegetable Life depends, and is preſerved; this is known by numberleſs Experiments *.

A. Hath not *Air* an Effect on Bodies which tends to diſſolve them?

B. Yes, the *Air* hath the Faculty of a *Menſtruum*, or a Power of diſſolving Bodies: It will reduce Cryſtal-Glaſſes to a Powder in Time; ſo divers Minerals, Earths, Stones, Foſſil-Shells, Wood, *&c.* which, perhaps from *Noah*'s Flood, have lain under Ground ſecure from Corruption; yet, being expoſed to the corroſive Quality of the *Air*, have ſoon mouldered away; ſo Iron, Steel, Copper, *&c.* may be ſoon diſſolved into a Ruſt, *&c.* But ſuch things are too common to be inſiſted on, or to want Proof.

* See Mr. *Hales's Vegetable Statics* throughout. *Borelli de Mot. Animal.* Mr. *Millar*'s Gardener's Dictionary, *Folio.* Dr. *Grew*'s Anatomy of Plants. *Joan. Clerici* Phyſ. Lib. IV. Cap. 1, 2. or an Abridgment of all in my *Philolog. Library*, under the Title *Botany.*

A. I have heard you make out already how *Air* is the Means of *Sound*; but, pray, what Advantages of *Light* and *Viſion* accrue thereby?

B. Very great (perhaps greater than you may be yet appriſed of) are the Benefits and Advantages of the circumambient *Air* in theſe Regards: For *firſt* were it not for the Rarefaction of the *Atmoſphere*, the Heavens by Day would have the Appearance of Night; the Stars, even the ſmalleſt, would appear and twinkle; the Sun indeed would appear a great Light in that Part of the dark Firmament where it was; but ſhould a Spectator turn his Back to him, he would ſee all *Night*, and *Darkneſs* ſurround him at Noon-tide. *Secondly*, The Sun at riſing and ſetting would have the ſame Brightneſs and Luſtre as at Noon-day, and ſo would be hurtful to our Eyes. *Thirdly*, As ſoon as the Sun deſcended the Horizon, we ſhould be in total Darkneſs, and a cloudy Night would then preſent us with the blackeſt Darkneſs poſſible. *Fourthly*, As we ſhould have no Twilight by Night, nor ſhining Luſtre of the Firmament by Day, ſo we ſhould want that Advantage we now enjoy, of not only being bleſſed with the Light of the Sun when abſent, but even of the actual Appearance of the Body of the Sun himſelf, each Day, before he riſeth, and after he ſetteth.

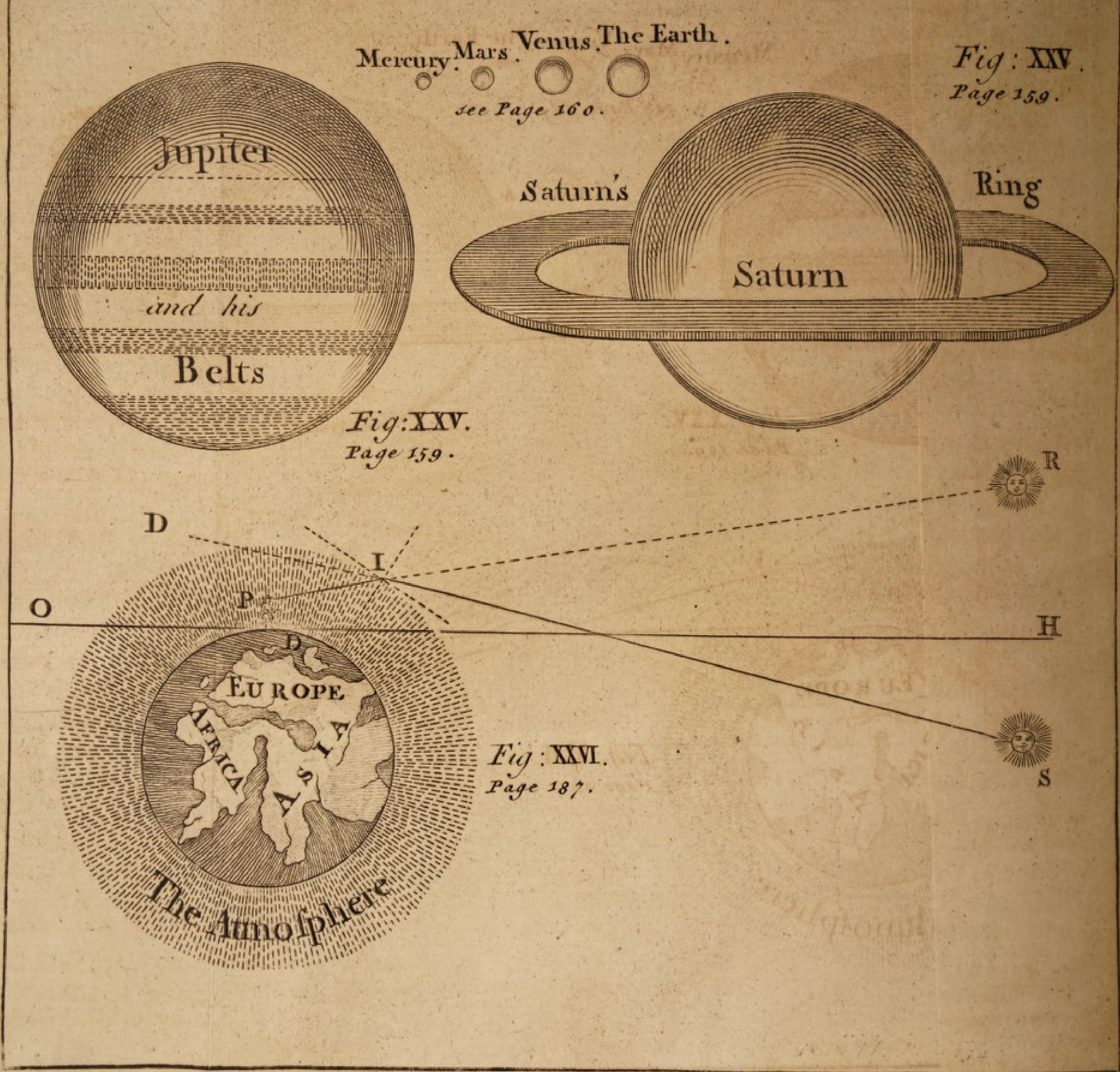
A. What, I beſeech you, *Sir*, do you ſuppoſe we can ſee the Sun when he is really under the Horizon?

B. Yes, we do, for the Space of ſome Minutes each Day.

A. Pray,

To front Page 187.

Plate XV.



A. Pray, *Sir*, if poſſible, let me underſtand how this can be by a Scheme?

B. I will, and you may very eaſily apprehend the Truth of this Aſſertion (though ſtrange) from thence, provided you remember what I ſaid of the Reflection and Refraction of Light, when we diſcourſed on that Subject.

A. I do remember it very well; pray proceed.

B. Then pleaſe to caſt your Eyes on *Fig.* XXVI. on *Plate* XV, fronting *p.* 187, which repreſents the Earth ſurrounded by its *Atmoſphere*: Now let HO be the Horizon of a Perſon at P, S is the Sun really under the Horizon, from which a Ray of Light SI proceeds, and falls on the upper Part of the *Atmoſphere* at I; this Ray, by the thicker Medium of the *Air*, is bent from its direct Courſe to D, into the oblique one IP, and ſo ſtriketh the Spectator's Eye; the Spectator then will ſee the Sun in the Direction of this refracted Ray PI, *viz.* at R, which is above the Horizon: And thus at ſome Times of the Year, we ſee the Sun above the Horizon near 10 Minutes, whilſt it is really below it on one Day taking the Morning and Evening together; at a Medium it is 6′½ each Day throughout the Year, which is as good as 3½ equinoctial Days in one Year; which is almoſt a whole Year's Sunſhine in a *Century* more than we could otherwiſe have had.

A. Sir, I perceive it very plainly, and give you abundance of Thanks *.

CHAP.

* See large Diſcourſes on this copious Subject in *Boerhaave*'s Chymiſtry, Part I. Page 277 to 304; with Dr. *Shaw*'s Notes thereon.

CHAP. II.

ANEMOGRAPAY, *or the* PHILOSOPHY *of the* WINDS.

A. HOW do you derive the Word *Anemography?*

B. From the two *Greek* Words ἄνεμος, *Wind*, and γραφὴ, a *Description*; it therefore signifies a philosophical *Description* of *Winds* in general.

A. What is the *Wind?*

B. *Wind* is nothing but a Stream or Torrent of Air, as a River is a Stream or Torrent of Water.

A. What Distinction do the Philosophers make of *Wind?*

B. My Lord *Bacon* distinguished *Winds* into four Kinds, *viz.*

1. General *Winds*, which always blow from the same Quarter.

thereon. Mr. *Clare*'s Motion of Fluids. *Newton. Principia Mathem. Phil. Naturalis, passim. J. Rohaulti Phys.* Part. III. Cap. 2. *cum Annot. Dni Clarkii annexis. J. Clerici Phys.* Part. III. Cap. 1. *Stairii Phys. Exper.* Explor. 19. *Casp. Bartholoni Specimen Philos. Nat.* Cap. 12. Mr. *Boyle*'s Memoirs for a general History of the Air. *Mariotte de la Nature de l'Air. Regnault*'s Phil. Conv. Vol. I. Con. 2, 22, 23, &c. *Musschenbroek*'s Epitome, Part II. Cap. 22. *Gravesande*'s, *Desaguliers*'s, *Hawksbee*'s, *Worster*'s, &c. Courses of Experimental Philosoph. *Cheney*'s Princip. of Philos. Part I. Cap. 5. Sect. 28. Relig. Philosopher, Vol. I. Contemp. 17. Mr. *Derham's Physico-Theology*, Book I. Cap. 1. Dr. *Hales*'s Vegetable Statics and Hæmastatics. Mr. *Millar*'s Gardener's Dictionary, Folio. *Chambers*'s Dictionary, and *Harris*'s Lexicon, under the Words *Air* and *Atmosphere*; and a great Number of other Authors quoted and referred to in Mr. *Johnson*'s Philos. Questions, from Page 84 to 92; and the Philos. Transactions.

2. Stated

To front Page 188.

Plate XVI.

A View of the General TRADE WINDS and Monsoons or Shifting Trade Winds.

Bowen Sculp.

2. Stated *Winds*, which blow only certain Seaſons from the ſame Point.

3. Servile *Winds*, which regard the Region, Time, Seaſon, *&c.*

4. Liberal *Winds*, which blow indifferently any where, or any how.

But this is not ſo natural as the following Diviſion of *Winds*, viz.

1. *General*, or coaſting Trade *Winds*.

2. *Periodical*, or ſhifting Trade *Winds*, called *Monſoons*.

3. *Common*, or caſual Winds, the ſame as the foregoing liberal *Winds*.

A. What are the different Qualities of *Wind?*

B. They differ (ſaith my Lord *Bacon*) not much more in the Points from which they blow, than in the Qualities with which they are diverſified; for ſome are violent, others gentle; ſome are cold, others hot; ſome are conſtant, others mutable; ſome moiſten and diſſolve, others dry and thicken; ſome gather rain, others are tempeſtuous and diſpel it; and others are ſerene and ſmooth.

A. Pray, what are the Cauſes of *Wind?*

B. Any Thing that can deſtroy the Equilibrium of the Air, and by acting on ſome Part with a greater Force, putting it into an Agitation, produceth ſuch a Stream or Current of Air, as we call *Wind.*

A. This is ſo very general an Account, as gives me but a little more Notion of the Thing than I had before.

B. In

B. In all Cafes we cannot be acquainted with Particulars; however, it is pretty certain that divers Things, as Eruptions of Vapours from Sea or Land, Rarefactions and Condenfations in particular Places, the Fall of Rains, Preffure of Clouds, *&c.* may alter the Equipoife, or Balance of the *Atmofphere*, and thereby caufe *Winds* more or lefs: Befides, feveral Caves, and fome great Lakes, emit or fend forth *Winds*; but the moft general Caufes of *Wind* are *Heat* and *Cold*, as is manifeft from the *general* and *periodical Trade Winds* between the Tropics, and thereabouts.

A. Pray, what are thofe *Winds* you call *general Trade Winds?*

B. Such as blow conftantly all the Year long from one Quarter; as from the N. E. or about the *North-Eaft*, on the *North-Side* of the Equator to 30 Degrees Latitude; and from the S. E. or about the *South-Eaft*, on the *South-Side* of the Equator to about 30 Degrees Latitude in the *Atlantic* Ocean, *Ethiopian* Sea, the *Indian* Ocean, and great *South-Sea:* Thefe *Winds*, for your better conceiving them, I have reprefented in the Map adjoined, by dark Lines in the aforefaid *Atlantic*, *Ethiopic*, and *Indian* Seas; in which you will fee divers Arrows fhewing the Courfe of thofe *Winds*.

A. This, Sir, is very helpful, and maketh the Thing eafier than your very Words can do: But doth the *Wind* blow conftantly in thofe various Courfes and Directions, fhewn by the Arrows, within a fmall Diftance of the Coafts of *Africa Weftward?*

B. Yes;

B. Yes; they are called the general coaſting Trade *Winds,* and always blow on the Points the Arrows ſhew.

A. But what is the Meaning that I ſee in the Map ſeveral Arrows in clear void Spaces, ſome pointing one Way, and others the contrary quite, with the Names of the Months abbreviated fixed to them?

B. I will inform you: It is in the *Arabian* Sea, the Bay of *Bengal,* the *Chineſe* Seas, by the *Eaſtern* Coaſts of *Afric,* and to 10 Degrees of *South* Latitude in the *Indian* Ocean, that you find theſe contrary Arrows; and in thoſe Parts you muſt know the *Wind* blows one half of the Year one Way, and the other Half the contrary Way: Theſe are called the *periodical* or *ſhifting Trade Winds,* which the Sailors call the *Monſoons.*

A. Then, I ſuppoſe, as the Arrows in thoſe ſeveral Places ſhew the various Courſes of the *Monſoons,* ſo their Times of ſhifting or changing their Points, are denoted by the Names of the Months affixed thereto.

B. Yes, they are, and therefore all thoſe, who ſail in theſe Seas, are obliged to obſerve the Seaſons proper for their Voyages, and in ſo doing they fail not of a fair *Wind,* and ſpeedy Paſſage.

A. How do you account for ſome *Winds* blowing always one Way, and others on contrary Points, in equal Periods of Time?

B. The moſt ſagacious Dr. *Halley* (the Author of all the preſent Philoſophy of *Wind*) gives this Account thereof, *viz.* That, accord-

ing

ing to the Laws of *Statics*, the Air which is leſs rarefied and expanded by Heat of the Sun's Beams, and conſequently more ponderous, muſt have a Motion towards thoſe Parts thereof, which are more rarefied, and leſs ponderous, to bring it to an Equilibrium, or Balance. And, 2. That the Preſence of the Sun continually ſhifting to the *Weſtward*, that Part towards which the Air tends, by Reaſon of the Rarefaction made by his greateſt meridian Heat, is with him carried *Weſtward*; and, conſequently, the Tendency of the whole Body of the lower Air is that Way: And thus a general *Eaſt-Wind* is formed in the *Atlantic* and great *South-Sea*, perpetually blowing *Weſtward*.

A. But, I obſerve, by the Arrows, thoſe *Winds* decline from the *Eaſt*, *Northward*, on the *North* of the Equator, and *Southward*, on the *South-Side:* Pray how happens that?

B. Becauſe near the Line, the Air is much more rarefied than at a greater Diſtance from it *Northward* and *Southward*; wherefore the Air being towards thoſe diſtant Parts leſs rarefied than in the Middle, will conſequently tend from the *North* and *South* to the Equator, and ſo become N. E. and S. E. *Winds*.

A. But why are not thoſe *Winds* as univerſal in the *Arabian*, *Indian*, and *Chineſe* Seas, and other Parts between the *Tropics*, which have the ſame Situation to the Sun, as the *Atlantic*, *Ethiopic*, or great *South* Ocean?

B. The Reaſon hereof is, undoubtedly, owing to their being ſurrounded by ſuch great Continents, which break the Continuity of the

 Oceans;

Oceans; and from the Nature of their Soil, and the Position of high Mountains, produce those several Variations of the *Wind* in those Places: Thus, the *Winds* set in upon the Land, even from *Westward*, on some Parts of *Guinea*; because the Soil being sandy, reflects prodigious Heat, which greatly rarefies the Air, and maketh the more cold, and dense, tend thither from the *Western* Sea to restore the *Equilibrium*.

A. And, pray, how is the sudden Change of the *Wind* to opposite Points, accounted for in the periodical *Winds*, called the *Monsoons*?

B. Thus: The cold and dense Air, by Reason of its greater Gravity, presses upon the hot and rarefied; and therefore the rarefied Air must ascend in continued Streams as fast as it rarifies, and being ascended, it must disperse itself to preserve the Equilibrium; and thus, by a contrary Current, the upper Air must move from those Parts where the greatest Heat is, and so, by a Kind of Circulation, the N. E. Trade *Wind* below will be attended with a S. W. *Wind* above, and the S. E. with a N. W. above. Now because the Air coming out of the N. E. over vast Continents of Land (which, when the Sun is *Northward*, are intolerably hot; but more cold and temperate, when the Sun is at the *Southern Tropic*) into the *Indian* Sea, is sometimes hotter, and sometimes colder, than that whereby this Circulation is returned out of the S. W. by Consequence, the under Current of Air is one while from the N. E. and another while from the S. W.

A. Do not the Seasons help to determine somewhat of this Matter, in which those Changes happen?

 B. Yes,

B. Yes, they plainly confirm what I have before ſaid; for in *April*, when the Sun begins to warm thoſe Countries to the *North*, the S.W. *Monſoons* begin, and blow during the Heat till *October*; when the Sun being retired, and all Things growing cooler *Northward*, and the Heat increaſing to the *South*, the N. E. *Winds* enter, and blow till *April* again: But yet, why the *Monſoons* change here, and not in the *Ethiopic* Ocean; and alſo why the Limits of the Trade *Winds* are fixed to about 30 Degrees of N. and S. Latitude, is not ſo well to be accounted for; and therefore muſt be left, with ſeveral other Intricacies of this Nature, to the Diſquiſition and Diſcovery of ſucceeding Ages.

A. Well, ſo much then for general and periodical Trade *Winds*; have you any Thing farther to obſerve of the common and variable *Winds*, incident to all Points and Places?

B. Yes, a few Things touching their Qualities, Velocities, and Extent or Limits.

A. What do you obſerve of their Qualities?

B. That thoſe *Winds* are dry and cold, which contain the leaſt Quantities of Vapours; thoſe *Winds* gather and generate Clouds, which carry with them great Quantities of Vapours; thoſe Winds are hot, which blow from off hot Regions; and cold, which blow from cold ones; thoſe are the moſt violent, which are agitated by the greateſt Force; and the contrary *.

A. And

* See much more on this Subject in Dr. *Halley*'s Hiſtorical Account of the Trade Winds and Monſoons in Philoſ. Tranſact. N° 183. Lord *Bacon's* Hiſtory of the Wind. *Bohun*'s Diſcourſe on the Origin and Properties of the Wind. *Clare*'s Motion of Fluids

A. And, pray, what is diſcovered of the Velocity of *Wind?*

B. It is found by Experience, that the Velocity of *Wind,* in a great Storm, is not more than 50 or 60 Miles an Hour; and that a common briſk *Wind* moves 15 Miles an Hour; and ſome are ſo ſlow as not to move one Mile an Hour.

A. In the laſt Place, what do you obſerve of the Extent, or Limits, of the *Wind?*

B. That it is very uncertain, and little known, unleſs of the aforeſaid Trade *Winds:* The moſt we know of common *Winds* in their Uſe, is in cooling and cleanſing the Air from all poiſonous Contagions, and peſtilential Exhalations; and thereby keeping it always pleaſant, pure, and healthful; whence appear their abſolute Neceſſity to animal Life, and Conſervation of the Univerſe.

CHAP. III.

METEOROGRAPHY, *or the* PHILOSOPHY OF METEORS *in general,* viz. VAPOURS, FOGS, MISTS, CLOUDS, RAIN, HAIL, SNOW, FROST, ICE, THUNDER, LIGHTNING, IGNIS FATUUS, *or* JACK IN A LANTHORN, FLYING DRAGONS, *and ſuch like.*

A. I Pleaſe myſelf with the Thoughts of converſing on Subjects, now very pleaſant,

Fluids, Page 237 to 240, and 248 to 265. *Rowning's* Comp. Syſtem, Part II. Diſſert. 5. And almoſt all the Authors referred to in the laſt Note.

and curious, ſuch as what you call the Doctrine of *Meteorography*; but before we proceed, pray let me know what is the true and proper Meaning of the Word *Meteor*?

B. The *Greek* Word μετέωρον, *Meteoron*, is compoſed of μετὰ, *beyond*, and ἀείρω, *to lift up aloft*; and therefore a *Meteor* implies that which is elevated aloft beyond us in the Air, as *Clouds*, *Lightning*, &c.

A. How many Kinds of *Meteors* do you reckon?

B. Some diſtinguiſh them into three Sorts, *fiery*, *airy*, and *watery*.

A. Which do they call *fiery Meteors*?

B. Such as are compoſed of a *fat ſulphureous Exhalation*, kindled by the nitrous Quality or Subſtance of the Air; and do then exhibit the Appearance of Light and Fire in the Air, as *Lightning*, *Flying Dragons*, &c.

A. What are thoſe called *airy Meteors*?

B. The Wind, and its divers Kinds; but properly ſpeaking, the Wind is no *Meteor* at all, nor are there any *Meteors* which conſiſt merely of Wind.

A. Pleaſe to recount me thoſe you call *watery Meteors*.

B. They are ſuch as conſiſt of *Vapours*, and watery Particles, which are ſeparated from one another, and raiſed by the Sun's Heat, and become modified in the Air into various Forms, as *Miſts*, *Clouds*, *Rain*, &c. in abundance.

A. Which do you hold it will be moſt natural to begin a Converſation withal, of thoſe ſeveral Sorts of *Meteors*?

B. It

B. It will certainly be moſt natural to begin with watery *Meteors.*

A. Well then, to make a Beginning, I obſerve you ſaid thoſe *Meteors* originally conſiſt of *Vapours*; pray, what are they?

B. *Vapours* are a Company of aqueous or watery Particles, ſeparated from the Surface of the Water, or moiſt Earth, by the Action of the Sun's Heat; whereby they are ſo far rarefied, attenuated, and ſeparated from each other, as to become ſpecifically lighter than the Air, and conſequently, they riſe and float therein; and thus, any Kind of Heat or Fire may cauſe *Vapours* *.

A. Pray

* The Manner in which Heat raiſes the Particles of a Fluid into the Air, or which is the ſame Thing, makes it ſpecifically lighter than Air, is a great Difficulty with Philoſophers, who have taken Pains to invent many Hypotheſes for the Solution thereof, which may be all ſeen, with their particular Confutations, in Mr. *Rowning*'s Comp. Syſtem, Part II. Diſſert. 6. and the Author himſelf declines giving any Account thereof on the Principles of the preſent Philoſophy.

But as it is no ſmall Diſparagement to the *Atomical* or *Newtonian Philoſophy* to ſuggeſt its Inſufficiency to account for the *Formation*, *Riſe*, and *Reſolution* of *Vapours into Rain*, I think it proper to propoſe the following Queries in Behalf thereof. (1.) Does not the received Philoſophy teach—That *Fluids* conſiſt of Particles which touch but in few Points, and are united by the Attraction of Coheſion? (2.) That Heat is Fire, and that the Particles of Fire are in a conſtant and violent Agitation and State of Motion among themſelves? (3.) That, ſince the Power of *Coheſion* is known to be leſs than the Power or Force of Action in the igneous Particles, theſe Particles muſt divide, ſeparate, and propel the Particles of the Fluid every Way from each other; and therefore, (4.) May not thoſe Particles of the Fluid, which lie in the Surface, be driven upwards beyond the ſmall Sphere of Attraction by the Action of the fiery Particles? (5.) And, then being extremely ſmall, may they not be lighter than the Air on the Surface of the Fluid, and therefore be forced to aſcend in it according to the Laws of *Statics*? (6.) Being buoyed up to a

 Height

A. Pray what *Meteors* are immediately formed of *Vapours?*

B. Fogs and *Mists: Fogs* are those Collections of *Vapours* which chiefly rise from fenny, moist Places, which become more visible as the Light of the Day decreaseth; if these are not dissipated, but unite with those that rise from Waters, as Rivers, Lakes, *&c.* so as to fill all the Air in general, then they are called *Mists*; and often they stink, from a sulphureous Exhalation, or Matter they contain.

A. What *Meteors* are next formed of *Vapours?*

B. Clouds are the next State of *Vapours*; for they consist only of a Congeries of *Vapours* exhaled from Sea and Land, and raised to that Height in the Air, where they become of equal Weight, or Gravity, with the Air; in those Parts, therefore, they float and swim, and by striking one against another, and mixing one with another, they coalesce, or thicken, and become more dense and weighty; the thinner or rarer the *Clouds* are, the lighter and higher they soar; but

Height where the Air is of equal Weight, will they not be there suspended in the Form of Clouds, according to the same Laws? (7.) May they not there (by the Means above assigned) be condensed and imbodied, and so become more weighty than the Air, and therefore endeavour to descend through it, according to the same Laws? (8.) But descending through a Body of considerable Resistance (as the Air is) will they not be again divided and separated into lesser Parts, which being heavier than an equal Portion of Air, will still keep descending in Drops or Form of Rain?

I see nothing unnatural or merely conjectural in all this, and sure I am, it is all consentaneous to the Principles of the present received Philosophy. If any think the Subject of these Queries deficient in regard of the Purpose, they are to shew it.

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the more denſe they are, the weightier, and the nearer they ride to the Earth.

A. Pray how high do you judge the *Clouds* to fly?

B. From about a Quarter of a Mile to a Mile; it is very common for Perſons, by climbing very high Mountains, to get above the *Clouds* and ſee them ſwim beneath them, cleaving againſt the Mountains they are on *.

A. That muſt be very curious to obſerve; but whence the various Figures and Colours of the *Clouds*?

B. The wonderful Variety in the Colours of the *Clouds*, is owing to their particular Situation to the Sun, and the different Reflections of his Light: The various Figure of the *Clouds* reſults from their looſe and voluble Texture, revolving into any Form, according to the different Force of the Winds.

A. That *Rain* is produced from the *Clouds* we all know; but in what formal Manner doth it happen?

B. Thus: when various Congeries of *Clouds* are driven together by the Agitation of the Winds, they mix and run into one Body, and thus diſſolve and condenſe each other into their former Subſtance of Water; alſo the Coldneſs of the Air is a great Means to collect, compact, and condenſe *Clouds* into Water: The Water thus produced of the *Clouds*, being heavier than

* Concerning the ſeveral Methods of meaſuring the Height of the Clouds, ſee my *Young Trigonometer's Guide*, Vol. I. Part II. Chap. II.

Air, muſt of Neceſſity fall through it in the Form we call *Rain*.

A. But why does it fall in Drops, and not in whole Quantities, as it becomes condenſed in the Air?

B. So it would fall in great Quantities, were it not for the Reſiſtance of the Air; but the Subſtance of the Air breaketh and divideth it into Parts, ſmaller and ſmaller, the farther it paſſeth through it, till at laſt it arrives to us in very ſmall Drops *.

A. Is not *Dew* a Kind of *Rain*?

B. Yes; only with this Difference, that whereas *Rain* falls at any Time, and in great Drops, *Dew* falls only at ſtated Times, and in ſuch very ſmall and fine Drops, that they are ſcarcely viſible, till they are fallen and condenſed into Drops on the Tops of Graſs, Boughs, *&c.*

A. In the next Place, pray, *Sir*, explain how the *Meteor*, we call *Snow*, is produced.

B. *Snow* is produced thus: When the *Vapours* are become conſiderably condenſed, yet not ſo far as to become liquefied, or diſſolved into Water, then, by a ſpecial Degree of Coldneſs in the upper Air, the Particles of the condenſed *Vapours* are compelled into a hard, rigid, and glacy Subſtance, ſeveral of which adhering together, form little Fleeces of a white Subſtance, ſomewhat heavier than the Air; and therefore deſcend in a ſlow and gentle Manner through it, being ſubject, by its Lightneſs, to all the various Motions of the Air and Wind; and is what, when arrived to us, we call *Snow*.

* See Note * in Page 197.

A. And,

A. And, pray, is not *Hail* formed after ſomewhat a like Manner?

B. Hail is thus generated: When the *Cloud* which raineth is very high in the Air, or when all the Regions of the Air are very cold, the falling Drops of Water are congealed thereby, and grow into a glacy Subſtance, ſomewhat white and hard, of different Size and Figure, according to the Particles of Water, the Degrees of Heat and Cold, the Wind, *&c.* and this, when come to us, we call *Hail.*

A. Although I ſuppoſe you do not reckon *Froſt* and *Ice* among *Meteors,* yet I believe this may be as proper a Place to diſcourſe of them as any; and therefore, if you pleaſe, be ſo good as to explain to me their Natures?

B. Dr. *Cheyne* ſaith, that *Cold* and *Freezing* ſeems to proceed from a ſaline or ſalt Subſtance floating in the Air, whoſe Particles are very ſharp and pointed, and theſe inſinuating themſelves (in a wedge-like Manner) into the Pores of the Particles of Water, do thereby fix, cryſtallize, and make hard the ſuperficial Parts of Water, and all humid Subſtances; and hence the incruſtated Surface of Earth, Dews, *&c.* we call *Froſt,* and the fixed and cryſtallized Superficies of Water, we call *Ice:* But, when the Heat of the Sun diſſolves thoſe freezing, ſaline Particles into a Fluid, the Surface of the Water, *&c.* all return to their former natural State; and this we call *Thawing.*

A. Have you any Thing farther to conſider, as *watery Meteors?*

B. No,

B. No, thoſe now deſcribed are the whole Tribe; and as we have already largely ſcanned the Nature of the Wind, which ſome (as I told you) improperly make a ſecond Sort of *Meteors*, let us now paſs to the Speculation of thoſe which are called fiery *Meteors*.

A. With a very good Will, *Sir*; nothing delights me ſo much as thoſe Kinds of natural Reſearches; and in the firſt Place, pray which do you count the principal of all the fiery *Meteors*?

B. Lightning, which is thus occaſioned: The Air doth abound with Steams and Exhalations of *Sulphur*, *Bitumen*, *Nitre*, and Salts of various Sorts, *Acids* and *Alkalies*; theſe being raiſed by the Sun's Heat into the higher Regions of Air, are there diſperſed and ventilated to and fro by the Winds; this Agitation produces a Mixture, and, conſequently, a Fermentation of thoſe combuſtible Sulphurs with the nitrous Acids, which is often to that Degree, as to kindle into Flame, and thereby cauſe thoſe ſhining Flaſhes of *Lightning* we ſee darting from the Sky *.

A. But, pray, *Sir*, what makes the *Thunder* with it?

B. Thunder is occaſioned by the kindling thoſe bituminous and ſulphureous Exhalations

* Concerning the Nature of *Bitumen*, *Sulphur*, *Nitre*, *Acids*, *Alkalies*, &c. See Part IV. Chap. II. and the Notes thereto annexed.

As *Sulphur* is the moſt *inflammable*, and *Nitre* the moſt apt for a *violent* and *ſudden Exploſion*, of all Kinds of Matter; ſo theſe two Subſtances are moſt reaſonably thought to afford the *Effluvia*, which compoſe the Mixture producing *Lightning* and *Thunder*; as they are the two principal Ingredients in *Gunpowder*.

in

in the Air by the nitrous Salts, in the ſame Manner as the Exploſion is produced by ſetting Fire to *Gunpowder*, or *Aurum Fulminans*; and the Reaſon why we do not hear the dreadful Noiſe of *Thunder*, ſo ſoon as we ſee the *Inflammation* or *Lightning*, is becauſe Sound is longer arriving to our Ears, than Light to our Eyes; as I have before told you.

A. I have heard talk of *Thunder-Bolts*, and their ſtrange Effects; pray, what do Philoſophers ſay of them?

B. What is called a *Thunder-Bolt*, is nothing but a more ſolid and moſt rapid Flame, which, with incredible Celerity, flies from the *Clouds* to the Earth, and thro' every Thing ſtanding in the Way, being interrupted by nothing. The more remarkable *Phænomena* of which are as follow: 1. That it affects high Places chiefly, as Mountains, Towers, Trees, &c. 2. That it will ſometimes burn a Perſon's Clothes, while his Body remains unhurt. 3. That, on the contrary, it will ſometimes break a Man's Bones, while his Clothes and Fleſh receive no Harm. And, 4. In like Manner it will ſometimes melt or break the Blade of a Sword in the Scabbard, while the Scabbard remains untouched; and, on the contrary, will ſometimes burn the Sheath, and not affect the Sword. The Reaſon of theſe ſtrange and contrary Effects, Philoſophers can but conjecture at, imputing it to the different Figure and Quality of the Particles of * *Lightning*,

* There is a Sort of Stone, or Mineral, which the common People call a *Thunder-Bolt*, and imagine it falls from the Clouds in

ning, which renders them capable of diſſolving ſome Subſtances, at the ſame Time that they will not touch others.

A. All this is very ſtrange indeed; pray what other fiery *Meteors* are remarkable?

B. The ſame aerial Fire, or ſulphureous Inflammation, hath different Names, according to the Variety of Figures and Sizes it appears under: As, 1. *Lampas*, a Lamp, when it burneth by little and little, on one Part only. 2. *Bolis*, a Dart, when the Exhalation appears kindled in a long Tract together. 3. *Trabes*, Beams, when the Inflammations appear in the ſame Place continually. 4. *Chaſma*, a Chaſm, when the Flame ſhines or glitters from the Breaks of dividing and ſplitting *Clouds*. 5. *Ignis Fatuus*, *i. e.* the fooliſh Fire, or Jack in a Lanthorn, when a fat unctuous Vapour is kindled, and wafted about by the Motions of the Air, near the Surface of the Earth, like a Light in a Lanthorn. 6. *Ignis Pyramidalis*, the pyramidical Fire, when it reſembles a Pillar of Fire, ſtanding upright. 7. *Draco Volans*, a flying Dragon, when the middle Parts be thicker and broader than the Ends. 8. *Capra Saltans*, a ſkipping Goat, when it appears to have a ſkipping Motion, and to be ſometimes kindled, and

in a Stroke of Thunder, and thereby does many Times great Miſchief, but this is a vulgar Error; the Stone ſeems, from the Make and Faſhion thereof, to reſemble more an *artificial* than a natural Production; and being moſt frequently found where Sepulchres have been, inclines ſome to think they are ſome Remains of Antiquity, and were formerly of Uſe in War, and *Arms*, which it was cuſtomary with the Ancients to bury with their Aſhes. See the Authors mentioned in *Rowning*'s Comp. Syſtem, Page 146 of Part II. and Phil. Tranſ. No. 313, 316, 319, 331, 336.

ſome-

ſometimes not. 9. *Stellæ cadentes*, falling Stars; when the more ſubtile Parts are burnt away, they fall by the Weight of their viſcous and earthy Matter remaining. And theſe are all the remarkable fiery *Meteors* *.

* Of theſe *Meteors*, the *Ignis Fatuus* is the moſt frequent and conſiderable; of which Sir *Iſaac Newton* thus writes, "The *Ignis Fatuus* is a Vapour ſhining without Heat; and is there "not the ſame Difference between this *Vapour* and *Flame*, as "between rotten Wood ſhining without Heat, and burning "Coals of Fire?" *Optics*, Queſt. 10.

The *Meteors* here mentioned are moſt of them but Parts of the wonderful *Phænomenon* called the *Aurora Borealis*, or Northern Lights, which is an Appearance of ſtreaming Light, darting from a dark Part of the Air which looks like a Cloud; which Streams or Streaks of Light, if low, are perpendiclar to the Horizon, and higher, ſeem to meet in a Centre near the *Zenith*; where they have various glancing, quivering and curling Motions; and when the *nitro-ſulphureous* Matter, of which it conſiſts, is all ſpent and burnt away, the *Aurora* commonly degenerates into a bright Twilight in the North, and there gradually dies away. See a large Account of this Phænomenon in all its Shapes in *Rowning's* Comp. Syſtem, Part II. Diſſert. 7. Monſ *Mairan's* Phyſ. and Hiſt. Treatiſe thereof, in the Memoires de l'Academie Royale des Sciences; or an Abſtract thereof in Philoſ. Tranſ. No. 431. See an Account of ſeveral Aurora's in the Philoſ. Tranſ. No. 320, 347, 348, 351, 352. That wonderful Meteor, *March* 19th, *A. D.* 1719, No. 360. Another the ſame Year, No. 363. Dr. *Halley* has made it appear from Obſervations on the Meteor ſeen on the 31ſt of *July*, between 9 and 10 at Night, *A. D.* 1708, that theſe Meteors are in the very upmoſt Part of the Atmoſphere, or between 40 and 50 Miles perpendicular Height. Alſo that *March* 19, *A. D.* 1719, was found by Calculation to be no leſs than 73½ *Engliſh* Miles perpendicular Height. For a more ample Account of Meteors, the Reader may conſult the Authors referred to in Note * in Page 187. Note * in Page 194, and Phil. Tranſ.

CHAP.

CHAP. IV.

PHANTASMATOGRAPHY, *or a Philosophical Account of the celestial Appearances,* viz. *the* RAINBOW, HALO'S, PARHELIUMS, PARASELENE'S, *&c.*

A. PRAY, *Sir,* why do you choose to use such a long hard Word as *Phantasmatography?* I can hardly speak it.

B. Because that best expresses my present Design, which is to let you understand what the Opinions and Discoveries of the best Philosophers are concerning the celestial *Appearances,* as the *Rainbow,* &c. this Word being composed of φαντάσματα, *Phantoms,* or *Appearances,* and γραφὴ, a *Description.*

A. But, *Sir,* by your Leave I would ask whether it be not an Innovation to call those Things by the Names of *Phantoms, Appearances,* or *Apparitions,* which (as yourself says) are by the greatest Philosophers ranked with, and deemed *Meteors?*

B. Be it an Innovation, or what it will, I always choose to call Things by such Names as express what they be, not what they be not; it is certain those Things we discourse of exist no way but in Appearance.

A. What, I pray you, is there nothing of Reality in these Things, as in the *Rainbow* for Instance, but a Form of different Colours?

B. Nothing more indeed; they all owe their Existence to one common Cause, *viz.* the *Reflection* and *Refraction of Light.*

A. Please

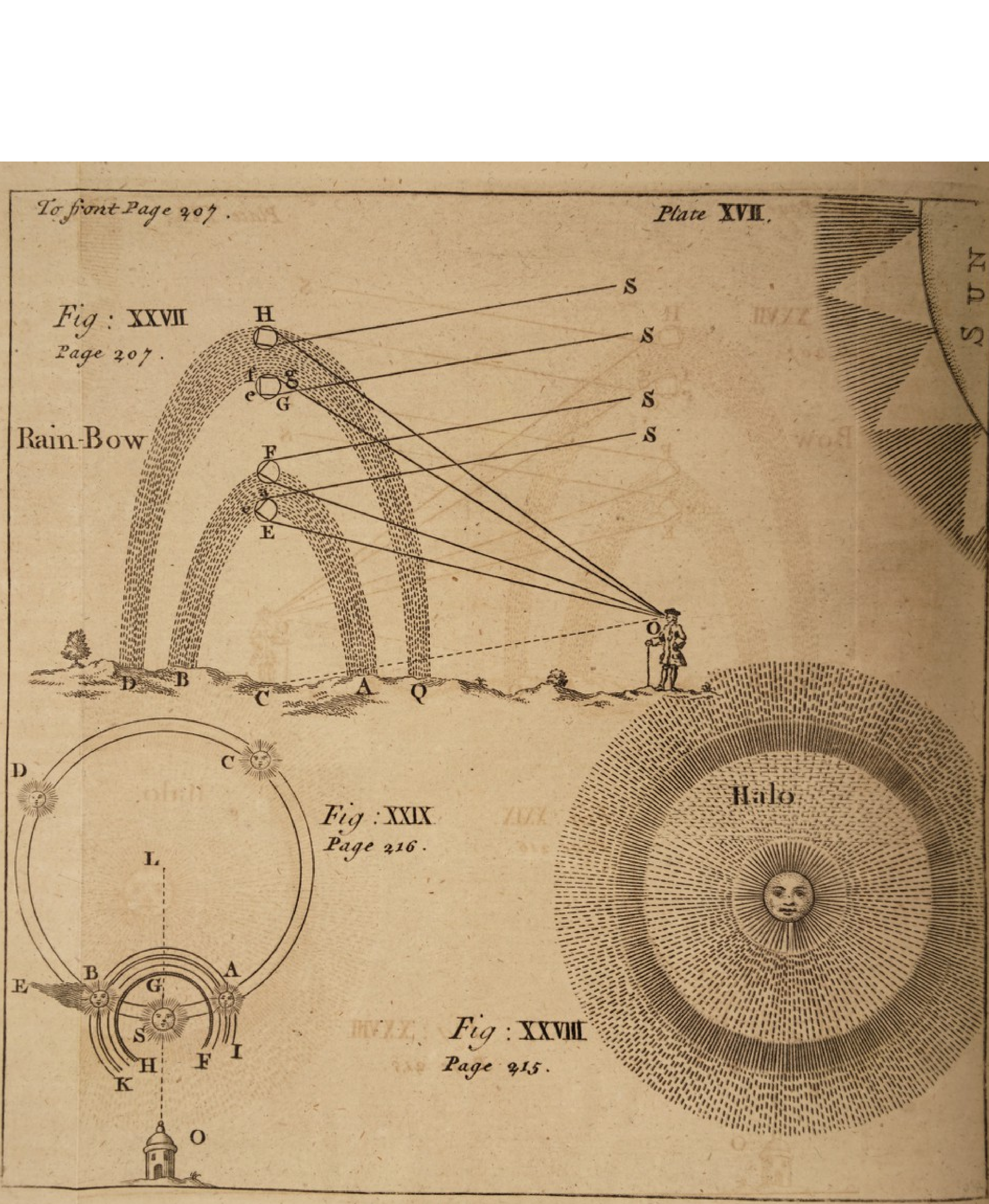
To front Page 207.
Plate XVII.
SUN
Fig: XXVII
Page 207.
Rain-Bow
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Fig: XXIX
Page 216.
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Halo
Fig: XXVIII
Page 215.

A. Pleaſe to explain a little more particularly the Manner how theſe *Phænomena* are produced; and, firſt, how the *Rainbow* acquires its beauteous and wonderful Form.

B. The *Rainbow* is one of the moſt ſurprizing of all the Works of God (which the *Hebrews* call קשת אלהים the *Bow of God*, and the *Greeks* ϑαυμαντὶς, *i. e.* the *Daughter of Wonder.)* This *Phænomenon* is ſeen in the falling *Rain*, or *Dew*, and not in the Cloud whence that *Rain*, or *Dew*, proceeds; it is cauſed by a *Reflection* and *Refraction* of the Sun's Rays from the globular Particles of *Rain*: There are often two *Bows* to be ſeen at the ſame Time, the interior, as AFB, which is more ſtrong and vivid; the exterior *Bow*, as QHD, which is more faint and weak; the interior *Bow* is formed by *two Refractions* of the Rays of Light, and *one Reflection* of them in the Drops of Water. See *Fig.* XXVII. on *Plate* XVII, fronting *p.* 207.

A. Pray, *Sir*, exemplify this Matter.

B. I will. In the interior *Bow (Fig.* XXVII. of the *Plate* as above) let EF be two Drops of the falling Rain, and let S*a* be a Ray of Light, falling on the Drop E in *a*, from whence it is refracted firſt to *e*, thence it is reflected to E, whence it is a ſecond Time refracted to the Eye, ſuppoſe at O: In like Manner, the ſame Thing happens in the upper Part of this *Bow*, in the Drop F.

A. Well, and what are we to learn from all this?

B. Hence you eaſily underſtand the Reaſon of the Colours of the *Bow*, if you have not forgot what I delivered to you when we were discoursing of Light and Colours: For here you see the Angle COE=40° $2'$ shall be the greatest Angle, in which the most refrangible Rays can after one Reflection be refracted to the Eye; and therefore all the Drops, in the Line OE, shall send the most refrangible Rays most copiously to the Eye, and thereby strike the Senses with the deepest violet Colour in that Region: In like Manner, the Angle COF=42° $17'$ shall be the greatest, in which the least refrangible Rays can after one Reflection be refracted to the Eye; and therefore all those least refrangible Rays shall come most copiously to the Eye in the Line OF, and strike the Senses with the deepest Red in that Region. Do you understand me, pray?

A. Yes, *Sir*, very well; and I also understand, that by Reason of the intermediate Degrees of Refrangibility of Rays coming from the Drops between E and F, the Space between E and F shall be painted with proper intermediated Colours; and therefore the whole Face of the *Bow* will be tinged with all the primogenial Colours in their natural Order, *viz. Violet, Indigo, Blue, Green, Yellow, Orange,* and *Red,* from E proceeding to F.

B. I am glad to see you so very happily understand the Matter; you will with the greatest Ease and Pleasure understand the *Phænomena* of the upper, or exterior *Bow* QHD, which in short are thus produced: Let G and H be two Drops in the extreme Parts of the upper *Bow*; now let SG be a Ray falling on the Drop in G, whence it is first refracted to *e*, from thence it is first

reflected

reflected to F, from F it is a ſecond Time reflected to g, and from g it is a ſecond Time refracted to the Eye at O: Now the ſame is to be underſtood in the upper Drop H: hence the Angle $COg=50^{\circ}\ 42'$ is the leaſt Angle, in which the leaſt refrangible Rays can after two Reflections be refracted to the Eye; and therefore the Drops in the Line Og ſhall ſtrike the Eye with the deepeſt Red, and the Angle COH $=54^{\circ}\ 22'$ ſhall be the leaſt Angle, in which the moſt refrangible Rays after two Reflections can emerge out of Drops; and therefore thoſe Rays ſhall come moſt copiouſly from the Drops in the Line OH, and ſhall ſtrike the Senſe with the deepeſt Violet in that Region: And by the ſame Reaſoning the Drops between GH ſhall ſtrike the Senſes with the intermediate Colours; and ſo the Colours, in the whole Width of the upper *Bow*, ſhall lie in this Order from G to H, *viz. Red, Orange, Yellow, Green, Blue, Indigo, Violet*; contrary to the Order of thoſe in the lower *Bow*.

A. Sir, I readily perceive the Reaſon of thoſe Colours in both the *Bows*, according to the Laws of Refraction you heretofore mentioned; but, pray, why are the Colours of the exterior *Bow* ſo much fainter than thoſe of the interior one?

B. Becauſe the Light is twice reflected in the Drops of the exterior, and but once in thoſe of the interior *Bow*, the Light becoming fainter by every Reflection.

A. I think, *Sir*, the *Rainbow* always appears perfectly round; doth it not?

B. Yes; accurately ſo; for the Lines OE, OF, OG, and OH, turned round their com-

O mon

mon *Axis* OC, ſhall with their Ends EFGH deſcribe the circular Borders, or Extremities, of the two *Bows*.

A. And do they always appear equally large?

B. Yes, all *Rainbows* are of the ſame Dimenſions; becauſe no *Bow* can appear but under the Angles of the ſame Quantities, as before mentioned.

A. But we do not always ſee an equal Quantity of a *Bow*, as I have often obſerved.

B. No, that is impoſſible you ſhould; for the Sun muſt be in the Horizon for you to ſee half the *Bow*, which is the moſt that can ever be ſeen; for then the Centre of the *Bows* C is on the Superficies of the Earth; but the higher the Sun riſeth above the Horizon, the lower the Centre C ſinketh beneath the Earth's Surface; and conſequently the leſs ſtill you can ſee of the *Bow*, till, at laſt, you can ſee none at all.

A. Pray how high muſt the Sun be for the *Rainbow* not to be ſeen at all?

B. When the Altitude of the Sun becomes equal to the Quantities of the aforeſaid Angles, under which the *Bow* appears, they cannot then be ſeen; that is, when the Sun's Height is equal to the Angle $COE=40^\circ\ 2'$, the inner Part E, of the interior *Bow*, deſcends the Horizon; when it is equal to the Angle $COF=42^\circ\ 17'$, the upper Part F, and ſo the whole interior *Bow* will entirely vaniſh and diſappear beneath the Horizon. Thus, when his Height is equal to the Angle $COH=54^\circ\ 22'$, the whole exterior *Bow* will be depreſſed below the Horizon, and then no Part of any *Bow* at all can be ſeen; hence all the *Winter* half Year both the

Bows

Bows may be ſeen all the Day, the meridian Height of the Sun then at greateſt being never above 38° 30′.

A. What elſe, pray, is remarkable of the *Rainbow?*

B. The Dimenſions in *Engliſh* Yards and Miles, I have calculated for every Part of both *Bows*, and are ſuch as are here ſet down at a given Diſtance of the Spectator, and Height of the Sun*. Alſo

* Suppoſe (as in *Fig.* LX. on *Plate* XIV. fronting *p.* 179) a Spectator at O beholds the Bows AEB and CGD at the Diſtance OQ=$\frac{3}{4}$ of a Mile, or 1320 Yards; and that the Height of the Sun be at that Time 16 Degrees: In ſuch a Caſe, I have determined the Dimenſions of the Bows as follow.

1. The Centre of the Bows P will be depreſſed below the Surface of the Earth 364 Yards=QP.

2. The leſſer Semidiameter of the interior Bow PE will be 1066 Yards; and the greater Semidiameter PF will be 1154 Yards; therefore,

3. The Breadth of the interior Bow EF will be 88 Yards, or 264 Feet.

4. Again, the leſſer Semediameter of the exterior Bow PG will be 1550$\frac{2}{10}$ Yards; and the greater PH, 1770 Yards; therefore,

5. The Breadth of the exterior Bow GH will be 219$\frac{7}{10}$ Yards, or 659 Feet;

6. Conſequently, the Breadth of the exterior exceeds the Breadth of the interior Bow by 395 Feet; which ſhews it to be more than twice the Width of the latter.

7. The Diſtance of the Summit F of the interior Bow from the Earth Q is 790 Yards; and the Summit of the exterior Bow H from Q is 1406 Yards.

8. The Diſtance between the two Bows from F to G is 396$\frac{2}{10}$ Yards.

9. The Diſtance of the Legs AB of the interior Bow on the Earth's Surface is 2052 Yards; that is, one Mile and 292 Yards.

10. The Diſtance CD of the Legs of the exterior Bow is 3014 Yards; that is, one Mile, and $\frac{7}{10}$ of another.

11. The Diameter of the interior Bow being 2132 Yards, the Circumference thereof will be 6694$\frac{1}{2}$ Yards, or 3 $\frac{8}{10}$ Miles, on the Inſide.

12. The viſible Segment AEB above the Earth, will be above 2750 Yards; or one Mile and a half, and ſomewhat more.

Alſo you have here learned the following Particulars: 1. That two *Bows* do appear together. 2. The Manner how they are both formed. 3. The Reaſon of the Diverſity of their Colours. 4. The Reaſon why the Colours of each *Bow* lie in an inverſe Order to each other. 5. That the *Rainbows* never appear but when it rains. 6. That the *Bow* is in the falling Rain, and not in the Cloud. 7. That it always appears in that Part of the Heavens oppoſite to the Sun. 8. The Reaſon why one *Bow* is ſo much more ſtrong, apparent, and vivid, than the other exterior one. 9. Why they are all in themſelves of an equal Bigneſs. 10. Why we ſee at ſometimes a greater, and ſometimes a leſſer Part of them. 11. Why we can never ſee above half a *Bow* at moſt, and when we can ſee none at all. 12. That the Dimenſions of a *Rainbow* may be computed in any known Meaſure.

A. Indeed theſe are all exceeding curious Circumſtances, and far more than ever I underſtood

13. The inner Circumference of the exterior Bow will be $9535\frac{9}{10}$ Yards, or a little more than $5\frac{4}{10}$ Miles; and the Part CGD above the Earth about $2\frac{3}{10}$ Miles.

Theſe are the principal Dimenſions of ſuch a Bow, which may give the Reader a general Idea thereof, and many Times is very near the Truth. I have ſhewed the Method of Calculation in my *Young Trig. Guide*, Vol. I. Part 2. Chap. 2. But, by the Miſtake of a Number, the Meaſures there given are erroneous; this Overſight I diſcovered not till it was too late to correct it.

They who would ſee the Mathematical Theory of the *Rainbow*, may conſult Sir *Iſaac Newton's Optics*, Book I. Part 2, Prop. 9. or Dr. *Clark's* Notes on *Rohault's Phyſics*, Part III. Chap. 17. Alſo in Dr. *Green's Principles of Philoſophy*; and Dr. *Halley's* Diſcourſe thereon, in *Philoſ. Tranſ.* N° 267. See alſo N° 375. Dr. *Pemberton's View*, Page 391. *Graveſande's Elem.* Book III. Chap. 21. *Chambers's Diction.* and *Harris's Lex. Tech.* under the Word *Rainbow*.

ſtood before: But you have ſaid nothing of the *Rainbows* which appear by Night in the *Moonſhine*; what think you of them, *Sir?*

B. They are in all Reſpects the ſame as thoſe occaſioned by the *Sunſhine* in the Day *.

A. But, if you aſſign ſuch a natural Cauſe for the Production of the *Rainbow*, would not there have appeared a *Bow* in all Ages and Places?

B. Yes, always ſince there have been Clouds, and Perſons to ſee the Reflection of the Sun's Light from the Particles of falling Rain.

A. Why, there have been Clouds ever ſince the Creation, have there not?

B. Yes, undoubtedly, and Rain too.

A. Pray, then, how could the *Rainbow* be any Thing of a *miraculous Production*, or be made the Sign of a new Covenant, which God made

* There are obſerved four Sorts of *Iris's* or coloured Bows. (1.) The *Rainbow*; of which already; and, for Diſtinction, may be called the *Solar Bow*. (2.) The *Lunar Bow*; of which ſee a remarkable Account in *Philoſ. Tranſ.* N° 331. (3.) The *Marine-Bow*; this appears at Sea in the Water which the Wind carries off the Tops of the Waves; the Colours in this are not ſo lively as in the *Common-Bow*; the moſt vivid are a Yellow next the Sun, and a Green next the Sea. They appear in great Number, ſo that 20 or 30 of them may be ſeen together. Laſtly, they have a Poſition contrary to that of the common Rainbow; that is, they have their curve Part turned towards the Sea, and the Legs upwards. See *Philoſ. Tranſ.* N° 337, and 369. (4) The *Terreſtrial Bow*; for ſo I call it, as being ſeen on the *Ground*; it is cauſed by Refraction of the Sun's Rays in Drops of Dew on the Graſs: Mr. *Langwith* tells us, in one he ſaw, the Colours were very near as ſtrong as thoſe of the common or *Solar-Bow*. It continually changed its Place with the Beholder. The convex Part was next the Eye, and the *Vertex* was very near him. The Colours took up leſs Space, and thoſe were more lively, that were neareſt him. According to the different Height of the Sun, the Figure of this Bow may be either an *Hyperbola*, *Parabola*, or *Ellipſis*. See *Philoſ. Tranſ.* No 369.

with *Noah* and the *New World*, as related *Gen.* ix. 13, 14, 15?

B. That Paſſage does not neceſſarily imply that it was any *miraculous Production*, or that it did *not exiſt before*; for *memorial Signs* or *Tokens* are *arbitrary Things*, and God might as well chooſe the *Rainbow* for that Purpoſe, as any *Novelty* whatſoever *.

A. How do you account for thoſe *Phænomena* we call *Halo's*?

B. They are Circles ſomewhat akin to the *Rainbow*, which appear about the Sun and Moon, and ſometimes variouſly coloured.

A. Pray what are the moſt remarkable Particulars in the *Halo's*?

B. The following: 1. They have always the Sun or Moon for their Centre. 2. They never appear

* In *Gen.* ix. 13. our Tranſlation hath it—*I do ſet my Bow in the Cloud*, which indeed makes it ſeem as if it were not there before; but if we attend to the Original, we ſhall find the Word נתתי to ſignify, not—*I do ſet*, but, *I do give*, or *appoint*, or *appropriate* my Bow in the Cloud, for a Sign, &c. Again, the Expreſſion קשתי, *my Bow*, plainly implies the Bow was then in being, and was a common and well known Thing. Once more the Word והיתה, which we render, *and it ſhall be*, may be as well rendered—*that it may be*, &c. the Prefix ו being often found to have the Signification of the Adverb *ut*, that. Wherefore the Verſes may be truly thus tranſlated; *I do give or appoint my Bow, which is in the Cloud, that it may be for a Sign or Token of a Covenant between me and the Earth*; *and it ſhall come to paſs, when I bring a Cloud over the Earth*, (ונראתה) *and the Bow ſhall be ſeen in the Cloud*, (וזכרתי) *that I will remember my Covenant that is between me and you*, &c. Thus, by giving the Particle ו its due Acceptation in three ſeveral Places, the three Verſes run very natural, and imply no new Wonder or Miracle. I hope thoſe Gentlemen who have been ſo ready in charging me with caſting Contempt on the Scriptures, will believe me, if I tell them once more, that I eſteem the Bible above all Books in regard of Religion, and that what I ſay reflects only on the *Superſtition* or *Ignorance* of thoſe who would make the Scriptures ſay any thing inconſiſtent with *Reaſon*, *Common-ſenſe*, or the *Nature of Things*.

appear in a rainy Sky, but in a rimy and frosty one. 3. They appear blue on the exterior Limb, or Border, and red on the interior. 4. The Air contained within them is more obscure than the ambient Air without round about them. 5. The Limb of a *Halo*, or Width of its Circle, is about half a Degree, or 30 Minutes. 6. The Diameter of the whole Circle of the *Halo*, is about 44 or 46 Degrees, more or less. See *Fig*. XXVIII. on *Plate* XVII, fronting *p*. 207.

A. And, pray, is the *Halo* formed in the same Manner as the *Rainbow*?

B. The *Halo* is formed by the Refraction of the Rays of Light, without any Reflection, as in the *Rainbow*; and this Refraction of the Light in the Hailstones in the Air, will be strongest at about 22°, or 22° 30′, distant each Way from the Sun or Moon, and gradually decay both Ways as the Distance increases or decreases; and consequently at that Distance there will be formed a Circle, we call the *Halo*, about the Sun or Moon, which *Halo*, as often as the Hailstones are duly figured, may be coloured; and then it must be red within by the least refrangible Rays, and blue without by the most refrangible ones: And this is the Substance of all we know worth mentioning of the *Halo's*.

A. Then a Word next, if you please, concerning the *Parhelia*; pray what are they in a philosophical Sense, and why so called?

B. The *Parhelia* are what the Vulgar call *Mock-Suns*, and *Paraselenes* are *Mock-Moons*, which sometimes appear in the Heavens, and are only Representations of the Face of the true

Sun or Moon by Way of Reflection in the Clouds; they are so called, because they appear παρὰ τὸν ἥλιον, besides the true Sun, and παρὰ τὴν σελήνην, besides the true or real Moon.

A. In what Manner do they appear?

B. Thus: 1. There is observed a very great white Circle parallel to the Horizon, as ACDB, passing through the true Sun at S. See *Fig.* XXIX. on *Plate* XVII, fronting *Page* 207. 2. In the Parts of this white Circle appear the *Parhelia:* As in 1629, *March* 29, there appeared at *Rome* four Mock-Suns, as ABCD, to a Spectator in the Observatory at O; though not all of them equal, nor equally strong and vivid, nor of equal Duration. 3. They are in Number unequal, being sometimes four, as here, sometimes more or less. 4. They appear sometimes tinged with the Colours of the *Rainbow*, now stronger, now fainter. 5. *Halo's* frequently appear at the same Time; as in the Case now mentioned, there appeared two broken ones, as the interior one FGH, very strong and *Rainbow*-like, and the exterior one, IABK, passing through the two *Parhelia* nearest the Sun AB, but so weak and faint as scarcely to be seen. 6. Among these four *Parhelia*, one, *viz.* the *Parhelium* B, appeared to have a Tail, Comet-like, extending to E, the Part opposite to the Sun S.

A. But, *Sir*, in viewing this Scheme, doth not I represent the Point vertically over the Observatory O, as well as the Centre of the great white Circle; and so the Spectator would see the true Sun, the *Halo's*, and the two *Parhelia*,

helia, A, B, before him, and the other two, C, D, behind him; would he not?

B. Yes, that is the right Way to conceive a true Notion of the *Phænomenon*.

A. Please to let me know how the Philosophers say they are formed?

B. The great white Circle all round you is formed by the Reflection of the Sun, from those icy Particles floating in the Air of the same Height of the Sun; and therefore the Sun must be in it, as at S: The *Halo's* FH and IK are produced as before said: The *Parhelia* ABCD are produced by two Refractions and one Reflection of the Sun's Rays falling on the icy Particles in certain Parts of the white Circle; whence there is an Image of the Sun not only formed, but painted with the Colours of the *Bow*: But the Causes of these *Phænomena* are not so obvious as those of the *Rainbow* and *Halo's*, and therefore we leave them *.

A. But, before we quite dismiss this phantastic Subject, pray give an Hint what that *Phænomenon* may be we call *Virgæ*?

B. This is only an Apparition of the Sun's Rays darting through the Interstices of the Clouds, or otherwise, in the Form of a Bundle of Rods as it were. And now, from those Things which are situated so remote from us,

* If the Reader be desirous of seeing a large and more various Account of *Halo's*, *Parhelia*, and other Appearances of the Kind, let him peruse Sir *Isaac Newton's Optics*, Book I. Part 2. Prop. 9. *Descartes's Meteora*, in his *Opera Philosoph.* Mr. *Hugens's* Account of the Causes of them, in *Philos. Trans.* N° 60. Also N° 22, 129, 13, 47, 102, 250, 251, 262; and all the Authors referred to in Note *, Page 187.

and in a Region altogether inacceſſible to Mankind, let us deſcend to the Contemplation of the manifold Curioſities and Wonders diſcovered in a Place we know better, and nearer Home; to wit, in the Globe of our Earth.

A. With all my Heart, *Sir*; for I cannot ſay, indeed, but that I am almoſt weary with travelling ſo long through all the ethereal Regions of the Univerſe; yet, as it hath been on the Wings of Contemplation, and I am ſaturated with the delightful Curioſities of Nature, I am ſo far from regretting it, that I count it the beſt and moſt profitably ſpent Part of my Time.

THE

Philosophical Grammar:

Or, VIEW of

Modern Philosophy.

PART IV.

GEOLOGY:

CONTAINING,

I. A philosophical View of the *terraqueous Globe*.
II. The Philosophy of *Earths, Stones, Metals, Minerals,* &c.
III. The Philosophy of *Water,* viz. the *Seas, Rivers, Springs,* &c.
IV. The Philosophy of *Plants* and *Vegetation.*
V. The Philosophy of *animal Bodies,* viz. the *human Body, Brutes, Fowls, Fishes, Insects, Reptiles, Shell-Animals,* &c.

Shewing the wonderful Discoveries of the modern Naturalists in those Parts of Science.

CHAP. I.

GEOLOGY, *or the general Doctrine of the* Globe; *of its various* Divisions *and* Subdivisions; *of the* Vicissitude of Seasons, *and other general Affections.*

A. PRAY, what is imported by the Word *Geology?*

B. A Discourse of the *Earth* in general, or *Terraqueous Globe*, as consisting of *Land* and *Water*, from the *Greek* Words γῆ, the *Earth*, and λόγος, a *Discourse*.

A. How is the Earth divided?

B. The first great and most general Division of the Earth is into Land and Water; which again are severally subdivided into other lesser Parts.

A. Pray how is the Land subdivided?

B. Into the following Parts, *viz.*

1. CONTINENTS, which are great Tracts of Main Land, containing whole Countries and Kingdoms; as *Europe*, *Asia*, *Africa*, and *America*.

2. ISLANDS, or Parts of Land environed by the Sea; as *Britain*, *Japan*, *Madagascar*, &c. *

3. PENINSULAS, which are Parts of Land encompassed by Water, excepting on one Part, by which they are joined to the main Land, or Continent; as *Morea*, &c.

4. ISTHMUS is that Neck of Land joining the *Peninsula* to the main Land.

5. PROMONTORIES, or *Capes*, are those high Parts of Land which run far out into the Sea in a Point; as the *Cape of Good Hope*, &c.

* See an Account of a new Island raised out of the Sea near *Saturnini* in the *Archipelago*, *May* 12, 1707, by Dr. *Sherrard*, in *Philos. Trans.* N° 314. Also of another new and burning Island raised out of the Sea near *Tercera* on *Novemb.* 20, 1720, by *Thomas Foster*, Esq; No. 372. This Isle is in Lat. 38° 29′, and Long. 26° 33′. In N° 361, there is an Account of the *Sunk Island*, as it is called, in the *Humber*, which was recovered from the Sea about seventy Years ago, and is about nine Miles in Circumference, and has a very fat and fertile Soil.

A. And

A. And, pray, what are the Subdivifions of the Water on the Globe?

B. Thefe following, *viz.*

1. OCEANS, are thofe vaft Collections of Water which cover fome greater Parts of the Earth's Surface; as the *Atlantic Ocean, Mare del Zur*, &c.

2. SEAS; thofe are leffer Affemblages of Water, which lie before, and wafh the Coafts of fome particular Countries; as the *Ethiopic, Indian, Arabian*, &c. Seas.

3. GULPHS, are thofe Parts of the Sea every where environed with Land, except one Paffage whereby they communicate with the Sea; as the *Arabian Gulph*, &c.

4. STRAITS, are thofe narrow Paffages of Water which either join a *Gulph* to the neighbouring Sea, or one Part of the Sea or Ocean to another; as the *Straits of Gibraltar*, &c.

5. RIVERS, are Streams of frefh Water arifing from fome Fountain-head, which by a continued Current arrive and difcharge themfelves into the Sea *.

A. What other Divifions do you make on the Surface of the Globe?

B. The Earth is again divided, with refpect to the Length of Days and Nights, into *Climates*.

A. What do you call a *Climate?*

B. CLIMATES are fuch Parts of the Earth's Surface on each Side the Equator, and parallel

* See an Account of the Rife of feveral of the moft confiderable Rivers in *Europe* by *J. G. Schinchzer*, F. R. S. in *Philof. Tranf.* N° 406. See alfo N° 119. And *Varen. Geog. gener.* Lib. I. Cap. 16. throughout.

thereto,

thereto, that the artificial Day in one ſurpaſſeth that in the other by half an Hour.

A. Are there yet any farther Kinds of Diviſions of the Earth's Surface?

B. Yes, and a very remarkable one too, *viz.* into the ZONES, called the torrid, temperate, and frigid *Zones* *.

A. Pray what doth the word *Zone* mean?

B. It is derived of the *Greek* ζώνη, a *Belt*, or *Girdle*; becauſe they, being large parallel Parts of the Earth's Surface, do encompaſs the Globe of the Earth, as a *Belt* doth the Body of a Man.

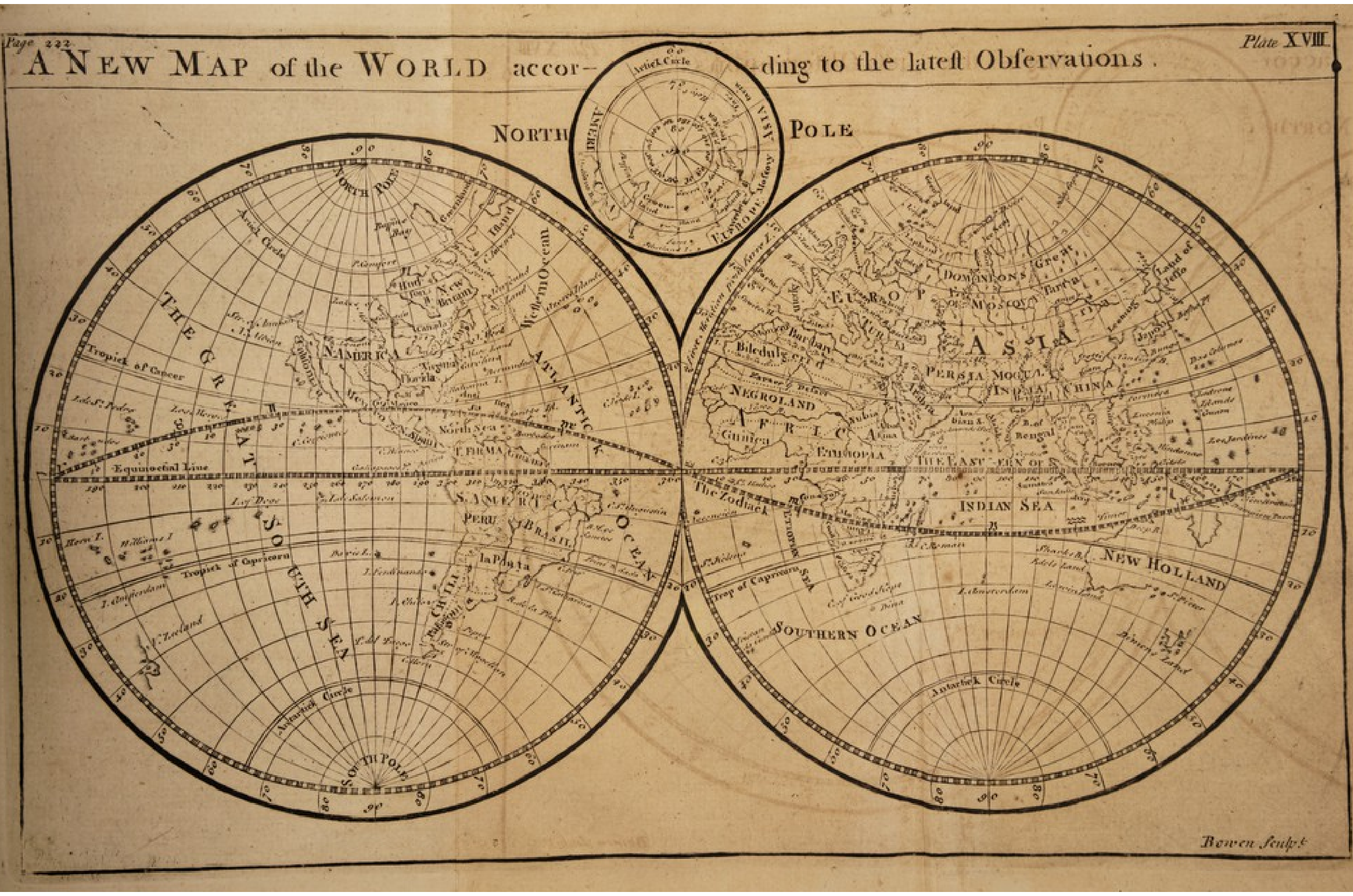
A. What is the *torrid Zone*, and why is it ſo called?

B. In the Map adjoined, you may obſerve a certain Space on the Earth's Surface, over the Middle of which paſſeth the Equator, and s included between two double Parallels, one towards the *North*, called the Tropic of *Cancer*, and the other *Southward*, called the Tropic of *Capricorn*; over all this Space, from the *North* to the *South*, you may obſerve the Line called the *Ecliptic*, or the Sun's Path, doth paſs; and conſequently doth at ſome Time of the Year or

* *Virgil* and *Ovid* have both given a very beautiful Deſcription of the *Zones*; of which the latter, in *Engliſh*, runs thus:

And as two equal Zones on either Side,
On left and right, the meaſur'd Heav'ns divide:
While the fifth rages with intenſer Heat;
So the ſame Lines the parted Globe compleat:
Exceſſive Heats poſſeſs the midmoſt Place,
A ſad, aduſt, inhabitable Space;
On two, eternal Hills of Snow are ſeen,
And two, indulgent Heav'n has plac'd between,
Whoſe Climes a due proportion'd Mixture hold,
Temper'd with equal Parts of *Heat* and *Cold*.

other



A NEW MAP of the WORLD accor- -ding to the latest Observations.
NORTH POLE
Arctick Circle
SOUTH POLE
Antarctick Circle
Tropick of Cancer
Tropick of Capricorn
Equinoctial Line
The Zodiack
THE GREAT SOUTH SEA
N. AMERICA
S. AMERICA
ATLANTICK OCEAN
North Sea
T. FIRMA
PERU
BRASIL
la Plata
CHILI
Florida
Virginia
California
New Britain
EUROPE
ASIA
AFRICA
PERSIA
CHINA
NEGROLAND
Guinea
ETHIOPIA
Nubia
Barbary
Biledulgerid
INDIAN SEA
SOUTHERN OCEAN
NEW HOLLAND
N. Zeeland
Bengal
Bowen Sculp.

other paſs twice over every Part thereof, and by its perpendicular Rays doth greatly heat and ſcorch it; and from its being thus *torrified* by the Sun's exceſſive Heat, it is called the *torrid Zone*.

A. Which do you call the *temperate Zones?*

B. Theſe are two Tracts lying next the *torrid Zone*, one on the *North*, the other on the *South*, each bounded by, or contained within, the Tropics and Polar Circles, as are plainly diſcerned in the Map; they are called temperate, becauſe the Sun never paſſeth over any Part of them, but ſhining obliquely on them, maketh them to have always a moderate Degree of Heat and Cold.

A. And where do you place the *frigid Zones?*

B. They are thoſe two Tracts of the Earth's Surface contained within the Polar Circles, *Northward* and *Southward*, as you ſee in the Map; over the Centre of each of theſe is the Pole; the Sun being at a great Diſtance from theſe, and abſent ſo long from ſeveral Parts thereof, together with the great Obliquity of his Rays when preſent, cauſeth prodigious Cold continually over all thoſe Parts; and they are therefore called the *frigid Zones*.

A. Pleaſe to let me underſtand the Reaſon of the different Degrees of Heat and Cold, in any one Place, throughout the Year.

B. This will be beater apprehended, if we firſt diſcourſe a little of the various Seaſons, and their Cauſes, in which the Differences of *Heat* and *Cold* are found; and firſt, if you pleaſe, we will enquire the Reaſon of the different Length of Days and Nights.

A. That

A. That will be very acceptable to me; for I must confess to my Shame, though I have lived so many thousand Days and Nights, I could never yet tell why one was longer or shorter than another; be pleased therefore to make the Matter evident, if possible, by a Scheme.

B. Yes, I will warrant it is possible. Cast your Eyes therefore on *Fig.* XXXI. on *Plate* XXI. fronting *Page* 234, and view well the Situation of the Globe; it is there in its proper Position for *London*, which you see in the *Zenith* at I, whose Horizon is the Line HO; all under which to us is dark, and all above it light.

A. Very good, so far I can follow you; pray go on.

B. Then next you must conceive the great Circle OPQ to be the Meridian of *London*, on which the Sun comes every Day at Noon, and every Night at Midnight, on some Part of it or other.

A. But, pray, why do you say on some Part or other?

B. Because the Sun is never precisely on the Meridian in the same Place two Days together; but every Day declines from, or approaches nearer to, the *Equinoctial Line* EQ, which surrounds the Earth in the Middle.

A. Pray how far does the Sun decline from the *Equinoctial* at most?

B. The Sun, from *March* 11 to *June* 11, declines from Æ to T, which is 23° 30′, or 1633½ *English* Miles on the Earth's Surface; then, from *June* 11 to *Sept.* 15, it returns again from T to the *Equinoctial* Æ, from which it passeth to V, where

where it is found about *December* 10; and thence returns again to Æ by *March* 10.

A. Then I ſee the Sun is neareſt *London* at T, at a mean Diſtance in Æ, and fartheſt of all from us at V.

B. Yes, it is ſo: Now obſerve the Sun in the Meridian at theſe three ſeveral Places, T, Æ, V; then, becauſe the Earth turns each Day once round its Axis PD, the Sun in each of thoſe Places will deſcribe a Circle; one of which, *viz.* the middle one, ÆQ, will be the *Equinoctial* itſelf; and the other two, TR and VW, will be parallel thereto on either Side, and are the Tropics of *Cancer* and *Capricorn*. Do you underſtand me, *Sir?*

A. Yes, pretty well; you mean, that the three Lines, TR, Æ, VW, repreſent the Path of the Sun from Noon in T, Æ, V, to Midnight in R, Q, W, on *June* 10, *March* 10, and *December* 10, do you not?

B. Yes, you take me very right; now it is obvious, when the Sun has paſſed half Way from Noon to Midnight, it will be found in the Line PD, (the ſame here as the Earth's Axis) in the Points G, Y, M, and that then it is Six o'Clock; alſo, when it touches the Horizon in XYZ, it there ſetteth from our Sight, and conſequently *terminateth* the *Day*, and *beginneth* the *Night*, on theſe Days.

A. Very well, *Sir*, I believe I ſee your Concluſions already.

B. Indeed, *Sir*, they are very evident: For, 1. Suppoſe the Sun in Æ the Equinoctial, then it is apparent, that it will on theſe Days, *viz.*

March 10, and *Sept.* 12, be in the Horizon Y precisely at Six o'Clock; and therefore his Path by Day ÆY, will be just equal to the same by Night YQ. 2. Suppose the Sun at T, as on *June* 10, then it is at Six o'Clock in G above the Horizon a great Way; but it descends the Horizon at X; and therefore the daily Arch TX is longer than the Arch by Night XR, by the Difference GX. 3. Suppose the Sun in V, then the diurnal Arch VZ is just as long as the nocturnal Arch XR before, and the nocturnal Arch ZW is here the same Length with the diurnal Arch TX, in the foregoing Case. Do you understand me hitherto ?

A. Yes, I believe I do: As the Sun declineth from Æ to T, and back again, the Length of Days exceeds the Length of Nights, in as much as it must pass some Distance beyond the Six o'Clock Line GY, before it can come to the Horizon; and on the contrary, while it is between Æ and V, it meets with the Horizon before it comes on the Six o'Clock YM, and therefore the Days are shorter than the Nights, by just so much as the Nights are shorter than the Days in the other Case: This is what you mean, is it not ?

B. Yes, the very same: I have only this to observe, that the farther you go *Northward*, the greater is the Difference or Inequality of Days and Nights; and the contrary.

A. That I also perceive plainly from the Figure; for the nearer HO inclines to ÆQ, the greater will be TX, and the lesser VZ, or the greater will be GX, or MZ, the Difference of

Day

Day and Night: But, pray, what means that obſcure Part of the Night, comprehended between HOAB, which is neither dark nor light?

B. It is the *Crepuſculum*, or what we call the *Twilight*, the Line AB being 18 Degrees below the Horizon HO, and during the Time the Sun paſſeth from HO, to AB, in the Parallel of any Day, his Rays, are partly refracted by the *Atmoſphere*; and ſo we have ſome faint Light 'till he gets below the Limit AB, when we are left in total Darkneſs.

A. I underſtand you mean, it is *Twilight* while the Sun paſſeth from X to R, from Y to S, and from Z to M, on the Day the Sun deſcribes the Parallels TR, ÆQ, and VW; do you not?

B. Yes, I do; and hence, at *London*, you may obſerve that when the Sun is in T, that is, in the Tropic of *Cancer*, there is no dark Night at all; for the Parallel of that Day TR doth not touch AB, nor will it for about a Month before and after; that is, from *May* 11, to *July* 10, there is no dark Night.

A. Pray, when doth the ſhorteſt *Twilight* happen in all the Year?

B. On *October* 1, and *February* 19; for then the Sun deſcribes the Parallel, whoſe diſtance *eo* is the leaſt, between HO, and AB, of any other whatſoever *.

A. Well, *Sir*, I thank you for your Labours to rectify my Notions of *Day*, *Night*, *Twilight*, &c. of which, tho' they are common Things,

* See the Method of inveſtigating the ſhorteſt *Twilight* in Dr. *Keill's Aſtronom.* Lect. XX. Page 239.

yet, I never had a good Notion before now: Nor do I yet well conceive the Reaſon and Manner of the various *Changes and Viciſſitudes of the Seaſons* which happen through the Year; and, if you could repreſent this to me in a Figure, I ſhould be greatly obliged to you.

B. I have contrived a Scheme for that very Purpoſe (*Fig*. XXX. on *Plate* XIX, fronting *p*. 228.) which pleaſe only to view very carefully, and you will ſee therein a natural Repreſentation of a *whole Year*.

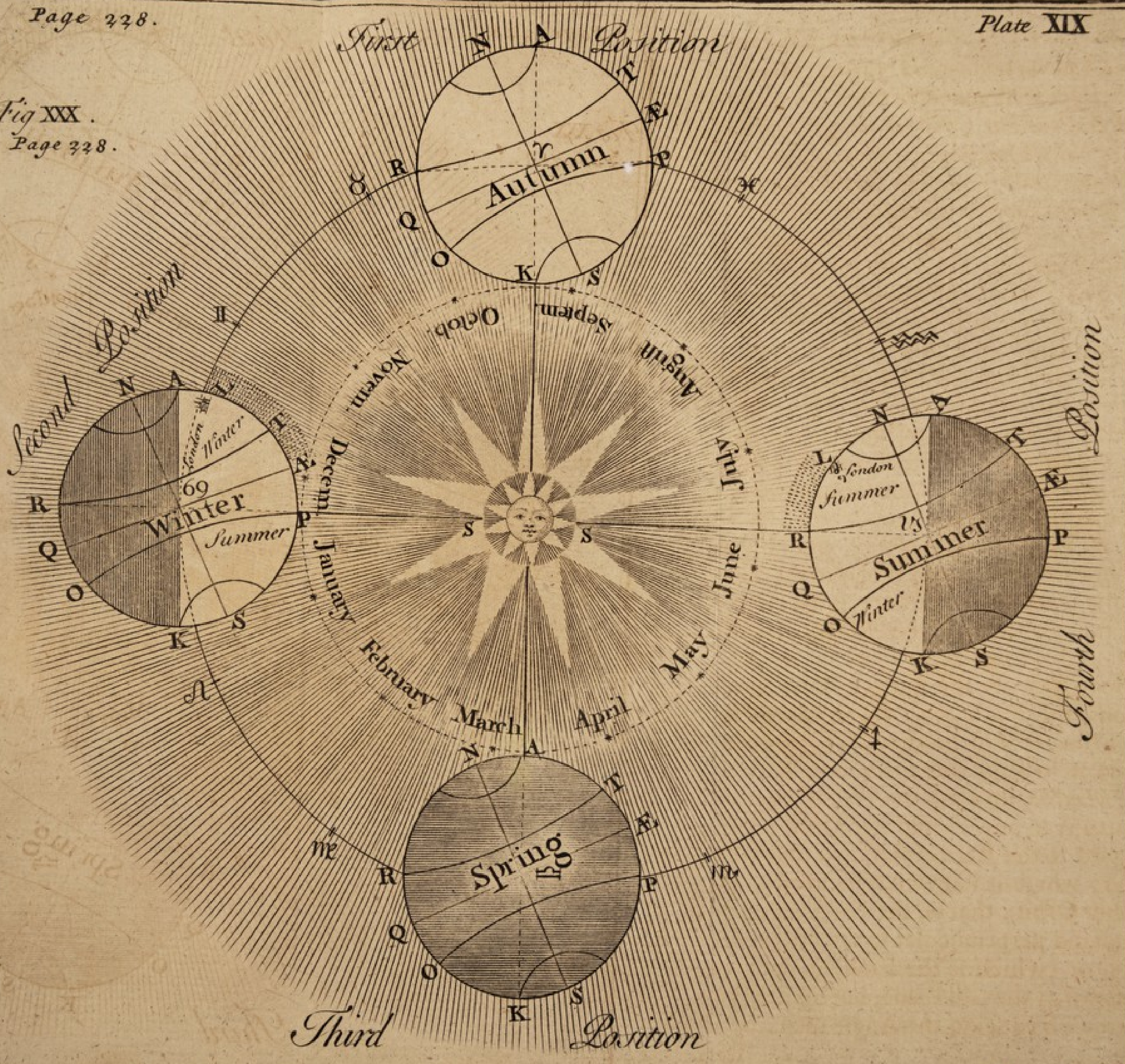
A. *Sir*, I obſerve it with all Diligence, and ſee ſeveral Things therein very remarkable: But yet, I beg you would pleaſe to point them out in the natural Order, in which they ſhould be conſidered, that I may the better apprehend the Deſign of the whole.

B. That I will; and *firſt*, you obſerve in the Center of the Scheme is placed the Sun S; about which, at a great Diſtance, is the circular Orbit of the Earth, called the *Zodiac*, divided into its 12 Signs, *viz*. ♈, ♉, ♊, ♋, ♌, ♍, ♎, *&c*. in which you ſee the Earth in four ſeveral Poſitions; the *firſt* in *Aries* ♈; the *ſecond* in *Cancer* ♋; the *third* in *Libra* ♎; the *fourth* in *Capricon*; ♑ within this there is a dotted Circle of *Months*, ſhewing the *Time of Year* when the Earth is in any Part of her Orbit: Now with regard to the Earth itſelf, you ſee its Poſition every where is ſomewhat inclined to the Plane of her Orbit; that is, the Earth's *Axis* NS doth not ſtand perpendicular to the *Plane of her Motion*, or (which is the ſame) is not parallel to the *Axis* of the ſaid Plane, but maketh an Angle therewith equal to the Angle made by the In-

Page 228.

Plate XIX

Fig XXX.
Page 228.



Bowen Sculp.

terſection of NS with AK; for this AK you ſee is always a Diameter of that Circle which boundeth Light and Darkneſs on the Earth's Surface, and is every where perpendicular to the Plane of the Earth's Motion, or parallel to the Axis of that Plane. Now the Earth's Axis, thus inclined, is every where parallel to itſelf; that is, the Angles N♈A in the *firſt*, and N♋A in the *ſecond*, N♎A in the *third*, and N♑A in the *fourth* Poſition of the Earth, are all equal to each other, and ſo are equal in every other Poſition through its Orb. The Quantity of this Inclination or Obliquity of the Earth's Poſition is 66 Degrees 30 Minutes, equal to the Angle N♈R, *&c.* Now it is evident, that, by Means of this parallel Inclination of the Earth, the *North* and *South* Parts of the Earth, or its Poles N and S, will be ſometimes nearer the Sun, ſometimes farther off, and ſometimes each Pole will be equally diſtant from the Sun; and from hence we ſhall ſee the Reaſon of, and how the Seaſons are all produced. For, 1. In the *firſt* Poſition of the Earth in *Aries* ♈, about the 12th of *September*, and in the *third* Poſition in *Libra*, in *March* the 10th, it is evident the Sun doth there enlighten the Earth from Pole to Pole, or the Circle bounding Light and Shadow doth then paſs through the Poles, and conſequently at equal Diſtances from the Equator ÆQ (in which the Sun then appears) the Sun's Heat will be equal on both Sides; and thus an *Equality of Days and Nights*, joined with a mean Proportion of Heat, conſtitute thoſe *two Sea-*

ſons of the Year, we call *Spring* and *Autumn*. 2. Again, in the *fourth* Poſition of the Earth in ♑, about the 10th of *June*, when the Sun will appear in the oppoſite Sign *Cancer* ♋, it is plain the *North* Pole N, and all the Parts about it to the Diſtance of A, will be ſituated nearer towards the Sun than before; and all the *South* parts removed farther from the perpendicular Rays thereof. The perpendicular Rays of the Sun here fall on R, which is diſtant from the Equator Q *Northward* 23° 30′; and therefore all Places in *North* Latitude, receiving the Sun's Rays nearer their *Vertex*, or *Zenith*, will find a greater Degree of Heat, and a longer Continuance of his Light by Day, and therefore have now their *Summer*, as at *London*, while all the Inhabitants of *Southern* Latitude have their *Winter*. 3. Laſtly, in the *ſecond* Poſition of the Earth in ♋, the Sun will ſeem in *Capricorn* ♑: It is manifeſt the *North* Parts will here be in Darkneſs, and have their *Winter*, as they in *South* Latitude had theirs, in the laſt Poſition; that is, by being removed farther from the Perpendicularity of the Sun's Rays; and under the Obliquity of the Sun's Rays the Heat is diminiſhed, and alſo the Duration of his Light by Day; which together muſt cauſe *Winter* in all the *Northern* Latitudes. I hope you have underſtood me through this long Harangue?

A. Indifferently I have; and can eaſily ſee from this Scheme the Reaſon why we muſt have thoſe Viciſſitudes of Seaſons, as you have explained it: But I really thought *Summer* had

been

been occasioned by the Sun's being very near us, and the *Winter* by his going farther from us, till I saw you assign other Reasons for it.

B. Aye, that is the general Mistake of common People, they think the Sun is really nearer in *Summer*, and farther off in *Winter*; when the truth is just the contrary, for the Sun is much nearer in the *Winter* to our Earth than it is in the *Summer*.

A. This is a *strange Paradox*, indeed; pray how do you make it out?

B. Nothing is more easily proved; for look once more on the Scheme, and heed it well, and you will see the Earth's Orb is not a *Circle*, but an *Oval*, whose longer Diameter is ♋ S ♑, in which the Sun is; but much nearer ♋, in which the Earth is at *Winter*, than ♑, its Place in *Summer*.

A. I understand you very well, *Sir*; you mean, the Distance SP is less than the Distance SR; which I did not before observe indeed, though I might, for it is obvious enough.

B. It is right, I see you apprehend me well; and therefore you will also understand, that the *Summer* half Year is somewhat longer than the *Winter* half Year; that is, the Part of the Earth's Orb ♎ ♑ ♈ is greater than the other Part ♋ ♎ ♈, and therefore more Time will be requisite to pass the *Summer* half Year than the *Winter*, by about eight Days; and hence, also, the Sun will seem to move somewhat slower in the *Summer* than in *Winter**.

* For a much larger and clearer Illustration and Representation of these Matters, see my large Print, entitled, SYNOPSIS SCIENTIÆ COELESTIS; or, *The Knowledge of the HEAVENS and the EARTH displayed.*

A. All theſe Things evidently follow indeed, *Sir*, from the Conſideration of the Earth's Orbit being an *Ellipſis* : But I am not fully ſatisfied about the Sun's Heat being ſo weak and faint in the *Winter*, when the Sun is really neareſt to us; and ſo very ſtrong and intenſe, when the Sun is really farther by much from us.

B. You will ſoon ſee the Reaſon of that when you conſider, 1. That it is not the Rays which fall on us, but thoſe which are reflected back from the Earth's Surface, that chiefly heat us. 2. That thoſe which fall on us moſt directly, or neareſt to the Perpendicular, are the moſt in Quantity, and act on us with the greateſt Force; Thus, in *Fig*. XXXII. on *Plate* XXI, fronting *Page* 234, the Rays of the Sun, on the longeſt Day of *Summer*, fall on *London*, under the Angle TLO, in *Spring*, or *Autumn*, under the Angle ÆLO, and in the Midſt of *Winter*, under the Angle VLO, and the Quantity of thoſe Angles are reſpectively 65°, 38° 30′, 15°; wherefore the Force of the Sun's Rays, in each of thoſe Caſes, ſhall be proportioned to the Sines of thoſe Angles, which are, as 88294, 62251, and 25881; that is, 10, 7 $\frac{5}{10}$, 3, nearly, for thoſe Numbers are in Proportion to the Sines TA, ÆB, and VC, of the aforeſaid Angles : The Quantity of the Rays alſo falling on the ſame Extent of Surface is greater or ſmaller, as their Obliquity is leſſer or greater, and ſo the Intenſity of Heat is greater and ſmaller ; and therefore the Sun's Heat in *Winter* muſt be weakeſt, becauſe then the Sun's Rays fall moſt obliquely on us. Beſides, 3. That Rays of the Sun paſs through a much greater Part of the

At-

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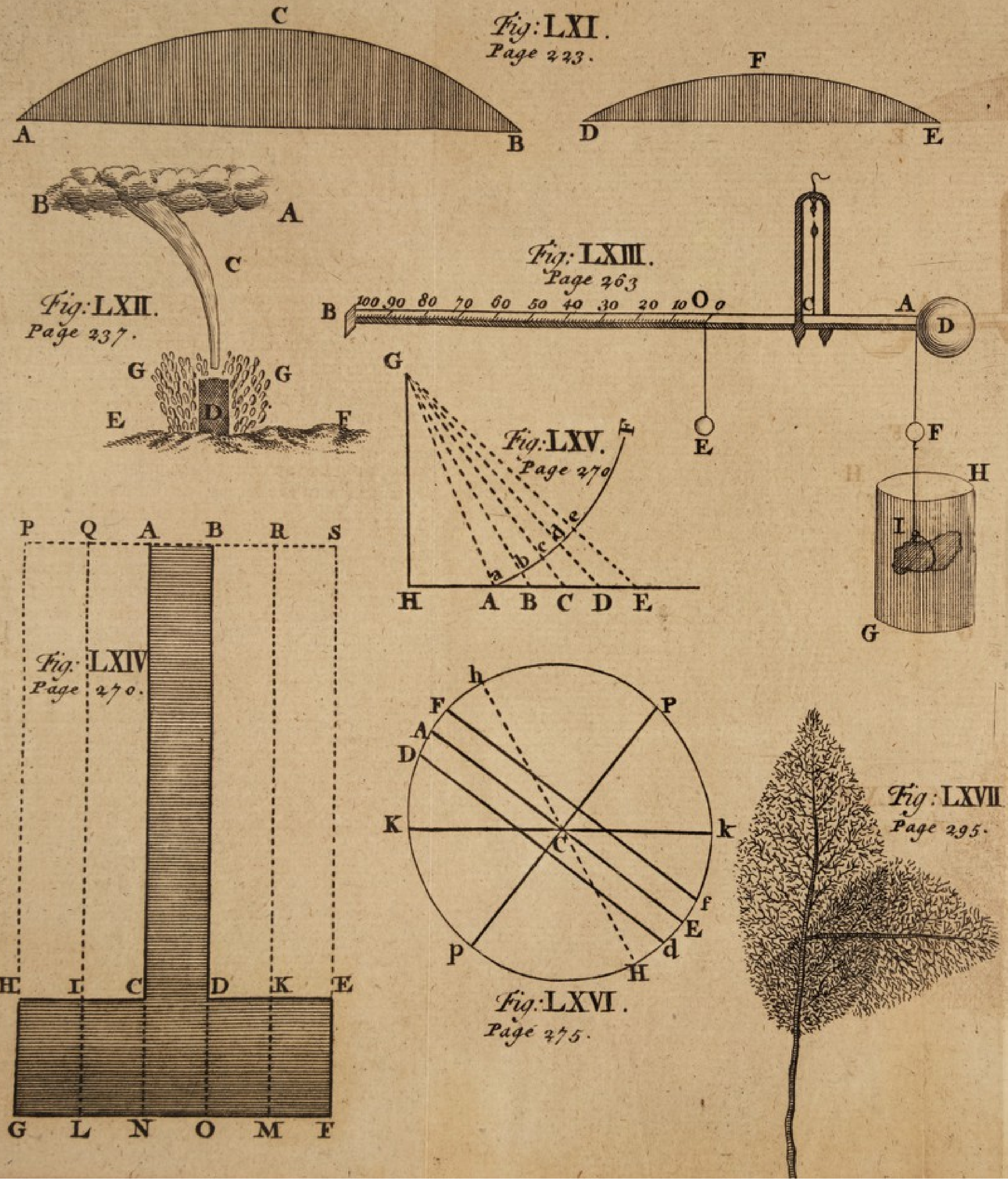
Plate XX.



Atmoſphere in the *Winter* than in *Summer* (as is evident from viewing the ſame in the ſecond and fourth Poſition of the Earth in the *Scheme*) and therefore muſt be, when arrived to us at L, more weak and faint, in the firſt, than in the latter Caſe *. *A. Sir*

* 1. The Numbers above, *viz.* 10, $7\frac{1}{2}$, 3, ſhew the comparative Intenſity of Heat of the Sun's Rays, under the ſeveral Altitudes TO, ÆO, and VO, ſimply, or in themſelves conſidered; but if we would know what *Proportion all the Heat of one whole Day bears to all the Heat of any other*, it is a Problem of another ſort.

2. This Proportion is expreſſed by the Areas of two Figures ABC and DEF (in *Fig.* LXI. on *Plate* XX, fronting *p.* 233.) the Baſes of which, AB and DE, are the Times of the Sun's Continuance above the Horizon; and the Perpendiculars erected thereon, and connected by the Curves ACB and DFE, are the Times of his ſeveral Altitudes for the given Days; that is, the Heat of one Day is to the Heat of the other, as the Sum of all the Sines of the Sun's Altitude on the firſt Day, is to the Sum of all the Sun's Altitudes on the other.

3. But to expreſs this more readily for any Day, the incomparable Dr. *Halley* has invented a general Rule or Canon, which he has given with its Demonſtration in *Philoſoph. Tranſ.* N° 203, which, as being very curious and important, I ſhall here explain and exemplify.

4. The Rule is: Multiply the Sum of the Sines of the Meridian Altitudes in any two oppoſite Parallels into the Sine of the Semidiurnal Arch; alſo multiply their Difference into the ſame Sine; the Sum of theſe two Products for the Summer, or their Difference for the Winter, is as the Sum of all the Sines of the Sun's Altitude, or as the Heat of the Day propoſed.

5. For Example: Let the Proportion of Heat be ſought for the 10th of *June* and *December*, when the ſun is in the Tropics of *Cancer* and *Capricorn*, for the Lat of 51° 32′. Then,

		Nat. Sines.
The Sun in *Cancer*, Mer. Altitude is	TO=61° 58′=	,882674
The Sun in *Capricorn*, Mer. Altitude	VO=14° 58′=	,258257
The Sum of theſe Sines is	— —	1,140931
Their Difference is	— —	0,624417
The Mot. from 12 to 6 is	90° 0′=TG;	
The Aſcen. Diff. is then	33° 11′=GX;	
The Sum is the Semidiur. Arch for the Summer Day	123° 11′=TX	Sine 0,836923.
The Diff. is the Semidi. Arch for the Winter Day	56° 49′=VZ	

Again,

A. *Sir*, you need ſay no more ; I am ſufficiently convinced there is abundant Reaſon for the

Again, the Radius being — — 1,000000
The Circumference of the Circle will be =6,283185
And the Meaſure of the Summer Arch 123° 11′ =2,149955
And the Meaſure of the Winter Arch 56° 49′ =0,991683

6. Having thus prepared the Numbers, then, according to the Rule the Product of 1,140931 by 0,836923 added to the Product of 0,624417 by 2,149955, is equal to 2,29734, which expreſſes the Heat of the Summer's Day. In like manner, 1,140931 by 0,836923 ſubtracted from 0,624417 by 0,991683, leaves 0,33895 for the Heat of the Winter's Day. But theſe two Numbers 2,29734 and 0,33895 are to each other very nearly in the Ratio of 7 to 1, which ſhews that the Quantity of Heat on *June* the 10th is ſeven Times greater than that on *December* the 10th, all other Circumſtances being alike.

7. According to this Rule Dr. *Keill* has computed the Heat of the Sun for every five Degrees of its Declination *North* and *South*, at the Latitude of 51° 0′ as in the Table here adjoined.

Sun's Declination.	North	South.
0	1.25824	1.25864
5	1.47393	1.04839
10	1.69293	0.84508
15	1.91489	0.65091
20	2 11919	3.46916
23½	2.29910	0.37980

8. Dr. *Halley* did alſo from this Rule calculate the annexed Table, ſhewing the Degree or Quantity of Heat at every ten Degrees of Latitude for the *Equinoctial* and *Tropical Sun* both Summer and Winter from whence alſo an Eſtimate may be made for the intermediate Degrees.

Lat.	Sun in ♈ ♎	Sun in ♋	Sun in ♑
0	20000	18341	18341
10	19696	20290	15834
20	18794	21737	13166
30	17321	22651	10124
40	15221	23048	6944
50	12855	22991	3798
60	10000	22773	1075
70	6840	23543	000
80	3473	24673	000
90	0000	25055	000

9. From theſe two Tables Dr. *Keill* has well obſerved the Advantages ariſing from the preſent *oblique Courſe* of the Sun in the Ecliptic, above what could have been enjoyed had the Earth had a *right Poſition*, or the *Sun moved continually in the Equinoctial Line*, as Dr. *Burnet*, and ſome other *Theoriſts*, pretend it did.

10. For

To front Page 234.

Plate XXI

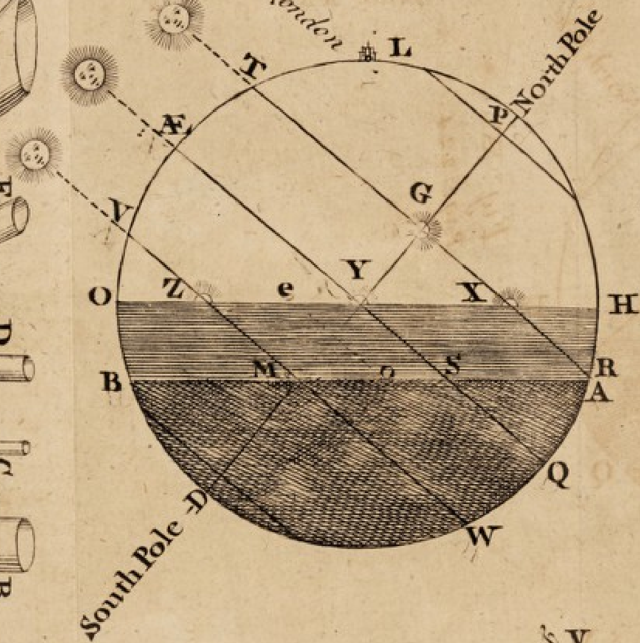


Fig: XXXI. Page 224.

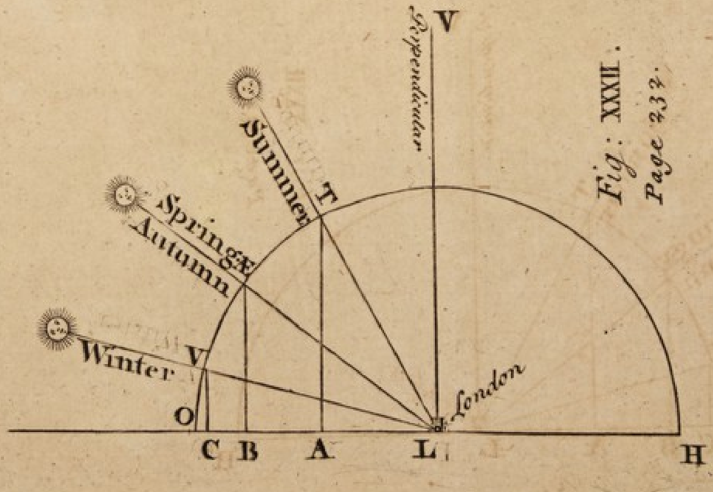


Fig: XXXII. Page 232.

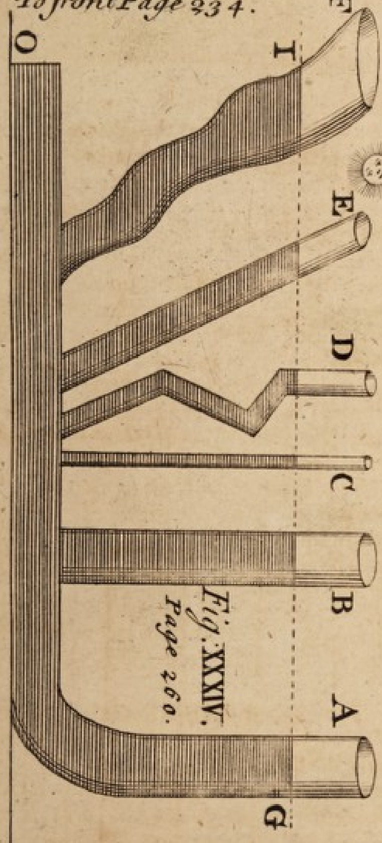


Fig: XXXIV. Page 260.

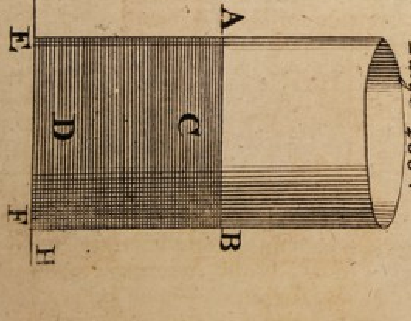


Fig: XXXIII. Page 260.

the Differences of Light and Heat, and all the Variety of Seaſons through the Year, though I never was ſo happy as to underſtand it before: We will now proceed to diſcourſe of the internal Subſtance of the *Globe*, if you pleaſe; for I have ſeveral Matters of great Importance to enquire of you about, relating to its *Conſtitution*, *Texture*, and various *conſtituent Parts*.

B. Sir, none will more gladly take the Pleaſure to reſolve you, according to the Judgments of the beſt Philoſophers of the Age, than your humble Servant: Pray therefore make a Beginning.

10. For from the firſt Table it is evident, the *Sum* or *total Heat*, which the Earth receives in Lat. 51° N. while the Sun deſcribes any two oppoſite Parallels, is greater than the Heat of two Equinoctial Days there; for Example, the Heat of the Sun in the 20th Degree of North Declination is 2,13919, and in the 20th Degree of South Declination, it is 0,46916, the Sum of both theſe, is 2,60835, which is greater than 2,51728, the double of the Heat of an Equinoctial Day 1,25864. And, by the ſecond Table, it appears all Latitudes beyond 45 Degrees enjoy this Benefit, and they alone need it.

11. Again, the ſame Gentleman proves that the *Torrid Zone*, and to near 46 Degrees in the Temperate Zones, the Heat of the Sun is *leſs* in the preſent Caſe than it would have been in the other. Thus the Sun's Heat deſcribing both the *Tropicks*, to thoſe under the *Equator*, is twice the Number 18341, *viz.* 36682: but the Heat of two Equinoctial Days is 40000, which is a great deal more than the other, and therefore the preſent Poſition of the Earth is moſt convenient for them, and conſequently for all the people of the Earth, and proves it to be that which it firſt received from the Hands of its *All-wiſe Former*. See Dr. *Keill's* Exam. of Dr. *Burnet's Theory of the Earth*, p. 70 to 76.

CHAP.

CHAP. II.

GEOGRAPHY, *or the* PHILOSOPHY *of the* CONSTITUTION, TEXTURE, *and conſtituent* PARTS *of the* EARTH, *deſcribing the various* STRATA's *of* EARTHS, FOSSILS, MINERALS, METALS, STONES, *and other ſubterraneous* SUBSTANCES.

A. PRAY, what is the internal Make and Conſtitution of the Globe of our *Earth?*

B. The *Earth*, generally ſpeaking, is conſtituted of the two Subſtances of *Earth* and *Water*; the *Water*, as the lighter Part, poſſeſſing the greateſt Part of its Superficies; and the *Earth* being the heavier Body, making up the internal Compoſition; about which it is, I preſume, you here ſolely enquire *.

A. Yes, what I would know is, of what the internal ſolid Body of the *Earth* doth conſiſt?

B. To this I can only anſwer, that ſo far as it is within our Scrutiny near the Superficies, we find it to conſiſt of different *Strata*, or *Layers* of *Earths, Minerals, Metals, Ores, Stones*, and various other compound Bodies both hard and ſoft: But what the more internal Parts or Compoſition of it may be, we can tell but very little: However, the deeper you go, the ſolider and more compact you find its Matter to be, and the more firmly and ſtrongly does it cohere together; yet it is very certain, that within the Entrails of the *Earth* are many Caverns, Receſſes, Windings, Conveyances, and vaſt Re-

* See a noble Deſcription of the firſt Formation of the Earth and the Heavens from their *Chaotic* State, in *Ovid*'s Princip. Metamorph. Lib. I. and *Milton*'s Paradiſe Loſt. Book III. ver. 709; and Book VII. ver. 216, to the End.

ceptacles of Water, *ſulphureous Subſtances*, &c. which are often the Cauſe of *Earthquakes*, and ſupply *Vulcanoes* with their fiery Eruptions, as *Mount Ætna*, &c *.

A. What do you ſuppoſe to be in the very Middle of the *Earth*; that is, in and about its *Center*?

B. No body can certainly tell; the *Earth*'s Center is near 400 Miles from us, and we can penetrate towards it but a few Fathoms; how very unlikely then is it, we ſhould know any Thing at ſuch a vaſt and impervious Diſtance?

* Sir *Iſaac*, mentioning ſeveral Experiments made with combuſtible and exploſive Subſtances, ſays;—" By theſe Experi-" ments compared with the great Quantity of *Sulphur* with " which the Earth abounds, and the Warmth of the interior " Parts of the Earth, and *hot Springs*, and *burning Mountains*, " and with *Damps*, *mineral Coruſcations*, *Earthquakes*, *hot ſuffo-" cating Exhalations*, *Hurricanes*, and *Spouts*, we may learn, " that *ſulphureous Streams* abound in the Bowels of the Earth, " and ferment with Minerals, and ſometimes take Fire with a " ſudden *Coruſcation* and *Exploſion*, and if pent up in ſubterra-" neous Caverns, burſt the Caverns with a great Shaking of " the Earth, as in ſpringing of a Mine. And then the Vapour " generated by Exploſion, expiring through the Pores of the " Earth, feels *hot* and *ſuffocates*, and makes *Tempeſts* and *Hur-" ricanes*, and ſometimes cauſes the Land to *ſlide*, or the Sea to " *boil*, and carries up the Water thereof in Drops, which by " their Weight fall down again in *Spouts*. Alſo ſome *ſul-" phureous Streams*, at all Times when the Earth is dry, " aſcending into the Air, ferment there with *nitrous Acids*, and, " ſometimes taking *Fire*, cauſe *Lightning* and *Thunder*, and " other *fiery Meteors*." Optics, Book III. Query 31.

See ſeveral ſurprizing Accounts of *Water-Spouts* in the *Mediterranean*, in *Philoſ. Tranſ.* N° 277. Two in *Yorkſhire*, N° 281, 284. One in *Lancaſhire*, N° 363. Another in the *Downs*, N° 270. That the Reader might have ſome Idea of theſe Spouts, I have here given the Figure of one, *Fig.* LXII. on *Plate* XX, fronting *p.* 233, where AB is the Cloud whence proceeds the curved black Spout C; D is the Water of the Sea, which at the Spouting of the Cloud boils up, and riſes in the Form of a ſolid Pillar to meet the Spout; GG is the Water of the Pillar, or Column D, ſcattered round about the ſame like Smoke or the Falling of a *Jette d'Eau*; EF is the Surface of the Sea.

Diſtance? However, the learned Dr. *Halley* has made it very probable, that a great *magnetic Body*, or *Load-Stone*, doth poſſeſs the central Parts of the *Earth*; which occaſioneth the *Variations* and *Declinations of our magnetic Needles*, which always conform themſelves to the Site and Direction of this *central Magnet*, or *Load-Stone*; which is ſuppoſed to deviate from the *North* and *South* Points, and from the horizontal Poſition, with reſpect to us *.

A. If that be ſo, it is very wonderful, and a noble Diſcovery: But, pray, what is it binds the ſeveral Parts of the *Earth*, or makes them cohere ſo cloſely together?

B. The Coherence of the *Earth* is entirely owing to the Power of Gravity, or the Weight of its conſtituent Parts; whence, as I before ſaid, it is reaſonable to believe the moſt weighty and ſolid Bodies lie neareſt the Centre of the *Earth*, as being the Centre of Gravity itſelf.

A. Well then, ſince the more interior Parts of the Earth are ſo little known, we leave them, and content ourſelves with what is to be known near the Superficies of it on which we live; and, pray, what do you firſt obſerve thereof?

B. That it does conſiſt of Bodies of a heterogeneous or different Nature intermixed with one another of different ſpecific Gravities, diſpoſed in Manner of *Beds*, which are called *Strata* or *Layers* of *Earth, Stones, Minerals*, &c. one under another.

* See a large Diſſertation on this Subject, and the whole Theory of the *Magnetical Variations* of the *Needle*, by the ſaid learned Dr. *Halley*, in *Philoſ. Tranſ.* N° 148 and 195, or the ſame tranſcribed into *Harris's Lexicon*, under the Word *Variation.*

A. Pray

A. Pray in what Order do these *Strata*, or Beds of *Earth*, &c. lie among themselves?

B. That they do not lie in Order of their specific Gravities, is evident (and so not every where alike) from the order of those observed in digging a Well at *Amsterdam* 232 Feet deep; which was thus; seven Feet of Garden Mould; nine of Turf, or Peat; nine of soft Clay; eight of Sand; four of Earth; ten of Clay; four of Earth; ten of paving Sand; two of Clay; four of white Lome; five of dry Earth; one of muddy Earth; fourteen of Sand; three of a Sandy Clay; five of Sand mixed with Clay; four of Sea-Sand mixed with Shells; then 102 of Clay together; and, lastly, thirty-one of Lome: Thus you see the different Make of the outward Parts of the *Earth*, which is very different in different Places.

A. Pray how came the Disposition of those various *Strata*, or Beds of *Earth* and *Minerals*?

B. This is not known as to the Time; some say at the Creation, others at the Flood; others supposed, that in the *chaotic* State of the *Earth* the heavier Bodies subsided, and lay in this Order by the Laws of Gravitation; but Experience rather contradicts than confirms this *Hypothesis*.

A. What Distinction, or Division, do you make of earthy Substances or Bodies?

B. They may be reduced to those general Heads: 1. *Earths*. 2. *Ores*. 3, *Fossils*. 4. *Mi-*

* See *Varren*. Geog. Gener. Lib. I, Cap. 7, Prop. 7. Also read Dr. *Woodward*'s Natural Theory of the Earth; and Dr. *Arbuthnot*'s Examination thereof, and his Comparison of Dr. *Woodward*'s and *Steno*'s Hypotheses, which is well worth the Reader's perusing.

nerals.

nerals. 5. *Metals.* 6. *Stones.* 7. *Extraneous Bodies* or *Subſtances.*

A. What do you include under the firſt general Head of *Earths?*

B. All thoſe ſofter earthy Subſtances we call *Clay, Lome, Marl, Sand,* and different Species of *Earths,* as *Terra-Japonica, Lemnia, Armenia,* &c.

A. Pray what do you think to be the Cauſe of thoſe Differences of earthy Subſtances now mentioned?

B. The Reaſon why they are differently hard, ſoft, coloured, qualified, *&c.* ariſeth from different Degrees of the univerſal and ſpecific Properties of the original conſtituent Particles of Matter, which each different Species poſſeſſeth in a different Meaſure; and this is the moſt that can be known of this Matter.

A. What do you include under the ſecond Head of *Ores?*

B. Thoſe *Earths* which contain conſiderable Quantities of metallic Particles; being that which is dug out of Mines, and whence Metals are extracted, and is denominated accordingly, as *Gold-Ore, Silver-Ore,* &c.

A. How came the *Earth* to be enriched with the Seeds of thoſe metallic Subſtances?

B. No doubt by the all-wiſe Creator, for the manifold Uſes of Mankind.

A. What terreſtrial Bodies do you intend by *Foſſils?*

B. Though *Foſſils* be a general Name for every Thing which is dug out of the *Earth*; yet I here intend thereby, 1. *Salts,* 2. *Sulphurs,* and

and ſuch like Bodies, which cannot be ſo well reduced to the Heads of *Minerals*, *Metals*, and *Stones* *.

A. What is the Nature of *Salt*, and the Kinds of it?

B. *Salt* (ſaith Monſ. *Lemery*) is a fixed incombuſtible Subſtance, that gives Bodies their Conſiſtence, preſerves them from Corruption, and renders Bodies ſavoury more or leſs as it is diverſly mixed in them; there are various Kinds of *Salts*, as fixed, volatile, eſſential, and foſſile; and ſaline Subſtances, as *Allum*, *Borax*, *Nitre*, *Tartar*, *Vitriol*, and *Sal Ammoniac* †.

A. Pray give me ſome ſhort Account of the Nature of theſe ſeveral Kinds of *Salts*.

B. I will, but it muſt be very brief, for want of Time.

* The great *Boerhaave* diſtributes Foſſils into two Kinds, *Simple* and *Compound*.

Simple Foſſils are ſuch whoſe parts, howſoever divided, are all of the ſame *Nature*; that is, of the ſame Gravity, Magnitude, Figure, Hardneſs, and Mobility; of theſe he reckons four Sorts, *viz.* *Metals*, *Salts*, *Stones*, and *Earths*.

Compound Foſſils are thoſe which may be divided into different or diſſimilar Parts, or are of different *Figure*, *Weight*, *Magnitude*, &c. and theſe are, (1.) All *hard Sulphurs*, as *Brimſtone*, *Arſenic*, *Orpiment*, *Bitumen*, *Aſphaltum*, &c. (2.) All *liquid Sulphurs*, as *Diſaſphaltum*, or *Jew's Pitch*, *Naptha*, *Petroleum*, &c. (3.) *Semimetals*, or *Minerals*. (4.) Bodies combined out of the preceding *Foſſils*, either ſimple or compound. *New Method of Chymiſtry*, Page 54.

† Dr. *Boerhaave's* Definition of Salt is this: *Salt is a foſſile Body, fuſible by Fire, and congealable again, in the Cold, into brittle Glebes or Cryſtals; ſoluble withal in Water, ſo as to diſappear therein; never malleable; and having ſomewhat in it which to the Organ of Taſte affords a Senſation of Acrimony or Sharpneſs.* Theor. of Chymiſtry, Page 105.

Alſo in Page 113, he ſaith, the Elements or common Principles of Salt are an *acid Spirit*, and an *inſipid Earth*, into which all are reſoluble but the ſimple Foſſils, as *Salt-Petre* and *Borax*.

1. *Fossile Salt*, is that which is called *Salt Gem*, by reason of its Transparency, and is altogether like the *Salt* we use with Food; it is dug out of the Mountains in many Places, as *Russia*, *Poland*, *Catalonia*, *Persia*, and in the *Indies*.

2. *Fixed Salt*, is that which remains after Calcination, and doth not rise, or is not rarefied and exhaled by Heat.

3. *Volatile Salt*, is that which easily riseth, and flieth off in insensible Steam and Vapour; such are the *Salts* of Animals.

4. *Essential Salt*, is that which is obtained from Plants by Crystallization; and is a natural *Salt* between *fixed* and *volatile*.

5. *Alum*, or *Roch Alum*, is a very binding *Salt*, found in the Veins of the Earth in many Places of *Europe*; being taken thereout in large transparent Pieces.

6. *Borax*, a green-coloured mineral *Salt*, found in the Veins of *Brass*, *Silver*, or *Gold Ore*.

7. *Nitre*, or *Salt-Petre*, is a *Salt* impregnated with abundance of Spirits out of the Air, which renders it *volatile*; it is found among the Stones and Earths of old Buildings; and is sometimes generated from Urine falling on Stones, &c. It is the Spirit of this Salt that kindles the Sulphur into a Flame in *Gunpowder*, *Lightning*, &c.

8. *Tartar*, is a terrestrious *Matter*, or earthly *Salt*, which sticketh to the Sides of Vessels, being separated from the Liquor by Means of its Fermentation; as that in *Wine Casks*, &c.

9. *Vitriol*,

9. *Vitriol*, is a *Fossil*, compounded of an *acid Salt*, and *sulphureous Earth*; there are four Sorts of it: 1. *Blue*, found in the Mines of Copper in *Hungary*, and *Isle of Cyprus*. 2. *Green*, found in *Germany*, *Italy*, and *England*. 3. *White*; and 4. *Red Vitriol*. This last was brought to us lately out of *Germany*, and is called *natural Colcothar*, or *Chalcitis*.

10. *Sal Ammoniac*, is either natural or artificial; the Natural is found in many Parts of *Africa*, and very hot Places under the torrid *Zone*; the Artificial is made at *Venice*, and divers other Places.

A. Please, in the next Place, to tell me what *Sulphur* is, and the Bodies you call *sulphureous*.

B. *Sulphur* is an inflammable *Fossil*, found in many Places in *Europe*, especially in *Sicily*; is of two Sorts: 1. The *Greyish*, called *Quick-Sulphur*; it is a Sort of Clay, apt to crumble, soft, and ready to take Fire; it consists of an *Oil*, an *acid Salt*, and *Earth*. 2. *Yellow*, or common *Sulphur*, called *Brimstone*; this containeth much *Oil*, an *acid vitriolic Salt*, and but little *Earth*.

A. Pray, *Sir*, what do the *Chymists* mean by that Principle they call *Sulphur*; not *Brimstone* sure, do they?

B. No, no; they mean an *Oil*, which is called *Sulphur*, by Reason of its Inflammability, and is a sweet, subtile, unctuous Substance, which is said to cause the Diversity of Colours and Smells, and to give Beauty or Deformity to Plants, &c. according to its Disposition in Bodies.

A. What Bodies do you reckon amongst the sulphureous Kind?

B. Theſe following: *Arſenic*, *Bitumen*, and its various Kinds, as *Ambergreaſe*, *Aſphaltos*, *Naptha*, *Amber*; alſo *Petroleum* is reckoned of this Claſs.

A. Pray rehearſe me alſo a ſhort Account of the Nature of theſe Bodies.

B. I deſign it; which take as follows:

1. *Arſenic*, is a foſſile Subſtance, conſiſting of much *Sulphur*, and ſome *cauſtic Salts*; it is of three Sorts, the white, or proper *Arſenic*; the yellow, called *Auripigmentum*; and the red, called *Sandaracha*.

2. *Bitumen*, is a Kind of Pitch, or ſlimy Clay; it is very much of the Nature of *Sulphur*, being very inflammable: It is of two Sorts, one liquid, which ſwimmeth like Oil on Water; the other more hard and compact, is dug out of the Earth.

3. *Ambergreaſe*, is a Kind of *Bitumen*, found in many Places on the Sea-ſhore; it grows hard in the Sun-Beams; the beſt Sort is gray when dry, eaſily ſoftens in the Heat, and appears blackiſh when wet.

4. *Aſphaltos:* This is that ſlimy bituminous Subſtance, of a purple Hue, which is found in the *Lake of Sodom*, or *Dead-Sea*, in the *Land of Paleſtine*; from whence its Waters are ſaid to ſtink to that Degree, than no Fiſh can live in them, nor the Birds in the Air fly over them, and live.

5. *Naptha*, is another Sort of *Bitumen*, being liquid; but ſomewhat more apt to take Fire, and is more hardly extinguiſhed.

6. *Amber*, is alſo a kind of coagulated *Bitumen*; though it is evident its firſt State is ſoft and viſcous, from the Flies, Ants, Straws, *&c.* found in its Texture; it is different in Colour, as white, yellow, and black; is found in ſmall Currents near the *Baltic Sea*, and the *Dutchy of Pruſſia*: It hath an electric Property; for, being rubbed, it will attract Hairs, Feathers, Straws, *&c*,

7. *Petroleum*, or *Oil of Peter*, is of a ſulphureous Nature; it diſtils through the Clefts of Rocks in *Italy*, *Sicily*, and *Provence*; and ſeems to be an *Oil* of ſome *Bitumen*, which the *ſubterranean Fires* have raiſed.

A, *Sir*, I thank you: I ſhould be glad, in the next Place, to be informed a little of thoſe Bodies of the *fourth* Head, called *Minerals*.

B. Thoſe are ſuch Sort of *Foſſils* as are not inflammable, nor ductile, nor to be melted, or liquefied; but are hard and brittle, may be reduced to a Powder, or, by Fire, calcined to a Calx; of which, the following are moſt worth Notice.

1. *Marcaſſite*, or *Biſmuth*, is a metallic Matter, white, ſmooth, hard, brittle, ſharp; is of a ſulphureous Nature, like to Tin; it is diſpoſed into Facets, or ſhining Scales, like Pieces of Glaſs; hence called Tin-Glaſs.

2. *Antimony* is a Mineral, conſiſting of a *Sulphur*, and a Subſtance approaching to that of Metal, containing alſo (as it is thought from its emetic Quality) an *acid Salt*; it is found in

divers Places, in *Transylvania*, *Hungary*, *France*, and *Germany*.

3. *Cinnabar* is a Mineral, consisting of a Mixture of *Quicksilver* and *Sulphur*, sublimed together by Means of a subterranean Heat, in the same Manner as the *Chymists* make artificial *Cinnabar*; it is, while in the Lump, of a brownish Colour, but, when powdered, is of a very high red.

4. *Chalk* is a mineral Earth, of a bituminous Quality, yet is an *alkali Salt*; is of a soft and friable Texture in many Places; and in others of a hard and massy Substance, called Quarry; it every where abounds in Hills, Ridges of Mountains, and other Places.

5. *Coal*; this is a Mineral, consisting of *Sulphur* in great Quantities, mixed with a terrestrious Substance; it is a Kind of a *resinous Bitumen*, of a middle Consistence, not easily inflammable, yet will run and melt with Heat; its Texture is not soon destroyed by Fire, but is thereby at last reduced to a Calx, or Cinder; it is dug in great Quantities out of the Earth in *England*, and other Places, and serves chiefly for Fuel *.

A. What is the proper Nature of *Metals*?

B. A *Metal* is a simple fossile Body, that *fuses* and becomes *fluid* by *Fire*, and by Cold *coagulates* and *hardens* into a *solid Mass*, capable of *distending* under the Hammer. The Bodies

* The Principles of all Fossils (says the same learned Author) are (1) *Mercury*, as the *Basis* of many of them. (2) A *subtile Sulphur*, which coagulates or fixes the Mercury. (3.) *Salt*; and (4) *Earth*. Theor. of Chymistry, Page 139.

to

to which this Definition belongs in every Part, are but *six*; viz. *Gold, Lead, Silver, Copper, Iron* and *Tin*; to which the Chymists add *Mercury* or *Quicksilver*, tho' it seems to be of itself a peculiar Species of *Simple Fossils*.

Gold is the noblest of all Metals, and is distinguished by the following *Properties* or *Characteristics*. 1. It is the *heaviest* of all Bodies in Nature, and its *Weight* is *inimitable*. 2. It is the most *ductile* and *malleable* of all Bodies. 3. It is the most *fixed* and *pure*, or *loses* the *least* in the Fire, of any Bodies. 4. It requires a vehement Fire to fuse it, tho' less than *Iron* or *Copper*. 5. It is dissolvable in no *Menstruum* but *Aqua Regia* and *Mercury*. 6. It readily and spontaneously *attracts* and *absorbs Mercury*. 7. It does not, when fused with *Lead* and *Antimony*, dispose or fly off with them in Fume, but remains fixed. 8. Its *Sound* when pure is not *clear*, but rather *obtuse*, like that of Lead. 9. It is the *simplest* or freest from *Mixture* of *heterogeneous Parts*, of all Compound Bodies yet known. 10. It is of a fine *yellow colour*, tho' subject to alter and fade. 11. It is found sometime *pure*, in Glebe or Gold Clods, as in *Hungary*, and Mountains of *Chili*; sometimes in a *pure Dust* or *Sand*, as in the Bottoms of some Rivers in *Guinea*; and lastly, in whitish *Clods* dug out of Mines 150 or 160 Fathoms deep, intermixed with other minerals, as *Antimony, Vitriol, Sulphur*, &c. 12. Gold is liable to *Rust*, as is found by holding it over the *Fumes* of *Sea Salt*. These are the *Criterions* of *Gold*, and are all of them always found pertaining to that Metal.

Mercury, by reaſon of its *Weight*, comes next to be conſidered; its Characters are, 1. That it is the *heavieſt* of all Bodies except *Gold*. 2. It is the moſt *fluid* of all Bodies; or its Parts ſeparate and recede from each other with the leaſt *Force*. 3. It is *diviſible* into the *minuteſt Part* of any Body. 4. It is extremely *volatile*, being convertible into *Fumes*, even with a *Sand-heat*. 5. It eaſily penetrates, and intimately adheres to Gold; not ſo eaſily to any *other* Metals; difficultly to Copper; and not at all to *Iron*. 6. Of all other Fluids, it is found capable of the *greateſt Cold* and *Heat*. 7. It is yet, by Reaſon of its great *Fluidity*, incapable of *congealing* or *freezing*. 8. It *diſſolves* in almoſt all *Acids*, and unites itſelf with them. 9. It is the moſt ſimple or unmixed of any Bodies after Gold. 10. It is *free* from any *Sharpneſs* or *Acrimony*. 11. It is found in great Plenty in the Mines of *Friuli* in *Italy*, in the Form of *ruddy Clods*, called *Cinnabar*; in *hard ſtony* Glebes; and laſtly, *pure*, called *Virgin Mercury*, running in Veins and Streams about in the Mine.

Lead, as to its Weight, comes next; whoſe chief Properties are, 1. That, next to *Gold* and *Mercury*, it is the *heavieſt* of Bodies. 2. Of all Metals it is the *ſofteſt*, and therefore very *ductile* and *flexible*. 3. It melts the ſooneſt of all *Metals*. 4. It very *eaſily diſſolves* in almoſt all *weak Acids*, but not ſo readily in *ſtrong ones*. 5. It *diſſipates* all Metals melted with it, but *Gold* and *Silver*, or carries them off in Fumes. 6. Of all Metals it is the leaſt *ſonorous*, and diminiſhes the *Sound* of others when mixed with it. 7. It hath the leaſt *Elaſticity* of any Metal. 8. It is ſometimes found *pure*, but oftener in *Mineral Ore*, which is a Sort of blackiſh fatty Earth, difficult to fuſe. Of Lead Mines there are abundance in *Germany, Hungary*, and *England*.

Silver hath the following Characters. 1. It is next to Lead in *Weight*. 2. Its *Fixity* is next to that of Gold. 3. As alſo its *Ductility* and *Malleability*. 4. Its *Fuſibility* by Fire is very eaſy, tho' more difficult than that of *Gold* or *Lead*. 5. It is diſſolvable in *Aqua Fortis* but not in *Aqua Regia*. 6. It *reſiſteth the Force of Lead* in *Fuſion*, or is not diſſipated in Fumes thereby. 7. It *reſiſts* not the Force of Antimony, but volatilizes and flies off along with it. 8. It yields not much *Sound* when purified; being *leſs ſonorous* than *Iron* or *Copper*, but more than Gold. 9. *Silver* is ſeldom found *pure*; ſometimes in the *Ore* of *Gold, Lead*, and *Copper*, but ofteneſt in a Kind of ſtony black Glebes, full of ſhining Streaks, as in the Mines of *Peru* and *Chili*.

Copper is a *Metal* of the following *Properties* or *Characters*. 1. It is next to Silver in Weight. 2. It is very *ductile* when pure. 3. It is of a beautiful *red Colour*, exceeding that of Gold. 4. Its Fixity in the Fire is greater than that of Lead or Tin, but leſs than that of Silver. 5. It is *difficult* of *Fuſion*, much more than *Silver*; yet *ignites* before it fuſes, which Silver does not. 6. It is diſſoluble by all the Salt Menſtruums known, whether *Acid, Alkaline*, or *Nitrous*, yea by *Water, Air*, &c. 7. If it be diſſolved in *Acids*, it turns *Green*; in *Alkali, Red*;

and by other Salts, *Blue*. 8. Its *Divisibility* is very great and surprizing; for *one Grain* dissolved, will tinge with *Blue* above 530620 *times* its *Bulk* of Water. 9. It *flies off in Vapour*, being fused with *Lead* or *Antimony*. 10. It is the most *elastic*; and 11. The *most sonorous* of all metals. 12. *Copper* is every where found, but most abundantly in *Sweden* and *Germany*, where there are whole Mountains of it; but the *richest Ore* is in the Mines of *Hungary*.

N. B. Brass is made of *Copper* thus: They calcine and pulverize *Calamine*, and mix it with a little Charcoal Dust; then they put seven Pounds of this Mixture into a melting Pot, with about five Pounds of Copper over it; then letting it down in a Wind-Furnace, after 11 Hours, it is drawn up again, the *Brass* being completed in the Dissolution.

Iron is the Metal to which the following Characters belong. 1. It is the heaviest of all Bodies after *Copper*. 2. It is the *least ductile*, the *hardest* and *most brittle* of all Metals. 3. It is *very fixed*, as to its metalline Part. 4. It *ignites long* before it *fuses*, and will not *fuse without Difficulty*. 5. The *more* it is *ignited*, the *softer* and more malleable it becomes, contrary to the Nature of all other Metals. 6. It is dissoluble by almost all Bodies in Nature, that have any Motion of Parts; as *Fire*, *Salt*, *Air*, *Dew*, *Water*, &c. 7. It is extremely *rubiginous*, or apt to contract *Rust*, by the *Action* or *Corrosion* of the aforementioned Bodies upon it. 8. If it be fused with *Lead*, *Antimony*, or *fixed Salt*, it readily dissipates into Fume, or vitrefies. 9. It is very *sonorous* and *elastic*, tho' inferior in these Respects to *Copper*. 10. Of all Bodies, it is the only one *attracted* by the *Loadstone*,; and 11. It has a Kind of *Magnetism*, or is capable of *attracting Iron* itself. 12. Iron is found in Mines, which are very common in most Countries in *Europe*; as *Norway, Poland, Germany, France, England,* &c. and its Glebe or *Mercassite* bears a near Resemblance to the *Loadstone*.

Tin is distinguished by the *Characteristics* following. 1. It is the *lightest* of all *Metals*, and the heaviest of all other Bodies beside them. 2. It is the *softest* of all Metals but *Lead*. 3. It has the *least Fixity* in the Fire of all Metals, and therefore loses the *most* of its *Weight*. 4. It is *fusible* by the least gentle Fire, and that long before *Ignition*. 5. It is easily *miscible* with other Metals, and diminishes their *Ductility*, except in *Iron*. 6. It will not *dissolve* in *Acids*, especially *strong ones*, without much Difficulty. 7. It is the *least sonorous* of any Metals but *Lead*; and yet it augments their Sound when mixed with them. 8. And tho' it is in itself very little *elastic*, yet when mixed with other *elastic* Bodies, it wonderfully increases their *Elasticity*. 9. Tin is principally found in *Cornwall* and *Devonshire*; and its *Glebe* or *Ore* is a *heavy spongeous Stone*.

A. What are the Elements or Principles of which Metals consist?

B. The *Elementary* or *Component Principles* of *Metals* are reckoned two, *viz. Mercury* and *Sulphur*; *Mercury* as the *Basis* or Matter of the Metal; and *Sulphur* as the *Binder* or *Cement*,

ment, which renders it fixed and malleable. This *Mercury* is the ſame as common *Quickſilver*, but only the moſt *defecate* and pure that is poſſible. But by the Principle *Sulphur* is to be underſtood, not the vulgar *foſſile Sulphur*, but a peculiar Sort of Matter called the *Sulphur of Metal*, which is ſuppoſed to be the Matter of *Light* or *Fire*, which uniting with Mercury, fixes it; and according to the different Degrees of its Union and Coherence therewith, it produces different Sorts of Metals. To this may be added, that a *Burning-Glaſs* will ſeparate a *vitreſiable Earth* from any the moſt perfect of Metals.

A. Well, *Sir*, I heartily return you Thanks; and if you are not tired with talking ſo long, I ſhould next be glad to hear you on the Subject of the ſixth general Head, *viz. Stones*.

B. No, *Sir*, I am never tired on the Subjects of Mathematics and Philoſophy; and therefore I will go on to enumerate ſome of the principal *Stones*, and hint to you the particular Properties of each of them.

1. *Marble*, is a curious Subſtance, ariſing from an earthy Juice, well purged, concocted, and digeſted in the great Laboratory of the Earth; a Body very compact and hard, and may be calcined to Powder, but cannot be melted.

2. *Alabaſter*, is a Kind of Marble, but more ſoft and friable, and is combuſtible like Lime, but as ponderous and polite as Marble itſelf.

3. *Porphyry*, is another Species of Marble, variouſly coloured, ſomewhat lighter than Marble, yet very hard.

4. *Flint*,

4. *Flint*, is an exceeding hard Subſtance, generated from the pellucid Particles of Sand compacted together, and indurated; and may be put into Fuſion; whence Glaſs is made.

5. *Cryſtal*, is a very pellucid tranſparent Gem; the moſt pure is found in the Tops of Rocks and Mountains, and dug out of the Bowels of the Earth alſo; it is not coloured, is ſofter than other Gems, and therefore ſhineth not much; it conſiſteth of an aqueous Subſtance, and is therefore eaſily liquefied and converted into Glaſs, ſaith *Cardan*.

6. *Adamant*, or *Diamond*, is in Colour and Figure much like *Cryſtal*, generated in the ſame Manner; but its Hardneſs far exceeds that of all other Bodies; for it will cut and penetrate the Texture of any of them; it has an electric Quality, in attracting Straws, Feathers, *&c.* being warmed by Attrition.

7. *Beryl*, is a Stone, much of the Nature of a *Cryſtal*, of a faint green Colour; found at the Root of *Mount Taurus*, in the River *Euphrates*, and in the *Indies*.

8. *Smaragdus*, an Emerald, of a lovely Green, and of ſo ſtrong a Luſtre, that it ſhineth in the Light of the Sun or Candles; it is very tranſparent, and ſaid to tinge the Air with its Greenneſs.

9. *Carbuncle*, is a precious Stone of tranſcendent Luſtre; being of a glowing fiery Colour, like a burning Coal, as the Name importeth.

10. *Ruby*, ſo named for its noble red Colour, is the moſt valuable of all precious Stones next the *Diamond*; it is ſaid to be firſt white, and to

grow

grow red gradually from a ſanguine Juice, from which it is nouriſhed and generated at firſt.

11. *Hyacinth*, or *Jacinth*, is a Species of the *Carbuncle*, of a red-lead Colour; it having its Name from a Flower of the ſame Colour.

12. *Amethyſt*; this is near the Nature of an *Hyacinth*, is of a purple Colour, ariſing as it were from a Mixture of Red and Blue; they are very hard, and the harder the better.

13. *Sapphire* (from the *Hebrew* ספר *ſpecious, beautiful*) is a precious Stone of a lovely Azure, or ſky-coloured Blue, found in many Places in the *Indies*.

14. *Topaz*; this precious Gem is reckoned to excel among all thoſe which ſhine with a golden Colour.

15. *Sardius*, a Gem called the *Cornelian*, or *Cornelian Stone*, from its fleſhy Colour; the beſt is found in *Sardinia*, whence the Name.

16. *Onyx*, a Gem partly pellucid, ſo called, becauſe it expreſſeth the human Nail in Colour and Splendor.

17. *Sardonyx*, is a precious Stone, ſomewhat pellucid, and is thus named, as if made up of a *Sardius* and *Onyx* together; it is diſtinguiſhed moſtly by black, white, and ſanguine Circles.

18. *Chalcedony*, was formerly reckoned a Sort of *Carbuncle*, but is now referred to the *Onyx*; it is very hard, and of a light cloudy Colour through its whole Body.

19. *Achate*; this is an opake Gem, yet ſparkling by reflected Light; and by various co-

loured veiny Lines, reſembles Trees, Rivers, Animals, *&c.* beautifully on its Surface.

20. *Jaſper* is, like the *Achate*, opake, and of various Hue; but the *Green* is the more general Colour of this Stone.

21. *Pearls* are Jewels, or precious Stones, bred in the Shells of Fiſh; of which there be various Kinds, not much to our Purpoſe here to recount *.

A. But, *Sir*, I think in all your long Catalogue of *Minerals* and *Stones*, you have not mentioned the *Loadſtone*.

B. No, *Sir*, I have not; the Reaſon is, becauſe this moſt wonderful of all Foſſils hath always merited a particular Conſideration.

A. Be pleaſed then, *Sir*, to oblige me with a ſhort Account of the Nature, and ſome of the chief Properties of this Stone.

B. The *Magnet*, or *Loadſtone*, is a Mineral found in Iron Mines, which is ſomewhat of the Nature of Iron, but is not malleable, nor will it melt, but may be reduced to Powder, or calcined to a Calx; its Particles therefore are more rigid, hard and implicated, than thoſe of Iron. The chief Properties of the *Magnet* are theſe: 1. The *Loadſtone*, at Liberty, doth always put itſelf in a Poſition, reſpecting the Poles of the World, and the ſame Parts always tend to the ſame Pole. 2. This Stone doth not pre-

* Whoever would ſee more concerning Metals, Minerals, Stones and other Foſſils, may meet with great Satisfaction in Dr. *Boerhaave*'s Chymiſtry, with Dr. *Shaw*'s Notes, from Page 51 to 141 of the Theory; and in Dr. *Fr. Nichol*'s Obſervations on Mines and Minerals, in Philoſ. Tranſ. N° 401, 403. *Woodward*'s Nat. Hiſt of the World, Part IV.

cifely

ciſely point to the Poles of the Earth, but de-clineth a little *Eaſtward* or *Weſtward*, more or leſs. 3. Two *Loadſtones*, placed at a certain Diſtance, approach to, or recede from, each other, as they are variouſly placed. 4. *Load-ſtones* do ſo attract each other, as to ſuſtain one another pendent in the open Air, provided the *North* Pole of the one be oppoſed to the *South* Pole of the other. 5. Sometimes a lighter *Mag-net* will ſuſtain a heavier one pendent, though a heavier Magnet will not ſuſtain a lighter one. 6. It is obſerved, this Virtue of turning to the Poles is not equally ſtrong in all *Loadſtones*, ſome doing it with greater Celerity than others. 7. There are obſerved ſome *anomalous Loadſtones*, which ſeem to have more than two Poles, or Points of Direction. 8. The *Loadſtone* attracteth Iron, as it were another *Loadſtone*. 9. The mag-netic Virtue is communicated to Iron or Steel by the Touch; thus a Needle, touched by the *Loadſtone*, will always keep in a Poſition to-wards the *North* and *South*. 10. *Loadſtones* are corrupted, if they lie long together, with *North* Pole to *North* Pole, or contrarily; they alſo loſe their Virtue by being made red-hot in Fire, with many other Properties of leſs Note.

A. And pray, *Sir*, whence is this Mineral endued with this ſurprizing Virtue?

B. I cannot find any of the Philoſophers can tell the formal Cauſe thereof; it is a Se-cret yet hid from Man, though he be bleſt with a Diſcovery of its Uſe *. *A*. Pray

* As the Properties of the *Magnet* and the Experiments illuſtrat-ing the ſame, are endleſs to recount; ſo the Authors who treat thereof,

A. Pray what Parts of the Earth are moſt productive of Minerals and Metallic Subſtances?

B. Mountains, which ſeem, as it were, deſigned as Matrices for the Generation and Maturation of Minerals and Metals; becauſe in them the moſt uſeful Foſſils are principally found.

A. Do Minerals, Metals, Stones, *&c.* grow in the Earth?

B. Undoubtedly: Yea, it is well known that divers Mines, when emptied of Stone, Metal, *&c.* have, after a while, recruited again. Alſo divers ſtony, ſparry Iſicles, and other ſtalactical Subſtances, may be daily ſeen engendered from the Exudations of ſome petrifying Juices out of the rocky Earth in great Caves; as I myſelf have ſeen in *Oky-hole* in *Somerſetſhire* *.

A. Well, but to make an End, what may you mean by extraneous Bodies in the Earth, the Subject of the 7th and laſt general Head?

B. The various *Exuviæ* of Fiſh, and other marine Animals; ſuch as petrified *Echini, Gloſſopetræ, Cockles, Oyſter-ſhells, Turbens,*

thereof, and the Hypotheſes they advance for the Solution of thoſe Properties are almoſt infinite. But they who deſire a large Diſcourſe on this ſurprizing Subject, may conſult *Jean. Clerici* Phyſ. Lib. II. Cap. 6. *Haukſbee*'s, *Deſaguliers*'s, &c. Courſes of Experiments. *Rohault*'s Phyſics, Part III. Chap. 8. *Jac. Ode*, Philoſ. Nat. Tom. II. Cap. 3. *Kircheri*, Ars Magnetica. *Whiſton*'s Doct. of the Magnet. *Stairii* Phyſiol. Explorat. XVIII. § 12 to § 37, incluſive. *Deſcartes*, Opera Philoſophica, Part IV. § 133, & ſeqq. Inſtitutio Philoſ. Tom. III. Part. II. § 3. Cap. 4. *Régnault*'s Converſat. Vol. I. Conv. 15, 16. *Lowthorpe*'s Abridgment. Vol. II. Page 630. *Eames* and *Martyn*'s Abridgment, Part II. Chap. 4. Miſcellanea Curioſa, Vol. I. Page 43. *Harris*'s Lexicon, and *Chambers*'s Dictionary, at the Word *Magnet*. Phil. Tranſ. N° 3[illegible]8, 39[illegible], 414, 423, 389, 366, 371, 412.

* See Mr. *Derham*'s *Phyſico-Theology*, Book III. Chap. 2. the Notes.

Scallops, &c. that are found in various Parts and great Depths of Earth, and are to be ſeen in the Cabinets of the Curious.

A. Pray, how came thoſe Bodies at firſt intermixed with the Earth?

B. None can certainly tell; it is ſuppoſed at the Deluge, or by ſome general Inundation of the Seas, whereby the Earth was rendered ſoft, and thoſe marine Bodies ſunk therein, and were covered over; and by the petrefying Quality of the Earth, in Time, turned into Stone *.

* Dr. *Woodward* ſays, the *Echini* and other lighter Shells are very numerous and frequent in all the Chalk-Pits of *Kent*, *Surrey*, *Eſſex*, and other Shires; being found indifferently, from Top to Bottom, in Pits that were 100 Feet deep; and in *Wells* much deeper. Alſo that the *Conchæ*, *Pectines*, *Cochleæ*, and Shells of a like Gravity, are found in the Sand Stone of all Countries, yea, even in the very Middle of *Flints* themſelves. Nat. Hiſt. of the Earth, Part I. Page 30, 31. Part IV. Page 183, &c.

It is common to find that the *Echini*, *Cochleæ*, *Conchæ*, *Pectines*, and other Shells, have their Cavities filled up with Ores, Flint, Spar, Vitriol, Sulphur, and other Minerals; theſe receive the ſpecific Figures of the Shells, they are formed or moulded in. And theſe Stones are what Authors call *Echinitæ*, *Cochlitæ*, *Conchitæ*, *Pectinitæ*, &c.

Steno, in his Book *de Solido intra Solidum contento*, ſays, there were many *marine Shells* found in a Stone taken out of the *Forum Volaterranum*, which many Ages before had been brought thither for Building; and therefore it was certain thoſe Shells could not have endured leſs than 3000 Years, and probably from the Flood.

See much on this Subject in Dr. *Woodward*'s Hiſtory of the *Earth*. *Steno*'s Book above mentioned. The Theories of Dr. *Burnet* and Mr. *Whiſton*. *Bartholini* Specim. Philoſ. Nat. Cap. 13. Pag. 130—133. Philoſ. Tranſ. N° 291, 305, 360, 368.

CHAP.

CHAP. III.

HYDROGRAPHY, *or the* PHILOSOPHY *of* WATER; *of the Laws of its* PRESSURE *and* GRAVITY; *of the* SEA, *its Origin, Roundneſs, Extent, Saltneſs, and Tides; of the Cauſe of* FOUNTAINS, RIVERS, LAKES, *and* BATHS, *with the Properties of their ſeveral Waters.*

A. WHAT is the Original of *Hydrography?*

B. The Word is compoſed of ὕδωρ, *Water*, and γραφὴ, a *Deſcription*; and here ſignifies a philoſophical *Deſcription of Water*.

A. You have already deſcribed me the different Diſtinctions of Water on the Earth's Surface, and likewiſe the Cauſe of its *Fluidity* and *Volubility*; pray what then remains to be farther conſidered of *Water?*

B. In the firſt Place we muſt more particularly conſider the Effects ariſing from Fluidity, and the Rules of Motion, called the *hydroſtatic* and *hydraulic* Laws of the Gravity and Preſſure of Fluids *.

* 1. The Word *Hydroſtatics* is derived from ὕδωρ, *Water*, and ςατικὴ, the Science of *Weight*, from ςατεω, *to weigh*. Conſequently, *Hydroſtatics* imports the Science which is converſant about thoſe Properties of *Water*, or any Fluids, which depend on, or reſult from the *Weight* or *Gravity* thereof.

2. *Hydraulics* is derived of ὕδωρ, *Water*, and αὐλος, a *Pipe*; for anciently the *Organ* and other Wind Inſtruments of Muſic were blown by Wind made by the Fall of *Water* inſtead of Bellows. Whence this Word in Time came to be applied to the *Art of making all Sorts of Engines for carrying or raiſing of Water, or which are worked or moved by Water*. And hence the ancient *Water Engines* deſcribed by *Hiron* are called *Machinæ Hydraulicæ*, i. e. Hydraulic Machines or Engines.

A. What are those Effects you call the *hydrostatic* Laws of *Fluids?*

B. We have not Time to consider all; the chiefest are the following.

1. *The Surface of a Fluid contained in a Vessel abiding free, will become plane, or parallel to the Horizon: Thus the Surface* AB, *of the Fluid* CD, *will be parallel to the Horizon* HO.

2. *The upper Parts* C *press the lower Parts* D, *which sustain them; and this Pressure is always proportional to the Height of the Fluid* AE. *See* Figures XXXIII. *and* XXXIV. *on* Plate XXI, *fronting* p. 234.

3. *This Pressure on the lower Parts, from the Gravity of the superincumbent Liquid, exerts itself every Way, and every Way equally.*

4. *In several Tubes, having a Communication with each other, as* ABCDEF, *whether equal or unequal, straight or crooked, erect or oblique, a Fluid will rise to the same Height* GI *in all,* Fig. XXXIV. *on* Plate XXI, *fronting* p. 234.

5. *When Liquids of different Gravities are contained in the same Vessel, the heaviest lies at the lowest Place, and is pressed by the lighter, in Proportion to the Height of the lighter.*

6. *The Bottom* EF, *and Sides* AEBF, *all round a Vessel, are pressed by the Parts of the Liquid contained which immediately touch them; and that in Proportion to the Height of the Liquid, not at all regarding its Quantity.* Fig. XXXI. *on* Plate XXI, *as above.*

7. *A solid Body immersed in a Liquid, is pressed by the Liquid on all Sides; and that Pressure increases in Proportion to the Height of the Liquid*

quid above the the Solid. Bodies very deeply immersed are, as it were, equally pressed on all Sides.

8. *Any Body, which is heavier than an equal Bulk of the Liquid into which it is immersed, will sink or descend therein.*

9. *If the Body be lighter than an equal Bulk of the said Liquid into which it is immersed, it will ascend to the Top, or swim.*

10. *But, suppose the Body be equal in Weight with an equal Bulk of the Liquid, it will neither ascend or descend, but remain suspended in the Liquor, wherever it is placed.*

11. *All equal Solids, but of different specific Gravities, being immersed in the same Liquid, lose equal Parts of their Weight.*

12. *A Liquid acquires the same Weight which the immersed Solid loses.*

13. *The immersed Parts of Bodies swimming on the Surface of the same Liquor, are to each other as the Weights of the Bodies.*

A. And, pray, how do you prove these Laws, and what are their Use?

B. They are founded on various Experiments, and their Use is to discover the different *Weights* or *specific Gravities* of *Liquids* and *Solids*, which is not only a very great and useful, but also a very pleasing and delightful Part of natural Philosophy *.

A. Pray

* The Proof of these Laws of Fluids is threefold, *viz.* (1.) *Physical*; which depends on a bare Contemplation of the Nature, Figure, and other Properties of the small Particles of Fluids, separately considered; and the *Phænomena* thence arising will evince the Truth of the said Laws. (2) *Mathematical*; for by considering of *Liquids* as *Solids*, and dividing them into *Planes*, *Columns*, &c. and representing their different *Heights*, *Gravities*, and *Velo-*

 cities,

A. Pray how do you find or eſtimate the ſpecific Gravities of Solids?

B. Thus, by the hydroſtatic Balance S, *Fig.* XXXV. on *Plate* XXI, fronting *p.* 262, let there be prepared a Glaſs Veſſel of Water E, and another Veſſel D, whoſe Weight in Water muſt be preciſely equal to that of the Weight C. Now the Weight C being affixed to the Scale A, the Solid, whoſe ſpecific Gravity is deſired, being firſt weighed in Air, muſt then be put into the Veſſel D, which is then affixed to the Scale B, and immerſed into the Veſſel of Water; then put Weights into the Scale B till there be a juſt Equipoiſe. Now from its Weight in Air, ſubduct its Weight in Water, and the Remainder will be as its *ſpecific Gravity* inverſely; and thus the Ratio's or Proportion of the *ſpecific Gravities* of ſeveral Bodies may be found.

A. As to the Manner of weighing thoſe Bodies, it ſeems pretty eaſy to be apprehended from the *Figure*; but as to computing the Ratio's, I believe I could better underſtand that by Example.

B. Why then I will give you one. Suppoſe you take a Piece of Lead and a Piece of Ivory, each weighing 69 Grains in Air, but weighing

cities, by algebraic Characters, it is eaſy, by Rules of Art, to raiſe Theorems, which are ſo many Hydroſtatic Laws. (3.) *Experimental*; for all thoſe Laws are capable of Proof by innumerable *Experiments*. See the ſeveral Courſes of Experiments, by Dr. *Deſaguliers*, *Graveſande*, *Hawksbee*, *Worſter*, &c. *Mariotte's Hydroſtatics*, engliſhed by Dr. *Deſaguliers*. *Robault's Mechanics*, tranſlated by *Watts*, Page 118. *Boyle's Hydroſtatical Paradoxes*. *Compend. Syſtem of Nat. Philoſ.* Part 2. *Sinclair's Hydroſtatics*. *Clarke's* Notes to *Robault's Phyſics*, Part I. Chap. 16. § 8. *Muſſchenbroek's Epit. Phyſ* Part 2. *Ditton's New Law of Fluids*. *Switzer's Gen. Syſtem of Hydroſtatics*. *Phil. Tranſ. abridged*, by Meſſ. *Eames* and *Martyn*, Part I. Chap. 6. *Chambers's Dict.* and *Harris's Lexicon*, under the Words *Fluids* and *Hydroſtatics*.

To front Page 262.

Plate XXII.

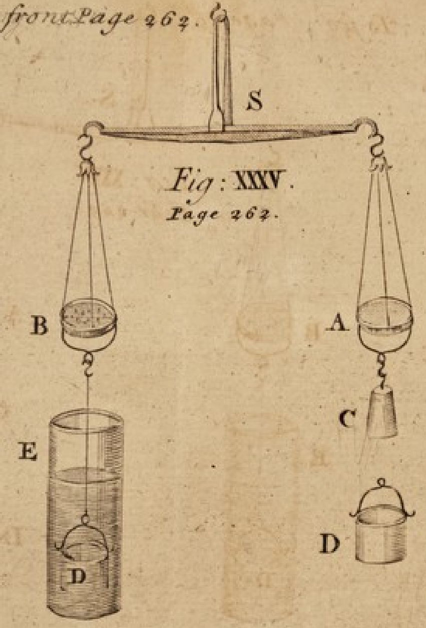


Fig: XXXV.
Page 262.

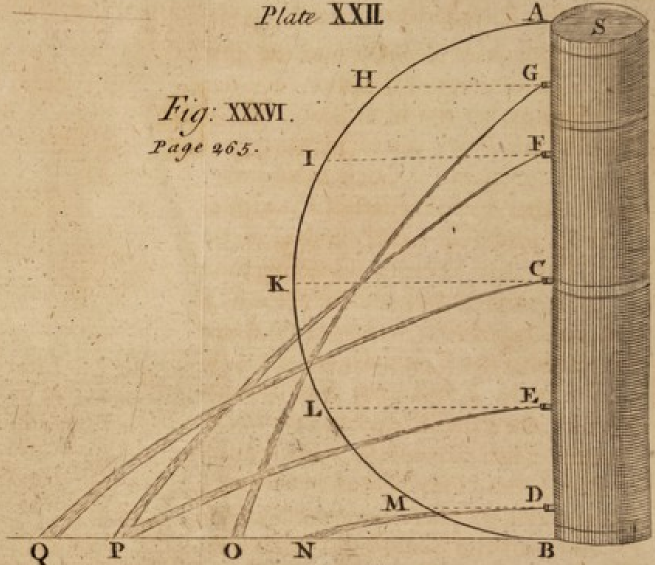


Fig: XXXVI.
Page 265.

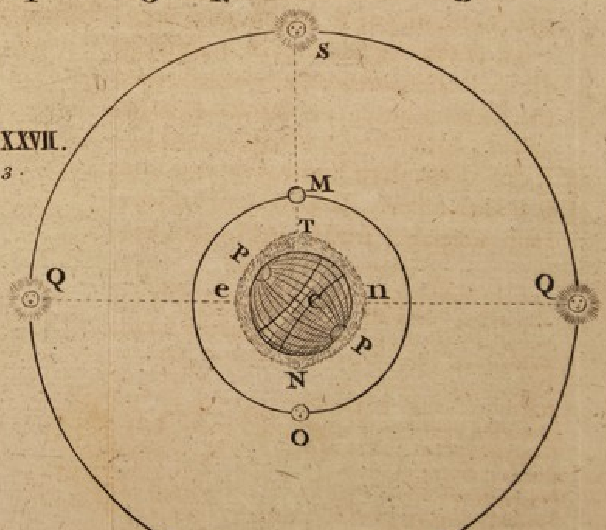


Fig: XXXVII.
Page 273.

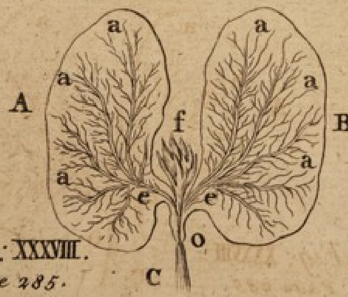


Fig: XXXVIII.
Page 285.

An Estimate of the ſpecific Gravity of Solids.

In Air 60 Grains.	In Wat.	Dim.	Prop.
Crude Mercury	$55\frac{3}{4}$	$4\frac{1}{4}$	14
Lead	$54\frac{1}{4}$	$5\frac{3}{4}$	11
Copper	53	7	8
Braſs	53	7	8
Crude Tin	53	7	8
Regulus of Antimony	52	8	$7\frac{1}{2}$
Regulus of Steel and Copper	52	8	$7\frac{1}{2}$
Block Tin	52	8	$7\frac{1}{2}$
Iron	$51\frac{1}{6}$	$8\frac{5}{6}$	7 fere
Cinnabar of Antimony	51	9	$6\frac{6}{9}$
Litharge of Silver	51	9	$6\frac{6}{9}$
Litharge of Gold	$50\frac{1}{2}$	$9\frac{1}{2}$	6
Silver Sixpence	49	11	$5\frac{1}{2}$
Calcined Copper	49	11	$5\frac{1}{2}$
Glaſs of Antimony	48	12	5
Lapis Calaminaris	48	12	5
Tutty	47	13	$4\frac{8}{13}$
Crocus Metallorum	$46\frac{1}{2}$	$13\frac{1}{2}$	$4\frac{1}{2}$
Crude Antimony	45	15	4
Prepared Steel	41	19	$3\frac{8}{19}$
White Lead	41	19	$3\frac{8}{19}$
Green Glaſs	39	21	$2\frac{18}{21}$
Red Coral	39	21	$2\frac{18}{21}$
Flint	38	22	$2\frac{8}{11}$
Bole Armoniac	38	22	$2\frac{8}{11}$
Lapis Judaicus	$38\frac{1}{3}$	$21\frac{2}{3}$	$2\frac{1}{2}$
Flint Glaſs	$38\frac{1}{8}$	$21\frac{7}{8}$	$2\frac{1}{2}$
Bone of a Sheep juſt killed	33	27	$2\frac{2}{9}$
Filings of Steel	30	30	2
Lemnian Earth	30	30	2
Ivory	29	31	$1\frac{2}{3}$
Hartſhorn	28	32	$1\frac{7}{8}$
Mineral Sulphur	28	32	$1\frac{7}{8}$
Crude Tartar	27	33	$0\frac{2}{3}$
Venice Glaſs	$26\frac{1}{2}$	$33\frac{1}{2}$	$1\frac{5}{6}$
Ruſt of Braſs	25	35	$1\frac{5}{7}$
Burnt Lead	24	36	$1\frac{6}{9}$
Gum Arabic	18	42	$12\frac{9}{21}$
Opium	16	44	$1\frac{4}{11}$
Lignum Guaiacum	15	45	$1\frac{1}{3}$
Gum Tragacanth	15	45	$1\frac{1}{3}$
Myrrh	12	48	$1\frac{1}{4}$
Gum Guaiacum	11	49	$1\frac{11}{49}$
Reſin of Scammony	10	50	$1\frac{1}{5}$
Lignum Nephriticum	10	50	$1\frac{1}{5}$
Iſinglaſs	6	54	$1\frac{1}{9}$
China Root	4	56	$1\frac{1}{14}$
Frankincenſe	4	56	$1\frac{1}{14}$
Gall	2	58	$1\frac{1}{29}$
Gentian	0	0	$0\frac{60}{75}$
Peruvian Bark	0	0	$0\frac{120}{153}$
Oak	0	0	$0\frac{60}{80}$
Fir	0	0	$0\frac{60}{108}$

An Estimate of the ſpecific Gravity of Liquids.

The Weight of a Piece of Lead in the ſeveral Fluids here below.	Weight.	Dim.	Prop.
In Air	455	0	0
Oil of Vitriol	379	76	$5\frac{75}{76}$
Herm. Spirit of Nitre	383	72	$6\frac{2}{7}$
Spirit of Nitre, with Oil of Vitriol	396	59	$7\frac{4}{5}$
Spirit of common Nitre	397	58	$7\frac{49}{58}$
Spirit of Nitre Bezoartic	397	58	$7\frac{49}{58}$
Double Aquafortis	400	55	$8\frac{1}{5}$
Spirit of Vitriol	406	49	$9\frac{1}{4}$
Spirit of Salt, with Oil of Vitriol	408	47	$9\frac{1}{4}$
Solution of common Salt	408	47	$9\frac{1}{4}$
Simple Aquafortis	410	45	$10\frac{1}{9}$
Spirit of Sal. Armon. Succ.	409	46	$9\frac{41}{46}$
Solution of Sal. Enix. oz. in Water 5 oz.	410	45	$10\frac{1}{9}$
Decoction of Gentian	$410\frac{1}{2}$	$44\frac{1}{2}$	$10\frac{2}{9}$
Spirit of Tartar	411	44	$10\frac{1}{4}$
Decoction of Snakeweed	411	44	$10\frac{1}{4}$
Spirit of Hartſhorn not rectified	411	44	$10\frac{1}{4}$
Decoction of Sarſaparilla	412	43	$10\frac{1}{2}$
Decoction of China Root	412	43	$10\frac{1}{2}$
Spirit of common Salt	$412\frac{1}{2}$	$42\frac{1}{2}$	$10\frac{1}{2}$
Decoction of Arum	$412\frac{1}{2}$	$42\frac{1}{2}$	$10\frac{5}{7}$
Solution of Arum 1 oz. 1 dr. in Water 6 oz.	413	42	$10\frac{5}{6}$
Syden. Liquid. Lauden.	413	43	$10\frac{5}{6}$
Liqu. Panacea of Opium	413	42	$10\frac{5}{6}$
Decoction of Peruvian Bark	413	42	$10\frac{5}{6}$
Decoction of Pomegranates	413	42	$10\frac{5}{6}$
Solution of Sal. Armon. pur. 1 oz. and white Vitriol, 1 oz. in Water 5 oz.	413	42	$10\frac{5}{6}$
Urine	$413\frac{1}{2}$	$41\frac{1}{2}$	11
Sweet Spirit of Nitre	414	41	$11\frac{4}{41}$
Common Water	414	41	$11\frac{4}{41}$
Tincture of Alum, with Water	414	41	$11\frac{4}{41}$
Decoction of Red Saunders	414	41	$11\frac{4}{41}$
Diſtilled Vinegar	$414\frac{1}{2}$	$40\frac{1}{2}$	0
Mint, Rue, Savin Water, diſtilled	415	40	$11\frac{3}{8}$
Vinegar	$415\frac{1}{2}$	$39\frac{1}{2}$	$11\frac{1}{2}$
Milk	$415\frac{1}{2}$	$39\frac{1}{2}$	$11\frac{1}{2}$
Infuſion of Horehound	416	39	$11\frac{2}{3}$
—— of Mint and Wormwood	416	39	$11\frac{2}{3}$
Elix. prop. with Sal. Volat.	$416\frac{1}{2}$	$38\frac{1}{2}$	$11\frac{2}{3}$
Infuſion of Tea	$416\frac{1}{2}$	$38\frac{1}{2}$	$11\frac{2}{3}$
Spirit of Saffron	417	38	12
Sweet Spirit of Salt	$418\frac{1}{2}$	$36\frac{1}{2}$	12
Tincture of Caſtor	419	36	12
Spirit of Wine Camph.	419	36	12
Mynſ. Tincture of Steel	420	35	13
Tincture of Sulphur, with Spirit of Turpentine	420	35	13
Oil of Turneps	420	35	13
Tincture of Coral	420	34	$13\frac{1}{3}$
Spirit of Wine	$421\frac{1}{2}$	$33\frac{1}{2}$	$13\frac{1}{2}$
Oil of Turpentine	$422\frac{1}{2}$	$32\frac{1}{2}$	$13\frac{1}{2}$
Spirit of Wine rectified	$423\frac{1}{2}$	32	14
Boiled Water	424	31	$14\frac{2}{3}$

them separately in Water, you find their Weights therein to be $54\frac{1}{4}$ and 29; now the Deficiency of these Weights are 5, and 31. Therefore the Ratio or Proportion of the Weight of Lead to that of Ivory, is as 31 to $5\frac{3}{4}$; that is, Lead is almost $5\frac{2}{3}$ Times heavier than Ivory.

A. Sir, I perfectly apprehend you now, and thank you; pray do you estimate the specific Gravities of Liquids after the same Manner?

B. They are estimated thus: Take a Piece of Lead, which suppose to weigh 455 Grains; then the same weighed in Oil of Vitriol will be found no more than 379, and in common Water 414 Grains. The Diminution in the first Case is 76, in the latter 42 Grains; these Numbers are inversely as the specific Gravities. Wherefore the Gravity of *common Water* is to the *Oil of Vitriol*, as 76 to 41; that is, almost as heavy again. Do you understand me?

A. Yes, *Sir*, very well: I only wish I had such a Pair of Scales as are fit for this Purpose; for then I should take a deal of Pleasure in making those Kinds of Experiments.

B. Sir, you may easily obtain a Pair; and till then, I can lend you a *Synopsis* of an Estimate of the *specific Gravity* of *various Solids and Liquids*, which I have taken from Dr. *Quincy*, if you think it worth your Perusal *.

A. Sir,

* 1 The best Method that I can find for discovering the *specific Gravity of Solids and Fluids*, with Ease, Expedition, and Certainty, is by means of a fine *Hydrostatic Steelyard* and *Sliding Rule*.

2. The Steelyard is thus cheaply and easily made: Take the Beam of a fine Pair of Scales, as AO (*Fig.* LXIII. on *Plate* XX, fronting *p.* 233.) let the Smith make the Arm CO of a sufficient Length CB, by joining a small Iron Rod thereto; to

 the

A. Sir, I am very much obliged to you for so extraordinary and useful a Piece of philosophical

the End of the other Arm at A fix a Ball of Lead, or Tin, *&c.* D, such that its Weight, together with that of the Arm AC, may exactly balance or equipoise the Weight of the other lengthened Arm CB.

3. The Arm CB being duly shaped, is to be graduated after this Manner: Suspend two equal Balls or Weights, E and F, one on each Side the Point C, at equal Distances, CA, CO, they there abide *in Equilibrio*; therefore O is the Point from whence the Degrees are to begin. If now you add 10 Weight of 10 Grains to the Ball F, and move the other from O a little towards B, you will find the Point 10 where the Weights will be exactly *in Equilibrio*. If you add 10 more Grains to F, the Ball E being again moved towards B, will give the Point 20, where it will equibalance the other. And thus by adding 10 Grains constantly to F, you will gain the Points of Division in the other Arm for every 10 Grains to an 100, or any greater Number; all which is evident from the Figure.

4. The *Steelyard* being thus graduated, a fine Thread of Silk (whose Weight is inconsiderable) is to be fixed to the Ball F with a Loop at the lower End, in which any Body, or Piece of Matter, may be put as at one, and then weighed by moving the Wire of the Ball E over the Degrees, as in the common *Steelyard*, till it comes to an Equilibrium; then the Body is to be suspended and weighed in a Vessel of Water, as GH; and then the Difference of its Weight *in* and *out* of the Water will be with Ease obtained, be the *Figure* or *Weight* of the Body what it will, within the Compass of the Instrument.

5. When, by this Means, you know what any given Number of Grains lose being weighed in Water, it is easy by the Sliding Rule to find what an 100 Grains will lose. Thus if 60 Grains of Lead lose $5\frac{3}{4}$, an 100 will lose $9\frac{3}{5}$ nearly; and thus a Table of the *specific Gravities* of *Solids* and *Fluids* may be constructed with the greatest Expedition. By this Steelyard I have examined many of the Gravities I have here given in the Table, and find they are very true.

6. But since *Gold* is not among the other Solids, I thought it would not be amiss if I here subjoin a small Table of the specific Gravity of Gold and the other Metals, with Air and Water, in one View.

Gold	19636	Iron	7852
Quicksilver	14019	Tin	7321
Lead —	11345	Stone	2000
Silver	10535	Water	1000
Copper	8843	Air	$1\frac{3}{17}$

Curiosity;

Curiosity: And, pray, have you nothing very remarkable to be observed from the foregoing Laws of the Pressure of *Fluids*?

B. Yes, more than I can here exemplify to you; however, that you may know something of them, learn their Use in the following Instance: Suppose AB (*Fig*. XXXVI. on *Plate* XXII, fronting *p*. 262.) a Cistern or Tube filled with Water always even to the Brim, as at S; now let there be any Number of Holes DECFG made through the same, the Water spouting through each of them, will fall to an horizontal Distance, which is double to the Distances of those Holes from the Periphery of a Circle AKB, described about the Length of the Tube as a Diameter *.

A. If this be the Case, I easily perceive why, in the Scheme, the Water spouting from the middle Hole C, falls farthest from the Tube; for, according to you, the Distance BQ, to which it falls, is equal to twice CK, that is, equal to the Height of the Tube AB; and as this CK is the farthest Distance from the Circle, the Double thereof BQ must needs be greater than the Double of any other Distance, and therefore its Water spouts the farthest.

B. You take the Reason of the Thing very well; you may also farther observe, that from two Holes EF, equally distant above and below the central Hole C, the Water will spout to an equal Distance BP, the Double of EL or FI, which are equal Distances from the Cir-

* Dr. *Gravesande* proves the Truth of this in his *Elements*, Book I. Chap. 24. p. 101, 102, 103. And Book II. Part 2. Chap. 7, 8, 9, are wholly on these Subjects.

cle:

cle: Alſo the Water from G will ſpout to O, which is double the Diſtance GH; and the Water from D will ſpout to N; for BN is double the Diſtance DM from the Circle.

A. I underſtand you thoroughly concerning this; have you any thing elſe to obſerve of the Preſſure of *Fluids*, pray?

B. One Thing amongſt many I could name is this: That, let a Body be ever ſo heavy, yet it may be made to ſwim in Liquids.

A. This is very ſurprizing indeed! What, can *Lead* or *Gold* be made to ſwim in Water, *Sir?*

B. Yes, by knowing their ſpecific Gravities: Thus, becauſe the ſpecific Gravity of Gold is to that of Water, as 19 to 1; therefore if you hold a Guinea to the Bottom of a Tube of equal Diameter (ſo as no Water can get in) by Means of a String; then put the Tube down in the Water above 19 Times the Thickneſs of the Guinea in Depth, and letting the String go, the Guinea will not ſink, but ride ſuſtained by the Preſſure of the ſubadjacent Water, which now is ſtronger than the Power of Gravity in the Guinea; and thus you may make any Body ſwim, how large, ſolid, and weighty ſoever *.

A. Well,

* 1. The Writers on Hydroſtatics demonſtrate, that the Preſſure of Liquids on the Bottom and Sides of Veſſels is always proportional to the Height thereof, and every Way equal at the ſame Depth.

2. To illuſtrate this, let GE (*Fig.* LXIV. on *Plate* XX, fronting *Page* 233.) be a Veſſel, from whoſe upper Part HE proceeds a tall Tube ABCD communicating therewith. Let this Tube and Veſſel be filled with Water, then ſhall the Preſſure of the Water on the Bottom GF be as great, and every way the ſame, as it would be, were the Veſſel itſelf as high as the Tube, and filled with Water to the Level of PS; that is, the Column of Water ANOB in the preſent Caſe has the ſame Effect on the Bottom of the Veſſel GE, as the Column of Water PGFS would have.

3. This

A. Well, I thank you for these general Instructions concerning the Nature and Effects of *Fluids*: And now, *Sir*, if you please, we will

3. This is no small *Paradox*, but is notwithstanding that very easy to conceive; for since Fluids act in every Direction, or press every Way, and every Way equally, and *Action* and *Reaction* is equal, and contrary; it must follow, that the Parts of the Bottom LN and GL (being equal to NO) will sustain the same Pression as NO, or as they would do, were the Columns of Water continued to the Height PQA. For in the Line CN, the Force of the Column of Water AO is exerted on each Side equally, and has the same Effect at IL as at DO, and therefore the lateral Pressure being equal, the perpendicular Pressures also on LN and NO will be equal.

4. Or thus: If the Pressure on the Part IL were less than on the Part DO, the Fluid in the Column CO would, by reason of its greater Gravity, have a Motion toward the Part IL, and the Surface AB would descend: But since there is a perfect Quiescence of all the Parts of the Fluid, and that in the Column CO is as much at Rest as that in the Column CL, it is evident their Pressures and Effects are every Way the same, and consequently that the Column CL presses as much on the Part LN, as the Column CO does on the Part NO. What is thus proved of the Colum IN, is to be proved of all the rest, HL, DM, and KF; which makes the Proposition manifest.

5. This *Paradox* is also easily proved by *Statics*; for suppose the Vessel fixed, and the Bottom GF moveable therein, and so adapted to it, that no Water should pass between it and the Sides of the Vessel; if this Bottom be hung to the Arm of a Balance by Means of a long Wire descending through the Tube, the Effect of the Water in the Tube may be compared with that in the Vessel, in regard of Weight. Thus suppose the Water in the Vessel to weigh one Pound, then admit the Height of the Tube AC be four Times the Height of the Vessel CN, if the Tube be filled with Water to AB, you'll find four Pounds must be added to the other one in the Scale to make an *Equilibrium*.

6. Or otherwise thus: Let the upper Part of the Vessel HE be connected with the lower art or Bottom GF by Means of Leather, in the Manner of a Pair of *Bellows*; then, if the Tube AD be fixed into the upper Part, and Water poured therein, it will raise the upper Part from the Bottom charged with Weights equal to the Weight of a Column of Water equal to PGFS.

7. I have been the more particular on this wonderful Property of Fluids, because it is not only in itself very curious, but of great Importance in many Affairs of Life; and they who would see more, may cousult the Authors above referred to, especially Dr. *Gravesande*'s *Elements*.

direct

direct our Discourse to the Contemplation of Water in particular; and first we will begin with the Waters of the Sea: What therefore do you find is known concerning their Extent, or what Proportion do the Superficies of the Sea bear to those of the dry Land?

B. This is not precisely known: I remember I once calculated the Proportion of Water and Land, as they are represented on my terrestrial Globe of 16 Inches Diameter, and found it to be somewhat more than $\frac{2}{3}$, but how much I cannot justly say, having lost my Notes of that Particular at present.

A. Pray how came the Earth to be covered over, so far the greater Part, by Water?

B. Thus it pleased God in the Beginning to order it; for wise Ends no doubt: The Waters of the Earth must necessarily rise to the Surface thereof, as being specifically lighter than Earth; and then it was as necessary there should be large Cavities therein for Receptacles to contain them, otherwise they would equally have overspread all the Superficies of the Earth, and so have rendered it utterly uninhabitable to Mankind *.

A. I understand the Figure of the whole Earth is round, and consequently the Superficies of the Sea must be so too, which I think

* On this Head hear the Philosophical Poet *Ovid:*
The Earth of closer and compacter State,
Fell self-incumber'd with her proper Weight;
On her the grosser Elements attend,
And to the deepest, lowest Part descend.
The Waters last took Place, and flowing round,
The girded Globe's extensive Circle bound.
Metamorph. Lib. I. *Sewell*.

you

you impute to the Action of Gravity or Power of Attraction in the Earth, do you not, *Sir*?

B. Yes, the Centre of the Earth being the common Centre of Gravity, and the Nature of Fluids being ſuch, that they equally yield to equal Powers, and the Power of Attraction being every where equal at equal Diſtances from the Centre, it follows, that the ſuperficial Parts of Water will every where conform themſelves to an equi-diſtant Situation from the Centre, and conſequently will form the Surface of a Sphere ſo far as they extend *.

A. Pray, *Sir*, is the Sea higher than the Earth, or Land, as it ſeems to be?

B. No; for by the Power of Gravity all Things conform to a ſpherical Surface, in which no one Part is higher than another; beſides, Fluids preſs every Part equally, and therefore would ſoon overflow the Shores, were they really loweſt.

A. How comes it to appear ſo, then?

* Thus *Ovid* again in the ſame Place:

Whatever God thus broke the formleſs Heap,
And bid the Parts a juſt Proportion keep,
Firſt, that the Earth might regular appear,
He rounds the Figure to a perfect Sphere, &c.

But herein the Poet is miſtaken; for the Figure of the Earth is not that of a *perfect Sphere*, but an *oblate Spheroid*, whoſe longeſt Diameter is that of the Equator, and the ſhorteſt, that from Pole to Pole, the Difference being about $34\frac{2}{10}$ Miles, according to Sir *Iſaac Newton*, in his *Principia*, Lib. III. Prop. 19, p. 415. See alſo Dr. *Keill*'s Examination of Dr. *Burnet*'s Theory of the Earth, Chap. 6. And a large Diſſertation on the Figure of the Earth by Dr. *Deſaguliers*, in Philoſoph. Tranſ. N° 316 to 389.

B. This

B. This refults from the *Fallacy* of *Vifion*, whereby all Objects, and the Parts of Land as well as Sea, the farther they are from us, the higher they appear: Thus in Pieces of Perfpective, the Parts are all placed higher above the Ground Line, as they are fituated more remote. The Reafon of all which is eafy from *Optics* *.

A. Is the Depth of the Sea known?

B. Varenius affirms, the Depth or Profundity of the Sea is in fome Places unfathomable; and in other Places is very various, being in fome Places $\frac{1}{26}$, $\frac{1}{3}$, $\frac{45}{100}$, $1\frac{1}{10}$, $2\frac{2}{10}$, $4\frac{1}{2}$ *Englifh* Miles, in other Places deeper, and is much lefs in Bays than in Oceans. The *Depths* of the *Sea* bear

* 1. It is well known, that the *denfer* any Medium is thro' which we behold Objects, the greater is the *Refraction*, or the more their Images appear elevated above the Horizontal Level; alfo the greater Quantity of the Medium the Rays pafs through, the more they will be bent from their firft Direction; on both thefe Accounts the Appearance of Things remote, and on the Sea, will be fomewhat above the Horizon; and the more fo, as they are more remote.

2. The Sight, with regard to diftant Things, is terminated with a fpherical Superficies, of which the Eye is the Centre, and therefore the more remote Things are, the higher they appear in this Superficies. For Inftance, let the Eye be at G viewing the diftant Surface of the Sea AE; and fuppofe AF be Part of the fpherical Superficies which terminates the Sight. Let A, B, C, D, E be feveral Parts of the Sea's Surface, thefe will appear in the Sphere of Vifion, at *a*, *b*, *c*, *d*, *e*, all above the horizontal Level HE; and every Part higher as it is more remote. See *Fig.* LXV. on *Plate* XX, fronting *p.* 233.

3. Nor is this the only Fallacy; but, if we fuppofe the Parts AB, BC, CD, and DE all equal to each other, they will appear very unequal to the Eye at G in the Sphere AF, that which is neareft being ftill the greateft; and the more remote the leffer. Again, if *ab*, *bc*, *cd*, and *de* be fuppofed equal, the Diftance on the Sea will appear to be equal, tho' they are really very unequal; and, in this Cafe, the more remote, the larger. See much more to this Purpofe in *Varenius*'s Geog. Gen. Book I. Chap. 13. throughout, but efpecially Prop. 1ft and 2d thereof.

great

great Analogy to the *Height of Mountains* on the Land, ſo far as is hitherto diſcovered.

A. Are you able to ſay whence the Saltneſs of the Sea doth ariſe?

B. It is very rationally judged to ariſe from great Multitudes both of Mines and Mountains of Salt, diſperſed here and there in the Depths of the Sea: The Salt being continually diluted and diſſolved by the Waters, the Sea becomes impregnated with its Particles throughout; and for this Reaſon, the Saltneſs of the Sea can never be diminiſhed *.

A. Pray what is the Uſe of this ſalt Property of the *Sea?*

B. The *Saltneſs* of the *Sea* preſerves its Waters pure and ſweet, which otherwiſe would corrupt and ſtink like a filthy Lake; and conſequently none of the Myriads of Creatures which now live therein, could then have Being: From hence alſo the Sea Water becomes much heavier; and therefore Ships of greater Size and Quantity may be uſed thereon. Salt Water alſo

* Dr. *Halley* ſuppoſes that it is probable the greateſt Part of the Salt of the *Sea* and of all *Salt Lakes*, (as in the *Caſpian* Sea, the Dead Sea, the Lake of *Mexico*, the *Titicaca* in *Peru*) is derived from the Water of the Rivers which they received; and ſince this Sort of Lakes has no *Exit* or Diſcharge, but by the Exhalation of Vapours, and alſo ſince theſe Vapours are entirely freſh or devoid of Salt Particles, it is certain the Saltneſs of the Sea and ſuch Lakes muſt from Time to Time increaſe; and therefore the Saltneſs at this Time is greater than at any Time heretofore. He farther adds, that if, by Experiments made in different Ages, we could find the different Quantities of Salt which the ſame Quantity of Water (taken up in the ſame Place, and in all other the ſame Circumſtances) would afford, it would be eaſy from thence, by the Rules of Proportion, to find the *Age of the World* very nearly; at leaſt, to deſtroy the Notion of the *Eternity of all Things*. Philoſ. Tranſ. N° 344.

doth not freeze ſo ſoon as freſh Water, whence the Seas are more free for Navigation.

A. I remember *Solomon* obſerves, that tho' all the Rivers run into the Sea, yet the Sea is not full, or doth not increaſe; pray is there any aſſignable Reaſon for this?

B. Yes; there are two Reaſons why the Sea doth not increaſe. 1. Becauſe Waters return from the Sea by ſubterranean Cavities and Aqueducts, through various Parts of the Earth. 2. Becauſe the Quantities of Vapours raiſed from the Sea, and falling on the Land, only cauſe a Circulation, but no Increaſe of Water. It hath been found by Calculation, that in a *Summer*'s Day there may be raiſed in Vapours from the *Mediterranean* 5280000000, or 5280 Millions of Tuns of Water, yet this Sea receiveth not from all its nine great Rivers above 1827000000, or 1827 Millions of Tuns *per* Day, which is but a third Part of what is exhauſted in Vapours; wherefore we may rather wonder the Sea is not leſſened than increaſed *.

A. I am very much pleaſed with theſe Accounts of the *general Properties* of the Sea: But, pray, what do you ſay to that moſt obvious and wonderful *Phænomenon*, the Tide, or *Flux* and *Reflux* of the Sea?

* See the Calculation at large in Philoſ. Tranſ. N° 212, or in *Joan. Clerici Phyſica,* Lib. II. Cap. 8. It has been found, that in the Years 1699, 1700, 1701, 1702, there fell at *Townley* in *Lancaſhire*, at the Foot of the Mountains, $39\frac{3}{10}$, 43, $41\frac{2}{100}$, $51\frac{5}{16}$ Inches of Water in Depth; and at *Upminſter* in *Eſſex*, theſe Depths were, for the ſame Years, $15\frac{6}{10}$, 19, $18\frac{7}{10}$, $20\frac{4}{10}$ Inches. But Dr. *Halley* found that the Depth of the Water evaporated in a cloſe Room in one Year was but eight Inches; from whence it is plain how much the Sun and Wind contribute to the Evaporation of Water.

B. It

B. It is now very well known, that the Tides are caused by the Attraction of the Moon, and are sometimes increased by the Attraction of the Sun conspiring therewith, as in Conjunctions, or new Moons, and those we call *Spring-Tides*; sometimes the Sun's Attraction acts counter to the Moon's, as in the Quadratures, and then the Tides are lessened, and are what we call *Neap-Tides*.

A. Pray be so good as to illustrate the *Doctrine of the Tides* by a Scheme.

B. I will. Suppose then C be the Earth, *Fig.* XXXVII. on *Plate* XXII, fronting *p.* 262, surrounded by Water PTN, M the Moon in Conjunction with, and O in Opposition to the Sun in S, and in her Quadratures from the Sun in Q: Now it is plain the Part of the Ocean T, to which the Moon M is perpendicular, will gravitate to the Moon more than any other Parts in the *Hemisphere* e T n; and therefore the Water in that Part will become lighter than usual, and so will tumify and rise up towards the Moon. On the contrary, the Water in N, being most remote from the Moon M, will be less attracted, or gravitate less towards the Moon, than any other Parts of the Land or Sea in the *Hemisphere* e N n; and therefore will keep at farthest Distance from the Moon, or, which is the same Thing, it becomes lighter than usual, and tumifies on the Part N, contrary to the Moon M. By this Means the Ocean must of Necessity conform itself to an oval Figure, whose longest Diameter is TN, and the shorter *en*: Now, because the Tides at T and N are existent both at the same Time, and oppoſite to each other, it is evident, they following the daily Courſe of the Moon, that they muſt conſtantly ſucceed each other under every Meridian at the Diſtance of 12 Hours Time, and therefore twice each Day, as we ſee they do. Do you apprehend me ſo far ?

A. Yes, very well ; pray proceed.

B. Then the reſt will be ſtill eaſier : For ſuppoſe (as Sir *Iſaac Newton* has) that the Attraction of the Sun be to that of the Moon at our Earth, as 1 to $4\frac{48115}{100000}$, or nearly, as 1 to $4\frac{1}{2}$; that is, as 2 to 9. But Mr. *Domkey* has ſince made it to be as 1 to $5\frac{10948}{1000000}$, or as 1 to 5, or more nearly ſtill, as 10 to 51 (whoſe Numbers I ſhall uſe) : I ſay, ſuppoſing this be the Proportion of the Sun and Moon's Power of attracting the Waters of our Seas, then it follows, that when the Sun and Moon are in Conjunction, the Waters at T and N will be attracted by both theſe Powers jointly; but, when the Moon is in Square to the Sun, that is, when thoſe Luminaries are in M and Q, then the Power of the Sun in Q acts contrary to that of the Moon in M ; and then the Waters in T and N are raiſed only by the Difference of thoſe Powers ; ſo that the *Spring-Tides* will be to the *Neap-Tides*, as the Sum to the Difference of thoſe Powers ; that is, as 6 to 4, or as 61 to 41. So that, if the Sun be able to raiſe the Water 1 Foot 11 Inches, the Moon will raiſe it above 9 Feet 7 Inches, and both together, about $11\frac{1}{2}$ Feet, which is ſtill greater, as the Moon is nearer the Earth.

A. Pray in what Parts of the Earth are the Tides greateſt of all ?

B. About

B. About the Æquator or Middle of the Earth: For the greater the Circle, in which the Tides revolve, the greater will be their Agitation; and were the Moon placed in the Pole, the Tide would remain immoveable about that Pole.

A. Are the Tides always largeſt preciſely at the Time of new and full Moons?

B. No; for by Reaſon of the Water's Libration, thoſe Tides are ſomewhat changed, being greateſt about three Tides later.

A. Are the ſame Tides (viz. *Spring* or *Neap*) in the ſame Place, all the Year round, equal?

B. No; for, as I ſhewed you a while ago, the Earth is ſomething nearer the Sun in the *Winter* than in the *Summer*; therefore the greateſt Equinoctial Tides are obſerved to happen ſome Time before the vernal Equinox, and after the autumnal one.

A. Does the different Poſition of the Moon in her Orb make any Difference of the Tides?

B. Yes; becauſe in the diurnal Revolution of the Moon, that Tide of the two ought to be greateſt, in which the Moon is neareſt to the *Zenith* or *Nadir* of the Place; therefore with us, the Moon being neareſt our *Zenith* in the *Northern* Signs, when above the Horizon, muſt then cauſe the greateſt of the two Tides when ſhe paſſeth our Meridian; but being neareſt the *Nadir*, when in the *Southern* Signs, ſhe makes the greateſt Tide here, when ſhe paſſeth the oppoſite Meridian, below the Horizon *.

A. Do

* Theſe, and all other Affections of the Tides ariſing from the different Latitudes of Places, will be eaſily and beſt underſtood by *Fig.* LXVI. on *Plate* XX, fronting *p.* 253. Where APE*p* is

 the

A. Do all these *Phænomena* of the Tides agree with Observations every where, or in all Parts of the Sea?

B. Very sufficiently in the main Oceans; but are more or less altered and interrupted in *Bays, Straits, Havens*, &c. where those general Causes cannot produce their Effects freely. And thus I have related to you all the general Affections of the Tides, which you may reduce to particular Cases yourself.

A. *Sir*, I am extremely obliged to you: pray tell me in the next Place whence *Fountains* and *Springs* may arise?

the Earth covered over with very deep Waters, C its Centre, P*p* its Poles, AE the Equinoctial, F*f* the Latitude of a Place, D*d* another at equal Distance on the other Side the Equinoctial, H *h*, the two Points where the Moon is vertical, and let K*k* be the great Circle wherein the Moon appears horizontal.

It is evident that a *Spheroid* described upon H*h* and K*k* shall nearly represent the Figure of the Sea; and C*f*, CD, CF and C*d*, shall be the Heights of the Sea in the Places *f*, D, F, *d*; in all which it is *High Water*: And seeing that in 12 Hours Time, by the diurnal Rotation of the Earth, the Point *f* is transferred to F, and *d* to D, the Height of the Sea CF will be that of *High Water* when the Moon is present, and C*f* that of the other *High Water* when the Moon is under the Earth; which in the Case of this Figure is less than the former CF. For CF is near the greatest Semi-diameter of the Spheroid CH, and C*f* is nearest the least CK.

And in the opposite Parallel, D*d*, the contrary happens; the Rising of the Water being always alternately greater and less in each Place when it is produced by the Moon's declining sensibly from the Equinoctial, that being the greatest of the two *High Waters* in each diurnal Revolution of the Moon, wherein she approaches nearest either to the *Zenith* or *Nadir* of the Place. Consequently, the Moon in the Northern Signs in that Part of the World makes the greatest Tides when above the Earth, and in the Southern Signs when under the Earth; the Effect being always the greatest where the Moon is farthest from the *Horizon* either above or below it; and this alternate Increase and Decrease of the Tides has been observed to hold good on the Coast of *England*, at *Bristol* by Captain *Sturmy*, and at *Plymouth* by Captain *Colepresse*. Philos. Trans. N° 226.

B. Foun-

B. *Fountains*, or *Springs*, are of two Sorts, *viz.* 1. Thofe which run in the *Winter*, and dry up in the *Summer*, called *temporal*: And, 2. Thofe which conftantly keep running, called *perennial Springs*. *Temporal Springs* arife generally from great Rains which fink thro' the Surface of the Earth, and are collected in the Crevices, and fubterraneous Veins and Channels, and feveral fmaller ones uniting, form larger Courfes, which tend, thro' various Windings and Declivities, to fome Part of the Earth's Superficies, where they break thro' and difcharge themfelves in little Streams and Brooks. Thofe which are called *perennial*, are fuppofed to derive their Waters from the Ocean itfelf, by Ducts and hollow Paffages running thence through the Bowels of the Earth to various Parts of its Superficies, where they difcharge themfelves, as do others. But many very learned Naturalifts are of Opinion, that thefe are fupplied with their Waters, if not wholly, yet chiefly, by *Rain*, as well as temporal *Springs*. The Learned are varioufly divided in their Judgments about the Original of *Springs*: However, this we know, that Lakes, Wells, and feveral Streams, and fome great Rivers, owe their Original intirely to Springs; as alfo all Baths and Fountains are only a Collection of Waters iffuing from thofe *Springs**.

A. It

* The great Number of thofe who hold that Springs are derived from the Sea, and of thofe who afcribe their Original to Rain and diffolved Snow, fee in *Johnfon's* Quæft. Philofophicæ, Cap. 2. Quæft. 34.

Dr. *Woodward* has an Hypothefis which makes the Origin of Fountains to confift in an Abyfs of Waters in the Bowels of the

 Earth

A. It is true, that I can ſee with my Eyes: But, pray, whence is it that their Waters have ſuch vaſtly different Qualities?

B. From the Qualities and Temperament of the Soil or Earth through which thoſe ſubterranean Waters paſs. Thus thoſe Waters which paſs thro' Lays or Beds of metallic or mineral Earth, carry along with them ſome of thoſe mineral Particles, and thence become endued with the Quality of thoſe Metals and Minerals; and thus we call them *mineral Waters*, of which there are various Species, as *acid*, *bitter*, *hot*, *cold*, *oily* or *fat*, *coloured*, *boiling*, *petrifying*, *ſalt*, &c. which conſtitute various Kinds of Baths and Wells of medicinal Waters: Thus thoſe Waters which boil up *hot*, are made ſo by ſubterranean Fires and Fumes of Sulphur, and other inflammable Subſtances. Thoſe which are *ſalt*, contract their Saltneſs from the Quantities of Salt they paſs through in the Earth; and thoſe which are *oily*, &c. from the ſulphureous and bituminous Matter melted in the Bowels of the

Earth; which Water, he ſays, is made to aſcend by Means of ſubterranean Fire. But Dr. *Arbuthnot* has refuted this Doctrine in his Examination of the Doctor's Hiſtory.

All this Time the moſt plauſible and commonly-received Hypotheſis concerning the *Origin of Fountains*, is that of Dr. *Edmund Halley*, viz. *The Condenſation and Precipitation of Vapours from the Tops of high Mountains by a cold and rarefied Air*; where, ſays he, the Water gleeting down by the Crannies of the Stone, Part thereof enters into the Caverns of the Hills, and gathers together as in an Alembic into the Baſons of Stones it finds; which being once filled, all the Overplus runs over by the loweſt Place, and breaking out by the Sides of the Hills, forms ſingle Springs. Many of theſe running down by the Vallies, form *Rivulets* or *Brooks*; many of theſe uniting their Streams in the Valley, and gaining plain Ground, become leſs rapid, and form a *River*; and many of theſe being united in one common Channel, make ſuch Streams as the *Rhine*, the *Rhone*, the *Danube*, &c. Philoſ. Tranſ. N° 192.

Earth by Heat and Spirit; and ſo of the reſt. Thus *Varenius.*

A. Pray, to conclude this Head, what do you think of the Original of *Rivers* ?

B. Some of them riſe, as I ſaid, immediately from Springs themſelves; others from the Conflux of many ſmaller Streams, Brooks and Rivulets, which together make one great Current or Stream. *Laſtly*, Vaſt Defluxions of Rain, melted Snow, condenſed Vapours, *&c.* from the Sides of high Mountains, tear up the Earth, and form the largeſt Channels and Rivers in the World, whoſe rapid Streams all run into the Sea in ſome Part or other.

CHAP. IV.

PHYTOGRAPHY, *or the* PHILOSOPHY *of* PLANTS *and* VEGETABLES, *of* VEGETATION, *of their Production, of the* SEED, *and* SEED PLANT *of the* ROOT, *of the* BLADE, STALK *and* TRUNK, *of the* BUD, LEAVES *and* FLOWERS, *of the* FRUIT, &c. *of the* PERSPIRATION *of Plants,* &c.

A. PLEASE, *Sir*, to explain to me the Word *Phytography.*

A. It is compounded of φύτον, a *Plant*, and γραφὴ, a *Deſcription*; and thus it implies a *phyſiological Deſcription of Plants*, and all Kinds of *Vegetables.*

A. Pray, *Sir*, what do you call *Vegetables* ?

B. All ſuch natural Bodies as grow and increaſe from Parts organically formed, or ſerving as Inſtruments to convey the Principles of vegetative Life; but have no proper Life or Senſation; ſuch as Plants, Shrubs, and Trees.

A. Pray explain to me what you mean by *vegetative Life*, or *Vegetation*.

B. The Faculty or Quality which Plants are endued withal, whereby they attract Nouriſhment, or nutritious Juices from Earth, and which circulating their Subſtance, cauſeth it to extend, unravel, or unfold its Parts by Degrees, till at length every Part turns out in its proper Form and Site, and thus the Plant is perfected.

A. Do you ſay, that the vegetable Life and Growth of Plants and Trees proceed from the Juices of Earth, and not from the Earth itſelf?

B. Yes, and that is the Truth; For Mr. *Boyle* found by Experiment, that a Plant of three Pounds, and after that, a Plant of 14 Pounds, were produced from a Quantity of Earth, watered only with Rain or Spring Water, which loſt ſcarce any Thing of their Weight, being preciſely weighed dry, before and after the Production of the Plants.

A. Indeed, I cannot ſay but ſuch an Experiment undeniably proves, that Plants receive their Growth and Weight from the Moiſture of the Earth altogether, and not from the Subſtance of the Earth itſelf.

B. Yes, I can give a more convincing Inſtance yet: *Van Helmet* dried 200 lb. of Earth, and therein planted a Willow weighing 5 lb. which he watered with Rain or diſtilled Water, and to ſecure it from other Earth getting in, he covered it with a perforated Tin Cover: After five Years, weighing the Tree with all the Leaves it had borne in that Time, he found it to weigh 169 Pounds three Ounces, but the Earth to have loſt only about two Ounces of its Weight *.

A. Sir, I am fully convinced and ſatisfied of this Matter: But, pray, how is the firſt *Generation* or Production of Plants accounted for?

B. All Plants and Vegetables are immediately produced and generated from ſome *Parent Plant,* or *Vegetable Seed,* of the ſame Species.

A. How can this be, when Plants have been often found to grow where Seeds were never ſown, or could come?

B. There may be a three-fold Anſwer given to your *Query:* For, 1. It is poſſible thoſe Plants may ſpring from Seeds which may have lain hid in the Earth in thoſe Places more than the Age of Man; for ſome Seeds retain their Fecundity 40 or 50 Years. 2. They might riſe from Seed wafted thither by the Wind, which by Reaſon of its wonderful Smallneſs could not be ſeen. 3. Thoſe Seeds alſo might be brought thither in the Dung of Animals at firſt, and ſo increaſe. However, nothing can be more effectually confuted than the atheiſtical Doctrine of the *ſpontaneous Production,* or *equivocal Generation* of Plants or Animals, in the Works of Modern Naturaliſts †. *A.* Well

* See alſo Dr. *Woodward*'s Experiments relating to this Matter, Philoſ. Tranſ. N° 253. *Harris*'s Lexicon, under the Word *Vegetation*; or in the *Philoſophical Library,* under the Title *Botany,* Page 437.

† By the *ſpontaneous Production* of Plants is meant, their *growing*

A. Well then, ſince you will have it that *every Plant* is produced from the *Seed of a Plant* of the ſame Species, be pleaſed to explain how this may be.

B. It is the Doctrine of modern *Phyſiologiſts*, that every Seed hath in itſelf what they call *Planta Seminalis*, or *Seed Plant*; that is, that the Plant which is produced from the Seed, is really and formally contained in the Seed (before it is ſown) in *Miniature*; and when the Seed is ſown, the Parts of the *Seed Plant*, now in *Embryo*, begin to vegetate, unfold, dilate, and at laſt burſt the *Matrix Seed*, and ſo ſwell out of its native Bed of *Embryoniſm*.

ing, as it were, of their own Accord, or *without Seed*; and this in regard of *Animals* is called *Equivocal Generation*, whereby they are produced without Parents *in Coitu*.

That this Doctrine is *directly Atheiſtical*, is but too manifeſt; for ſuppoſing the Generation of ſome Plants and Animals to be ſpontaneous or caſual now, we can't tell but that the Generation of all might have been ſo at firſt; and if the Being of any Thing be caſual, or proceeding from *Chance*, it is certain all we can find in the Nature or Compoſition of ſuch a Being, muſt alſo be fortuitous or by Chance. And thus all the Arguments derived from the wonderful Mechaniſm of the Whole, and the ſurpriſing Structure of the ſeveral Parts of *vegetable* and *animal Bodies* (the two great Magazines of Natural Religion) are utterly deſtroyed. But this is ſo notoriouſly contrary to common Senſe and Reaſon, as to need no Refutation.

Indeed, to thoſe who know not the Uſe of the Microſcope, and have made no nice Enquiry into the Nature of Things, but conſider every Thing in a rude and vulgar View, there may poſſibly appear ſome ſpecious Arguments for *ſpontaneous Generation*; but they who are willing, may ſee them all confuted in *Bentley's Boyle's* Lect. Sermon 4. *Derham's* Phyſico Theol. Book IV. Chap. 15. Note (1.) *Watts's* Philoſ. Eſſays, Eſſay 9. *Wollaſton's* Relig. of Nature, Page 88. *Fr. Redi* Exper. Nat. & de Gen. Inſectarum. *Ray's* Wiſd. of God, Page 344. *Clerici* Phyſ. Part. IV. Cap. 2. § 33, & ſeqq. *More's* Antidote againſt Atheiſm, Book II. Chap. 6. *Harris's* Lexicon, at the Word *Generation*. With the ſeveral Authors mentioned in *Johnſon's* Philoſ. Quæſt. Page 26, 27, and 33, 34.

A. Pray

A. Pray how came they by ſuch a ſtrange Notion of the Production of *Vegetables*?

B. By the Help of a *Microſcope*; for thereby they have diſcovered and ſeen the involved *Stamen* of the future Plant in every ſingle Seed, which is a very curious and delightful Spectacle indeed *.

A. Why then, according to this new Doctrine, the firſt original Seed of each Kind (at the Creation) contained in it all the future Seeds and Plants, which were produced from it in all ſucceeding Ages; and yet itſelf no bigger then, than we ſee it now.

B. Yes, it did ſo indeed; and what is proved to be Fact, cannot be called in Queſtion.

A. I cannot help queſtioning it: Is it poſſible, for Inſtance, that one of our white boiling Peaſe (which is capable of producing above an Hundred-fold each Year) ſhould at the Time of the Creation contain within its ſmall globular Bulk (about $\frac{1}{4}$ of an Inch Diameter) all that yearly Product of Peaſe, Cods, and Haulm or Stalk, of that Kind ever ſince?

B. You know Matter doth conſiſt of Parts or Corpuſcles, inconceivably ſmall; and to raiſe your Admiration the higher, let us make the

* By the *Stamen* is to be underſtood thoſe Rudiments or ſimple original Parts of a Plant or Animal which firſt exiſt in the *Embryo* or *Fœtal State*, or in the *Seed*; and which afterwards, by Diſtinction and Accretion of nutritious Juices, extends itſelf to its utmoſt Bulk, and then the Plant or Animal is ſaid to be perfectly formed, or arrived to its mature State. This, in Plants, is likewiſe called *Germen* or *Gem*, alſo *Plantule*, or ſmall Plant; and may be ſeen in all Seeds with the Microſcope, and in ſome with the naked Eye, as the Bean, and eſpecially the Kidney-Bean, where the very Ribs of the Leaves of next Year's Plant are viſible in the Seed of this.

following Calculation: Suppoſe in your own Caſe, that one white Pea will produce an 100 in the firſt Year; then thoſe 100 will produce each an 100 more the ſecond Year, and ſo in all 10000; theſe would produce in the third Year 1000000, in the fourth Year 100000000, in the fifth Year 10000000000, and ſo on, increaſing each Year in a geometrical Proportion, whoſe common Ratio is 100; ſo that the Product in any Year will be expreſſed by a Number conſiſting of an Unit, with ſo many Cyphers annexed, as is equal to twice the Number expreſſing that Year; therefore ſuppoſing the Age of the World were 5673 Years this preſent Year, then all the Peaſe produced from that one Pea, to this Time, would require a Number, conſiſting of 11346 Places of Figures, to expreſs them: But the Number of Peaſe (reckoning 50 to a Foot in Length) which would be contained in a Cube circumſcribing the Orb of the Planet *Saturn* (which Orb is 1554000000 Miles in Diameter) would require no more than 44 Places of Figures to expreſs them: The Quantity of Peaſe hitherto produced would equal ſuch a Number of thoſe immenſe Cubes, as would conſiſt of 11303 Places of Figures; which is vaſtly beyond all Compariſon and human Thought! Beſides the far greater Quantity of Haulm, Cods, Roots, Leaves, *&c.*

A. Well, thoſe who are bleſt with the Gift of Credulity to believe any Thing, may believe this; for my Part, I think it is the greateſt Impoſſibility, that a ſmall Pea ſhould contain the Quantity of Matter beforeſaid, which is ſuffi-

cient

cient to fill Millions of Millions of Millions of Worlds.

B. Then I find there is no making a modern modish Philosopher of you, *Sir*, in every Point?

A. No, I cannot but think in this Case they are some Way mistaken. I remember you told me, the Vulgar were often deceived by Vision without a Glass; and it is possible the Learned may be sometimes with one: But leaving this to the Inventors, pray what Kind of Process doth Nature take to raise the Plant from the Seed in the Ground?

B. The Method of Nature here (as in all her other Works) is most admirable, as will appear in the curious Mechanism and Construction of a Bean Root, for Instance; (see *Fig.* XXXVIII. on *Plate* XXII, fronting *p.* 262.) In that *Figure* AB represents the two Lobes of the Bean slit, which are joined together by a little white Sprig in O; in each Lobe you see the Branches *aaa*, of that called the Seed Root *ee*, every where displayed thro' the Body of the Bean: These Branches of the Seed Root *ee* feed the little Sprout, or Earth Root *oc* (descending downwards) with the Pulp or Matter of the Bean (prepared by the Ferment of the Earth) till the said Earth Root is capable of penetrating the Earth, and extending its Parts sufficiently enough to extract, for itself and the Plant it is to sustain, Nourishment from the Juices and Moisture of the Earth: For from this Earth Root there springeth upward the Sprout F, called (by Dr. *Grew*) the *Pluma* or *Feather*; and in this Pluma, and the Earth Root together, is contained, in *Miniature*, all the future Plant.

A. Why then it appears, that the Matter or Subſtance of the Bean ſerves much the ſame Purpoſe to the Seed Root, as the Yolk of an Egg to the Embryo Chick; or as the Earth doth afterwards to the Radicle, or Earth Root itſelf?

B. Yes, it doth ſo; and having enabled the Earth Root to ſhoot into the Earth, in order to procure its own Nouriſhment, it is then, by Means of the Seed Root, turned to the Uſe of the *Pluma*; cauſing it alſo to ſprout upwards, in order to become a Trunk hereafter.

A. What becomes of thoſe Seed Lobes AB, when the Earth Root no longer requires their Uſe?

B. They are, in moſt Seeds, carried upwards with the *Pluma* out of the Earth, after which they compoſe the *Seed Leaves*, as they are called, as in *Cucumbers* and *French Beans* we ſee them.

A. What is the Uſe of thoſe *Seed Leaves* to Plants?

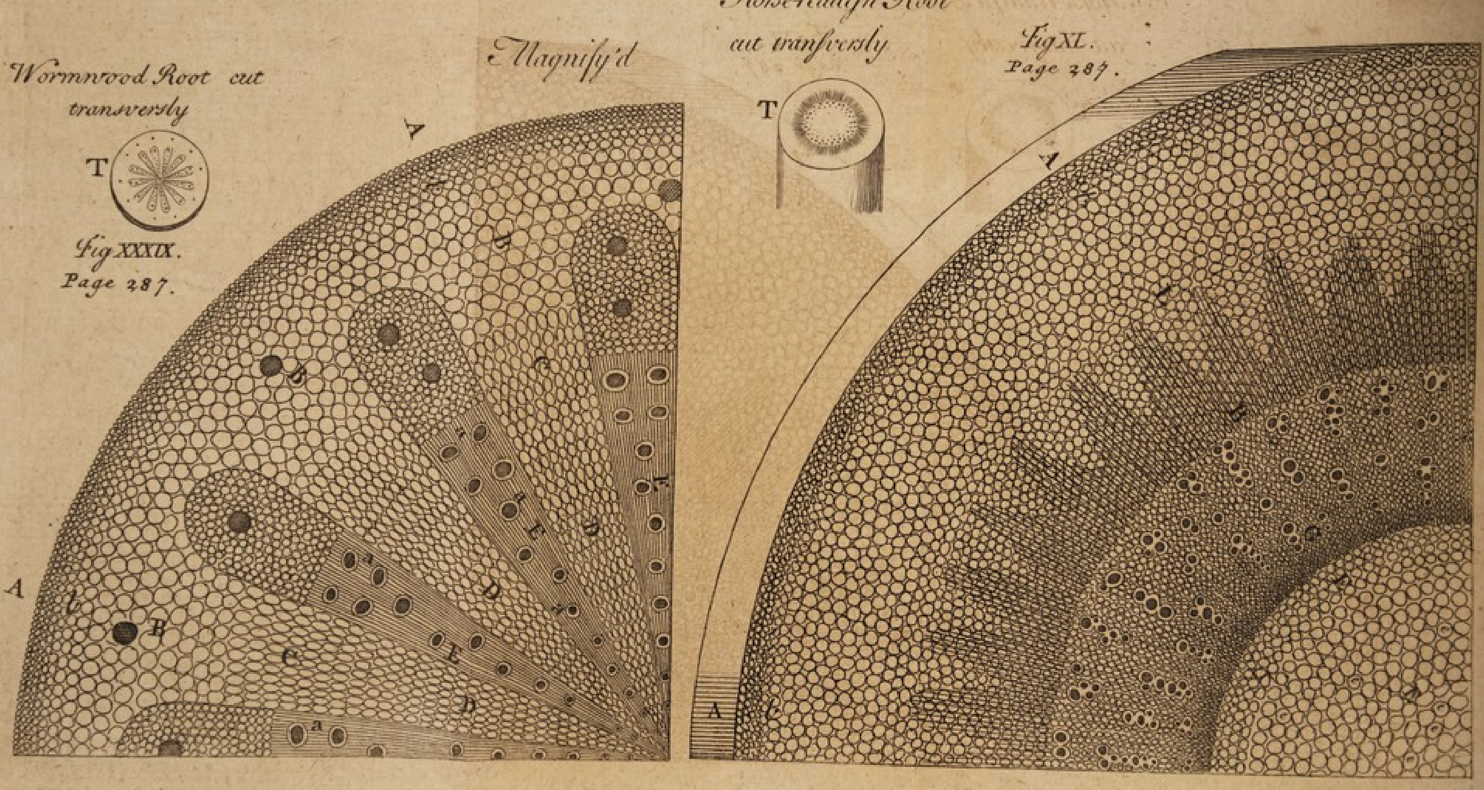
B. The Effects and Uſes of theſe Seed Leaves (ſaith the learned *Malpighi*) are ſo neceſſary, that if they are pulled off, the Plant will not grow; or if it ſhould any Way increaſe, it won't be compleat, but always defective. The Learned are divided as to their particular Uſes to Plants.

A. In the next Place, pleaſe to let me know particularly in what Manner the Root of the Plant procures Nouriſhment for its Growth and Increaſe.

B. In order to this, I muſt ſhew you the Make and Conſtruction of the Root, and, as it were, anatomize the ſeveral Parts to your View;

and

To front Page 287. Plate XXIII



and then point out their Uſes. To this End, I ſhall chooſe two Roots, *viz.* a Root of *Wormwood,* as *Fig.* XXXIX. on *Plate* XXIII, fronting *p.* 287; and a *Horſe-Radiſh* Root, *Fig.* XL. on the ſame Plate; in each of which, T repreſents the Root cut tranſverſely as it appears to the naked Eye: The other great quadrantal Figures are each a Quarter of the aforeſaid Section T, magnified to the Sight by a *Microſcope*; which thus enlarged, ſhews the various organical Parts of which it is compoſed, and by which Vegetation is performed.

A. And does this Glaſs, indeed, thus magnify and enlarge the ſmall Section T? What wonderful Diſcoveries have been reſerved for this curious and inquiſitive Age! Pray deſcribe to me the different Appearances of thoſe magnified Sections.

B. I will, in the following Order. 1. A*b* is the Skin or Rind, or outward Membrane including the Root. 2. From A to C in the *Wormwood* Root is the Bark, which is a membranous Subſtance, conſiſting partly of a great Number of little Bladders or Veſicles BBB; the ſame is repreſented by AB in the *Horſe-Radiſh* Root: It alſo conſiſteth in Part of a ligneous or woody Subſtance, as from B to L in the Root laſt named. 3. The Wood of the Root is all that Part between B and E in the *Horſe-Radiſh* Root; and from CC, to the very Centre in the *Wormwood* Root. 4. The Wood of the Root conſiſteth alſo of two different Subſtances, *viz.* a ligneous one, properly the Wood, as EEE, and a parenchymous one, like that of the Bark, as DDD,

DDD, inserted regularly between the Portions of Wood; these are very distinct in the *Wormwood* Root, but in the *Radish* Root, and in several others, they are not so visible. 5. In the Wood you see the Orifices of several Tubes, or hollow Veins *aaaa*, which are the Mouths of Air-Vessels. 6. From G to E, in the *Radish* Root, is another little Circle of Vessels, like those of the Bark. 7. *Lastly*, From E to the Centre, in the *Radish* Root, is the Pith, which consisteth of the same parenchymous, or spongy Substance of Bladders, as doth the Bark, and Part of the Wood; but the Pith is not common to all Roots, as you see there is none in the *Wormwood* Root *.

A. And, pray, what is the Use of the several Parts of the Root now described?

B. The Bladders in the Bark render it a spongy Substance, which therefore is fit to imbibe and suck up the watery Parts of the Soil, which are impregnated with the Principles of vegetable Life and Growth: This impregnated Water imbibed by the Bark is what we call the *Sap*; the Skin of the Root serving as a Filtre, to strain and purify it at its first Entrance. 2. The *Sap*, thus strained and imbibed, doth ferment in the Substance of the Bark, whereby it becoms farther prepared, and so doth more easily insinuate itself into the parenchymous Sub-

* The Word *parenchyma* was formerly used to denote that red fleshy Substance which lies between the Interstices of the Vessels in the Bowels, and gives them their Bulk; as in the *Liver*, *Kidneys*, *Spleen*, &c. from whence it was afterwards used to signify the soft, spongeous, or pulpy Parts of any Body, as of the Leaves, Roots, &c. of Plants. And hence it is usual to say, such Parts are *parenchymous*, that have such a Matter and Texture.

stance

ſtance of the Root; whereupon, partly by the Appulſe of freſh *Sap*, and partly by the pulſive Motion of the extended Bladders of the *Parenchyma*, the *Sap* is forced thence into the other Parts of the Root; and is ſtill more and more ſtrained in its Paſſage from Bladder to Bladder.

3. The *Sap*, thus diſtributed through the whole Root, doth ſupply its organical Parts with thoſe Principles of Nouriſhment which every one requires; and thus the Root, by the conſtant Application of thoſe nutritious Principles, receives its *Increment*, *Solidity*, and *Growth*, or *vegetative Life* and *Motion* in every Part.

A. To what End do thoſe you call Air-Veſſels ſerve?

B. In them is contained a proper Kind of vegetable Air or Vapour, which ſerveth to ferment the *Sap* now entering the ligneous Part, the better to qualify it for Aſſimilation, or uniting therewith.

A. Why, I pray, do the Roots of ſome Plants yield a milky Juice or Liquor, and others a clear watery one, when cut?

B. Becauſe that in each Root, the Fluid or Liquor of each organical Part is made chiefly by different Filtration of the *Sap* through the Sides thereof; therefore thoſe which ſtrain more freely the aqueous or watery Part of the *Sap*, contain a *Lympha*, or clear Water; and are hence called *Lymphæducts*; and where theſe are moſt numerous in Roots, ſuch Roots, when cut, will bleed a *Lympha*. As, on the other Hand, thoſe Veſſels, which are diſpoſed to admit the oily or balſamic Part of the *Sap* moſt copiouſly, are called *lactiferous Veſſels*; and Roots, which contain a great Plenty of thoſe, will, when cut, bleed a milky, oily, or balſamic Liquor.

A. When the Root is thus formed, and inſtructed with all its ſeveral Organs of Vegetation, as you have now related; pray which is the next Step which Nature takes in the Production of the Plant?

B. The Root being now become the Procurator for the future Plant, doth, by extracting from the Earth, by its Veſſels, proper vegetable Juices and Aliment, adminiſter or communicate the ſame to the *Pluma*, or *Seed-Plant* (ſuſtained, till now, from the Subſtance of the Seed, by the Seed-Root, or Seed-Leaves) and thereby cauſeth it to ſhoot forth vigorouſly and increaſe, and gradually to ſwell out or unfold all its Blades, Branches, Buds, Leaves, Flowers, and Seeds again, from various Parts of its Stalk or Trunk.

A. Then, I ſuppoſe, the ſame Mechaniſm, or *Apparatus* of organized Parts, is continued from the Root to the Trunk or Stem of the Plant for the Communication of this vegetable Suſtenance; is it not?

B. Yes; and that you may ſee it is ſo, I have taken *Fig.* XLI. on *Plate* XXIV. fronting *p*. 290, from Dr. *Grew*, for your Satisfaction: In which T repreſents one Quarter of a Section of a Haſle-Branch, as it appears to the Eye; AGB is the ſame as it appears through a good *Microſcope*; wherein AB is the Skin; ABCD the Bark; QQQ the Parenchyma of Bladders, or Sap-Veſſels; HI a Ring of a ſpecial Sort of Veſſels: PP common Sap-Veſſels; CDEF the

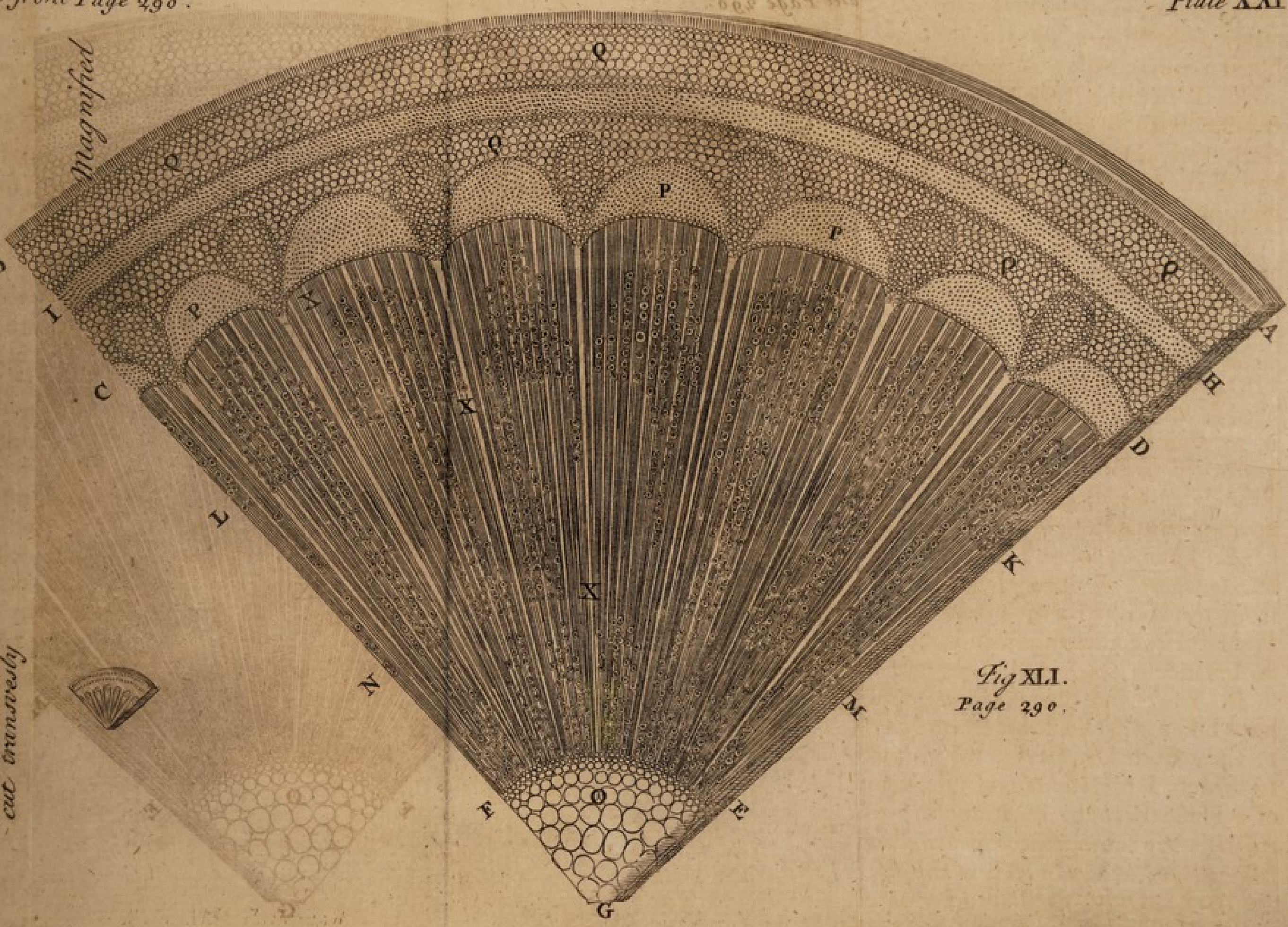


Fig XLI.
Page 290.

ligneous Subſtance, or Wood, of three Years Growth; KLFE the Wood of two Years; MNEF the Wood of the firſt Year; XX the *parenchymous* Inſertions; O the Pith full of Veſicles; the black Parcels are the ſolid Wood; thoſe numerous Holes appearing all over the ſame, are the Mouths of Air-Veſſels: Thus you ſee the organical Conſtitution of the Stalk, or Trunk, is the ſame with that I before ſhewed in the Root.

A. It is ſo indeed, and I am ſurprized to ſee ſuch wonderous Contrivance and Analogy of the Organization of Vegetables! But, pray, go on.

B. The nutritious *Sap* aſcends the firſt Year of a Plant's Growth by the Veſſels of the Pith; after which the Pith becomes dry, and ſo continues. 2. The next Part, through which the *Sap* riſeth, is the Wood, by the Air-Veſſels, and that only in the Spring. 3. The third Part, by which it aſcends, is the Bark, as before ſaid, the greateſt Part of the Year; and this is the general Theory of the Motion of the *Sap* *.

* Thus the learned Dr. *Grew*; but it is a Matter of great Controverſy how the Sap aſcends, and what Courſe it takes after it is imbibed by the Roots, whether it is by the *Bark*, the *Pith*, or the *Wood*, or all, as above-mentioned. The Retainers to each Hypotheſis, and the Arguments produced to ſupport it, ſee in *Shaw*'s Notes to *Boerhaave*'s Chymiſtry, p. 146, 147, and 148 of the Theory.

Some Naturaliſts ſtrongly maintain a *Circulation of the Sap* in Plants and Trees: But the Reverend Mr. *Hales*, in his *Vegetable Statics*, will not allow it, but endeavours to prove the contrary, Vol. I. Exper. 46, *&c.*

Dr. *Boerhaave* ſays, that, ſince the Sap is furniſhed by the Earth, it will conſiſt of ſome *foſſile Parts*, ſome Parts delivered from the *Air* and *Rain*, and others from putrefied Animals, Plants, *&c.* and that therefore in Vegetables are contained all Kinds of *Salt*, *Oil*, *Water*, *Earth*, and probably all Kinds of Metals too, ſince their Aſhes always afford ſomewhat which the Loadſtone attracts. *Theory of Chymiſtry*, by *Shaw*, Page 147.

 A. But,

A. But, ſince both Root and Branch contain Air-Veſſels, pray, in what Part of the Plant doth the Air firſt enter it?

B. The chief Entrance of Air is at the Root, along with the *Sap*; but it alſo enters, more or leſs, at the Trunk, Leaves, *&c.* Parts of the Plant: The Air, or airy Part of the *Sap*, being thus raiſed in its proper Veſſels, is filtred through the ſame into the Veſicles of the parenchymous Inſertions in the Wood; and thus is diſtributed through all the Parts of the Plant or Tree *.

A. Pray why are the Stalks of ſome Plants hollow within?

B. Partly for the more expedient Ripening of the Fruit or Seed, which is better effected by a more plentiful Supply of Air by theſe hollow Trunks; and partly for the better determining the true Age of the Plant; for the Air in this Hollow, by drying up the *Sap*, ſhrinketh the *Sap*-Veſſels ſo far as to hinder the Motion of the *Sap* therein; whence the Plant muſt periſh of Courſe: Hence it is, that the greater Part of annual Trunks are hollow.

A. Pleaſe next to ſay, whence the Form or Figuration of the Trunks of Plants and Trees proceeds?

B. Chiefly from the Air in the Air-Veſſels: Thus almoſt all Shrubs have a greater Number of Air-Veſſels, and thoſe of a ſmaller Size;

* Mr. *Hales* has proved, by many curious Experiments, that all Plants perſpire in a conſiderable Degree, but *Ever-greens* the leaſt of any. He diſcovered, that the Quantity of Nouriſhment, imbibed and perſpired in a *Sun-Flower*, is to that of a Man, Bulk for Bulk, as 17 to 1. *Veget. Statics*, Exper. 1.

which, therefore, moſt eaſily yielding to the magnetic Attraction of the external Air, do conſequently ſpread much abroad; by which ſpreading the Air-Veſſels do ſooner and more eaſily ſtrike into the Bark, and ſo produce collateral Buds and Branches, and that upon the firſt Riſing of the Plant from the Root; and thus it becomes a Shrub: But, if the ſaid Air-Veſſels are very large, as in Oak, Walnut, Elm, *&c.* they will not ſo eaſily yield or ſhoot out collaterally; and ſo the Trunk grows up taller and more entire.

A. Why do ſome Trees run up ſo very ſlender, and others ſo very thick and big?

B. This is from the Poſition of the Air-Veſſels; for where they lie moſt circular round the Center in Form of Rings, as in Elm and Aſh, there the Tree in Proportion grows more tall and taper, and leſs thick: But, when the ſaid Veſſels ſpread more broad, and are poſtured in Lines from the Center, as in Oak, *&c.* then the Tree grows very thick; in this Caſe, the diametrical Growth of the Wood is more promoted than in any other: For which general Reaſon, alſo, Trees grow round or angular.

A. Pray, how comes it to paſs, that ſeveral Stalks of Plants have *Joints* or *Knots?* And what is their Uſe?

B. Becauſe, in forming the Branch or Blade, both the Rind and woody Subſtance thereof are, upon their ſhooting forth, divaricated from their perpendicular Poſture to a croſs Poſition, and as they with the other grow and thrive together, they bind and throng each other into a Knot. The Uſes of Knots are two, *viz.* for ſtrengthening the Stem, and for finer Growth; for the Knots ſerve to ſtrain and tranſmit the Juices more refined to the upper Parts, and to the Fruit.

A. How do you account for the *Production* and *Textures* of the *Leaves?*

B. The Parts of the Leaf are ſubſtantially the ſame with thoſe of the Branch; its Skin is the Continuation of that of the Branch; the Fibres, or Nerves, diſperſed through the Leaf, are only Ramifications of the Branch's Wood, or ligneous Body; the parenchymous Subſtance, which lies between the Fibres, is nothing but the Continuation of the cortical Body, or Subſtance of the Bark, ſpread through the ſame *.

A. Pray

* The Leaves of Plants (ſuch as have woody Fibres) are eaſily anatomized, and a Skeleton of the Fibres made as follows:

1. The Leaves muſt be gathered when full grown, or old, but not dry; then expoſe them in an open Veſſel of Water, and as faſt as it evaporates fill it up again.

2. After about a Month or two the Leaves will begin to putrify, or grow ſoft; and the Pellicle, or thin Skin on each Side, will firſt begin to ſeparate from the pulpous Part of the Leaves.

3. The Leaf is then to be put into a broad Pan of Water, where you have Room to ſqueeze the pulpous or green Subſtance of the Leaf, which muſt be very gently, and it will eaſily ſeparate from it, and leave an entire Skeleton of Fibres.

4. Or ſometimes I have only laid the Leaf, ſtript of its Skins or Membranes, on a Piece of Paper, where, after it has lain a little to dry, I have only taken hold of the Tail of the Leaf, and, gently raiſing it, the Skeleton has freely ſeparated from the Pulp, which adhered to the Paper.

5. In many of theſe Skeletons, as that of the Apple-Tree, Cherry-Tree, Holm, *&c.* you will find, that all the Fibres, great and ſmall, are double; or that there are two Layers or Planes of Fibres, which, you will obſerve, may be eaſily ſeparated from each other through the whole Skeleton.

6. Theſe

A. Pray what is the Uſe of *Leaves?*

B. Firſt, For Protection, which they afford to each other, and to the Flower in the Bud; as alſo to the Fruit itſelf in ſome Plants. *Secondly,* For Augmentation; for the Capacity for the due Spreading and Ampliation of a Tree, or Plant, are its Leaves. *Thirdly,* They ſerve to the greater Purity and Preparation of the *Sap;* the groſſer Parts of which are retained in the Leaves, while the more elaborate and eſſential are ſupplied to the Flower, Fruit, and Seed, as their proper Aliment. *Fourthly,* They ſerve to Perſpiration; for thoſe Orifices, obſerved to be in Leaves, perform the ſame Functions in Trees, as the Pores of the Body do in Men; that is, to cauſe an inviſible Perſpiration in Plants *.

A. Pray

6. Theſe two Planes of woody Fibres, which oppoſe the Skeleton of a Leaf, are ſuppoſed to be analogous to the Arteries and Veins of an Animal Body. But there is no diſcerning which are the arterial, and which the venal Fibres. See the Figure of the Skeleton, and its Duplicature, of an Apple-Leaf in *Fig.* LXVII. on *Plate* XX. fronting *Page* 233.

7. After a like Manner may Fruits be prepared, and Skeletons of them procured, as *Apples, Pears, Peaches,* &c. They muſt be ſound and good, pared very nicely, then boiled gently till they are thoroughly ſoft; then, taking them out, and putting them into a Baſon of cold Water, hold the Tail in one Hand, and, with one Finger and Thumb of the other, rub the Pulp gently off, and preſerve the Skeleton in Spirit of Wine rectified.

8. Carrots, and other Roots that have woody Fibres, muſt be boiled without paring till they grow ſoft, and the Pulp comes off. Not only many Sorts of Roots, but the Bark of ſeveral Trees alſo, may be reduced after this Method into Skeletons, preſenting rare and curious Views of Vegetables. *Philoſ. Tranſ.* N° 414, and 416.

* Notwithſtanding the great Perſpiration in Animals and Plants, I never yet could diſcover any Thing like Pores in the Scarf-Skin of the one, or the fine Membranes which cover the Leaves of the other; though I have often ſought them in the moſt proper Subjects, and with the beſt Sort of double reflecting Microſcopes.

 I know

A. Pray what do you obſerve concerning the *Flowers* of Plants?

B. In the *Flower* may be obſerved: 1. The *Empalement*, or *Calyx*, or the Cup, which containeth the Flower, and is deſigned for the Guard and Security of the other Parts of the Flower. 2. The *Foliation*, or Compoſure of Leaves, which are of divers Forms and Colours; whoſe conſtituent Parts are the ſame as thoſe of the Leaves, *viz.* Skin, Parenchyma, Air, and Sap-Veſſels. 3. Within the *Foliage* ſtands the *Attire*; that is, thoſe fine upright Stems with their *Apices*, and the *Style* in the very Middle of all; and theſe are the general Parts of which the Flower doth conſiſt.

A. Pray can you tell the Uſes of thoſe ſeveral Parts of the Flower?

B. The *Empalement*, as I ſaid, is for the Security of the Flower in *Embryo*, and afterwards for the Support of the Foliage, to keep the Leaves of the Flower in due and decorous Poſture, which

I know Mr. *Lewenhoek* (in *Tranſ.* N° 369) tells us, that he has viewed theſe Pores or Spiracles very clearly in the *Leaves of Box*; and that, on one Superficies of ſuch a Leaf, he has computed 172090 Pores, and on the other as many. The *Royal Society* has received and admitted this to paſs for Truth; whereas, I believe it may be eaſily made to appear, that nothing is more falſe, and that, inſtead of ſeeing 344180 Pores, he never ſaw *one*. It is no hard Matter alſo to point out the Grounds of the Fallacy, or to prove, that this is not the only Error which this *Prince* of the *Virtuoſi* has fallen into, and publiſhed to the World. But theſe Matters muſt be referred to a future Tract on theſe Subjects. I ſhall only here obſerve, that there is ſomething exceeding fine and delicate in the Texture of the Pellicle or fine Membrane which covers the Box Leaf, and alſo in the Skeleton made thereof. Alſo that the *tranſparent Spherules*, or round clear Drops, ſtanding all over the Surface of the Leaves of *Hyſſop*, *Mint*, &c. and others of other Forms and Colours on other Plants, make a very pleaſant and delightful View in the Microſcope.

would otherwiſe hang uncouth and taudry, as a Lady without her Bodice. The *Foliage*, or Leaves of the Flower, defend the Attire, and in ſome Plants the Fruit; it alſo ſerves for the further Refining and Separation of proper Parts of the *Sap* for the perfecting the Seed. The *Attire* is an Ornament and Diſtinction in Flowers. It ſupplies alſo divers Kinds of ſmall Animals with Food, which harbour therein; that is, in the Hollowneſs of the Style. *Laſtly*, it is ſuppoſed, it alſo ſerveth as *Male Sperm* to impregnate and fructify the Seed *.

A. What is the Nature and Compoſition of Fruit, I pray you?

B. The general Nature and Compoſition of all Fruit, is one and the ſame; that is, their eſ-

* That there is ſuch a Thing as a *Sex* in Plants; that ſome Plants are *Male*, others *Female*, and moſt *Hermaphrodite*; and that the Flower is the *Pudendum* of the Plant, as containing the Parts of Generation; are Points agreed on as certain by modern Naturaliſts.

2. The *Male Parts* of a Flower are the *Stamina*, or Stems, and their *Apices*, or little Tops, which contain the fine Powder, or *Farina*, which is imagined to be the *Semen*, or Sperm of the Plant.

3. The *Female Parts* are the *Style*, which ſerves to receive the Semen; and the *Seed-Caſe* at the Bottom of the Style, which is judged to be the *Matrix*, or Womb of the Plant.

4. Some Plants have only the Male Parts of the Flower, and they never bear Fruit; others the Female Parts only, and they bear Fruit. In others, as *Cucumbers*, *Melons*, *Gourds*, Walnut, Oak, Beech, &c. the *Male* and *Female* Flowers grow at ſome Diſtance from each other. But,

5. Moſt Plants are *Hermaphrodite*, or have the *Male* and *Female Parts* in the ſame Flower, as the Pulp, Lily, Polyanthus, &c.

6. The Learned can't, as yet, fully prove the Manner of Impregnation and Generation of Plants; it is generally agreed, that the *Farina* falling from the *Apices*, is received by the *Style* or *Piſtæ*, which conveys it to the Seed-Caſe below, where it impregnates the Embryo-Seed contained therein. There is much to be ſaid for and againſt this Hypotheſis, a ſhort View of which Controverſy the Reader may meet with in *Shaw*'s Notes to *Boerhaave*'s *Chymiſtry*, Page 149 and 150 of the Theory, and in the other Botanical Authors.

ſential

ſential and truly vital Parts are in all the ſame and but the Continuation of thoſe which I have already obſerved to you, do conſtitute the other Parts of the Plant. But, by the different Conſtitution and Textures of theſe Parts, divers conſiderable different Fruits reſult, as *Apples, Pears, Plums, Nuts, Berries,* &c.

A. Pray what are the particular Parts which compoſe thoſe different Fruits?

B. The *Apple* doth conſiſt of theſe four, *viz.* the *Pilling*, the *Parenchyma* or *Pulp*, *Branchery*, and *Coar*. The *Pear* hath five diſtinct Parts; the *Pilling*, the *Parenchyma*, the *Branchery*, *Calculary*, and *Acetary*. The *Plum* (to which the *Cherry*, *Apricot*, *Peach*, &c. may be referred) conſiſts of four Parts; the *Pilling*, *Parenchyma*, *Branchery*, and *Stone*. The *Berry* conſiſteth of four Parts; the *Pilling*, the *Parenchyma*, *Branchery*, and *Seed*. The *Nut* conſiſteth of three Parts; the *Cap*, the *Shell*, and *Pith*. All which are regularly treated of by Dr. *Grew* in his *Anatomy of Plants*.

A. Pray (to be ſhort) what are the principal *Uſes* of *Fruit*?

B. The Uſe of Fruit is two-fold: For, *firſt*, it ſerveth Man (and I may ſay Beaſt) as a delicious and pleaſant Meat, or Food; beſides the various Purpoſes of Medicine. *Secondly*, It ſupplies the Seed with a due, and moſt convenient *Sap*; the Fruit doing the ſame Office to the Seed, as the Leaves do to the Fruit, *viz.* that, by a due Purification and Exaltation of the *Sap*, the Seed may obtain its Perfection.

A. Pray what is the *Seed*, in its State of *Generation*?

B. As

B. As the original, ſo the ultimate End and Perfection of Vegetation, is the Seed. How it hath been in its State adapted to Vegetation, we have already ſeen. Its State of Generation is as follows: The *Sap*, having in the Root, Trunk, and Leaves, paſſed divers Concoctions and Separations, is now, at laſt, in ſome good Maturity, advanced towards the Seed. In the Fruit, as was ſaid, it is ſtill farther prepared, and the more eſſential Part is tranſmitted into that particular Part of the Branchery, called the *Seed-Branch*; which, becauſe it is a good Length, and very fine, doth yet farther maturate the *Sap* in paſſing through it: In this mature State, it is conducted through the Seed-Branch into the Coats of the Seed, as into the Womb. The meaner Part of the *Sap* to the outer Coat, the more fine is tranſmitted to the inner Coat, where it is farther prepared by Fermentation; and thence is filtred through a fine Skin into the inmoſt Part or Subſtance of the Seed, and there becomes a Liquor fit for the actuating the future Embryo-Seed, or cauſing it to vegetate, and the Plume to ſhoot forth.

A. But pray, *Sir*, before you quite diſmiſs the Subject of Plants, pleaſe to let me know what you think of *Moſs*, *Muſhrooms*, and thoſe *fungous Excreſcences* adhering to the Sides of Trees?

B. *Muſhrooms*, *Moſs*, and other *fungous* Subſtances, are a ſpurious Kind of Plants, or which may be called excrementitious Plants, ſince they ariſe intirely from the Bodies of other Plants, or from a Kind of viſcous Mucilage of the Earth: They grow, indeed, and have Roots, ſome inſerted

into

into the Fibres of the Plant producing them, as *Miſletoe* is radicated into the Fibres of the Oak; and *Moſs* to the Fibres of the Barks of Trees. *Muſhrooms* ariſe from various Matters in Earth or Wood, and are found to conſiſt of a vaſt Bundle of Fibres, proceeding from the Subſtance on which they grow; theſe make the Stalk, and thence divaricating, ſpread and extend themſelves into a ſpherical Canopy, or Head, which contains a ſucculent Parenchyma; on the under Part of which, I am apt to think, the Seed may be produced, (though none hath hitherto been ſeen) which being wafted about by the Wind, falls in divers Places of the Earth, and there takes Root and grows: Thus *Moſs* undoubtedly bears Seed, by which the various Sorts thereof are propagated; though, for their Smallneſs, they cannot be ſeen *.

A. I am

* 1. Of *Moſs*, Naturaliſts make mention of about 300 different Kinds; though thoſe which grow common are not above 50. They have great Variety in their Growth, Form, and Make; and moſt of them afford an agreeable Sight in the Microſcope. I never could diſcover any Thing like Flower-Seeds in many of them; and therefore they are truly judged to be Plants of their own Kind.

2. Dr. *Liſter* takes the Gills of Muſhrooms to be the very Flower and Seed of the Plant; indeed no other can be diſcovered by the Microſcope. The *Mouldineſs* on Leather, Paſte, Pickles, *&c.* is of the *Muſhroom* Tribe; they are well known to be of a ſpeedy Growth; they conſiſt of Multitudes of fine Stalks or Stems; on the Tops whereof grow round Heads, containing a Kind of Liquor, as I have often found by bruiſing them under the Microſcope.

3. The *Fungi*, or what we call *Jews-Ear*, *Agaric*, &c. which grow on the Rind of Trees, are of a very porous Subſtance; if the Superficies of ſome be viewed with a Microſcope, it will appear like a Honey-Comb, full of Holes, which go deep, and make a fiſtular Subſtance. In theſe there is ſtill leſs diſcernible of Roots, Flowers, or Seed.

4. The

A. I am greatly obliged to you, *Sir*, for this conciſe and regular Epitome of the *Science of Vegetation*; and conſequently the *true Theory of Plants:* I never underſtood ſo much before, nor, indeed, have I Time to peruſe *voluminous Authors.*

4. The *Puff-Balls* are another odd Sort of Production; theſe at firſt have a fleſhy Subſtance pretty firm, which by Degrees becoming more ripe, changes to a Kind of Duſt, which Mr. *Bradley* takes to be the *Seed.*

5. The *Truffle*, like the Puff Ball, is formed under Ground; it lies about ſix or eight Inches deep; is of a firm and fleſhy Subſtance within, and cortical without; the fleſhy Part, if viewed in thin Slices under the Microſcope, appears to be compoſed of roundiſh, opake, and very ſmall Particles, thickly interſperſed through a white, tranſparent, and ſeemingly vaſcular Subſtance, which runs in large and finer Veins all over the Subſtance of the Truffle. They are of two Kinds, one round, the other of an Egg-like Figure. They are of a ſtrong and very diſagreeable Odour; but are eſteemed in Food as a very delicious and luxurious Piece of Dainty. They are found very common in the Woods of *Italy* and *France*; and, of late, in divers Parts of *England.* And Dogs are here taught to hunt them out with as great Sagacity, and as eaſily, as to ſet Game.

6. As to what relates to the *Submarine* Vegetables, or thoſe which grow in and under the Sea, as the large green membranous *Seabelts*, which grow on Stones; the *Fuci*, and other *Sea-Weeds*; the *Coralines* on Stones and Oyſter-ſhells; the *Sea-Fan*; the *Coral*, which grows on *Rocks*; the *Sponge*, &c. they are ſo numerous, and various, as not to be treated of here; only this I ſhall obſerve, in general, that they appear to be deficient in Roots, Flowers, and Seeds; and are moſt of a very wonderful Texture and Make, eſpecially the *Sponge*, which makes the fineſt of Spectacles in the Microſcope.

7. For Abundance more on this Head, conſult Dr. *Grew*'s and *Malpighi's Anatomy of Plants. Tournefort's Inſtit. Rei Herbariæ. Bradley on Gardening*, and his *Philoſophical Account of the Works of Nature.* The *Spectacle de la Nature*, Vol. II. *Miller's Gardener's Dictionary*, Fol. *Ray's Method and Hiſtory of Plants. Hales's Vegetable Statics*, Vol. I. *Pomet* on Drugs. *Clerici Phyſ.* Lib. IV. Cap. 1, 2, 3. *Shaw's* Notes to *Boerhaave's Chymiſtry*, Page 142, &c. *Derham's Phyſico-Theology*, Book X. The *Philolog. Library*, under the Title *Botany*, Page 431. *Chambers* and *Harris's Lexicon. Philoſoph. Tranſ.* abridged by *Lowthorp*, Vol. II. Chap. 5. *Jones's* Continuation, Vol. IV. Part 2. Chap. 5. *Eames* and *Martyn's* Continuation, Vol. VI. Part II. Chap. 5.

CHAP.

CHAP. V.

ZOOGRAPHY, *or the* PHILOSOPHY *of* ANIMALS; *of the* HUMAN BODY, *and its solid and fluid Parts*; *a* SURVEY *of the Nature of* BEASTS, *of* FOWL, *of* FISHES, *of* INSECTS, *of* REPTILES, *of* SHELL-ANIMALS, *&c. of Health, Disease, Vigilance, Sleep, Dreams, Hunger, Thirst, Death.*

A. PRAY what is the Etymology of the Word *Zoography*?

B. It is composed of the *Greek* ζῶον, an *Animal*, or *Living Creature*, and γραφὴ, a *Description*; and thence it imports a physiological *Description* of the Nature and Properties of a *Living Creature*, which we call by the general Term *Animal* *. *A.* How

* 1. The Word *Animal* is a Derivation from the *Latin* Word *Anima*, which Word, with the *Romans* and all *Latin* Writers, signifies the *Soul*: Now let us see what Ideas the *Latins* expressed by this Word, that we may have the better Notion of what we call the *Soul*, and how far Animals have a Share therein.

2. The Word *Anima* was derived from the *Greek* ἄνεμος, which signifies the *Wind* or *Air*, which therefore must be the original, or primary Sense of this Word; and so *Virgil* uses it, *Quantum Ignis Animæque valent*, Æn. 8. Secondly, it was used for the *Breath*; thus *Plautus*, *An fœtet Anima Uxoris suæ?* Thirdly, it was often used for the *Body*. Fourthly, for the *Mind*; which was generally expressed by another Word, *Animus*. Fifthly, it sometimes signified the *Passions*; as, *Comprime Animam*, Plaut. Sixthly, the most usual Signification of all, was the *Life*, or that Principle by which Bodies *live*, *move*, and have *Sense*.

3. In *Greek*, what we call *Animal*, is called simply ζῶον, a *Living Creature*, from ζάω, *to live*. The *Greeks* indeed have a Word for the *Soul*, viz. ψυχὴ; but then this Word also was derived from the Word ψύχω, *to blow*, *to breathe*, *to cool*, &c. and so hath no other Signification in the original Use, than that of the *Breath*, or *Blast of Wind*; after which, it comes to be used for the

A. How many Sorts of *Animals* are there?

B. Naturalists generally distribute Animals into *seven great Kinds*, viz. (1.) *Rational Animals*, or Mankind. (2.) *Quadrupeds*, or four-footed Beasts. (3.) *Birds*, or Fowl. (4.) *Fishes*. (5.) *Insects*. (6.) *Reptiles*. (7.) *Conchilious*, or *Shell-Animals*. Of each of these we will take a *short Survey*; and then conclude with a few Reflections on the *common Accidents* of Animal Life.

A. I presume your intended Survey of *Man* will extend no farther than the *Animal Part*; pray, therefore, what are the *Component Parts* of our Bodies?

B. The human Body consists of *solid* and *fluid Parts*, which in general are called the *Solids* and *Fluids*, or *Humours* of the Body.

A. What are the general Divisions of this Part of *Philosophy*?

B. I shall here divide it with respect to the different Perfection of *Animals*; viz.

1. *Anthropography*, of the *human Body*.

the *Body*, the *Life*, and the *Mind*, all which Senses are frequent in the New Testament, and other *Greek* Writers.

4. Lastly, the Words which signified the *Soul* among the *Hebrews*, were two, *viz.* נפש, which signifies the *sensitive Soul*: And נשמה, the *human* or *rational Soul*; but both these Words, likewise, in their original and primary Sense, were used for *Halitus*, *Flatus*, *Respiratio*, that is, for the *Breath* or *Respiration* in Animals. See *Gen.* ii. 7. *Job* xxxvii. 10. *Isaiah* ii. 22, &c.

5. Now if the Words in three original Languages, which were used for the *Soul*, do primarily mean no more than the *Breath*, and, at most, the *Life* of Living Creatures, I think, it is evident that all Creatures which *breathe*, and have *Sense* and *Life*, may properly, yea *literally*, be said to have a *Soul*; which Soul, in all Animals, is in a greater or lesser Degree perfect, according as their Faculties and Powers of *Life*, *Sense*, and *Mind*, are so.

2. *Zoo-*

2. *Zoography*, of the Bodies of *Brutes* in particular.

3. *Ornithography*, of the Nature of *Birds* or *Fowl*.

4. *Ichthyography*, of the Nature of *Fishes*.

5. *Entomatography*, of the Nature of *Insects*.

6. *Herpetography*, of the Nature of *Reptiles*.

7. *Zoophytography*, of the Nature of *Shell-Animals*.

A. Pray what do you particularly include under the first Division, which you call *Anthropography*?

B. A brief physiological Description of all the component Parts of the *human Body*; which Parts are of two different Kinds, *viz*. *Solids* and *Fluids*.

A. Which are the *solid Parts* of the human Body?

B. Those which follow: 1. *Bones*. 2. *Cartilages*. 3. *Ligaments*. 4. *Muscles*. 5. *Tendons*. 6. *Membranes*. 7. *Nerves*. 8. *Arteries*. 9. *Veins*. 10. *Ducts*, or fine tubular Vessels of various Sorts. Of these simple Solids the more *compounded Organs* of Life consist.

A. Pray, which are those *compound Organs* of Life?

B. The *Brain*, and *Cerebellum*; the *Lungs*; the *Heart*; the *Stomach*; the *Liver*; the *Spleen*; the *Pancreas*; the *Kidneys*; the *Glands*; the *Intestines*; together with the Organs of Sense, *viz*. the *Eyes*; the *Ears*; the *Nose*; the *Tongue*.

A. Which are the *fluid Parts* of the human Body?

B. They are theſe: 1. The *Chyle.* 2. *Blood.* 3. *Saliva*, or Spittle. 4. *Bile.* 5. *Milk.* 6. *Lympha.* 7. The *Semen.* 8. The *pancreatic Juice.* 9. *Urine.* 10. *Phlegm.* 11. *Serum.* And, 12. The *aqueous Humour* of the Eyes.

A. Pray what is a *Bone,* and how generated?

B. A *Bone* is a Bundle of hard Fibres, tied to one another by ſmall tranſverſe Fibres. In the *Fœtus* thoſe Fibres are porous, ſoft, and eaſily diſcerned; it is probable they are nouriſhed by the ſerous Part of the Blood. As their Pores fill up with a Subſtance of their own Nature, ſo they increaſe, harden, and grow cloſe; thus when the Pores are full of this Subſtance, the Bones are grown to their utmoſt Extent, Hardneſs, and Solidity.

A. Are there not *divers Sorts* of Bones in the Body?

B. Yes; ſome are hollow, and filled with *Marrow*; others are *ſolid* clear through; ſome are very *ſmall,* others very *large*; ſome are *round,* and others *flat*; ſome are *plane,* others *convex,* or *concave*; where they are joined to each other, they make the various *Joints* throughout our Bodies.

A. Pray what is the *Uſe* of the Bones?

B. They are in us, as the Timber in the Building; the Uſe of which is to give *Strength, Firmneſs, Solidity, Form* and *Beauty* to the Whole.

A. Pray can you tell the Number of Bones in a human Body?

B. Dr. *Keill* has reckoned 245; others make them to be 249, *viz.* In the Skull 14; in the

U Face

Face and Throat 46; in the Trunk 67; in the Arms and Hands 62; in the Legs and Feet 60.

A. What do Bones yield by a *chymical Analyſis?*

B. They produce much *volatile Salt* and *Spirit,* which are very ſubtle and penetrating; ſome *Sulphur,* very ſtinking; a little *Phlegm,* and much *Earth.*

A. What is that Part you call a Cartilage, I pray you?

B. A *Cartilage,* or Griſtle, is a ſmooth and ſolid Body, ſofter than a Bone; in it are no Cavities or Cells containing Marrow, nor is it covered with any Membrane to make it ſenſible, as are the Bones. The *Cartilages* have a natural Reſort or Elaſticity, whereby they retrieve their natural Figure or Situation. They are chiefly in thoſe Places where a ſoft and eaſy Motion is required, as in the *Ears, Noſe, Windpipe,* &c. They cover alſo the Ends of all the Bones that are joined together for Motion.

A. Pray what are their *Uſes?*

B. They are appointed for the ſpecial Structure of ſome Parts, as the Ears, Noſe, *&c.* and for the eaſy Motion of the Bones in the Joints.

A. What do you call a Ligament?

B. A *Ligament* hath its Name from *Ligo,* to bind, and is a white ſolid Body, ſofter than a Cartilage, yet harder than a Membrane; they have no Cavities containing Marrow, nor any Senſe: Their chief Uſe is to bind and faſten the Bones (in their Articulation) together, leſt they ſhould be diſplaced by any violent Motion.

A. Pray what is a *Muſcle?*

B. A

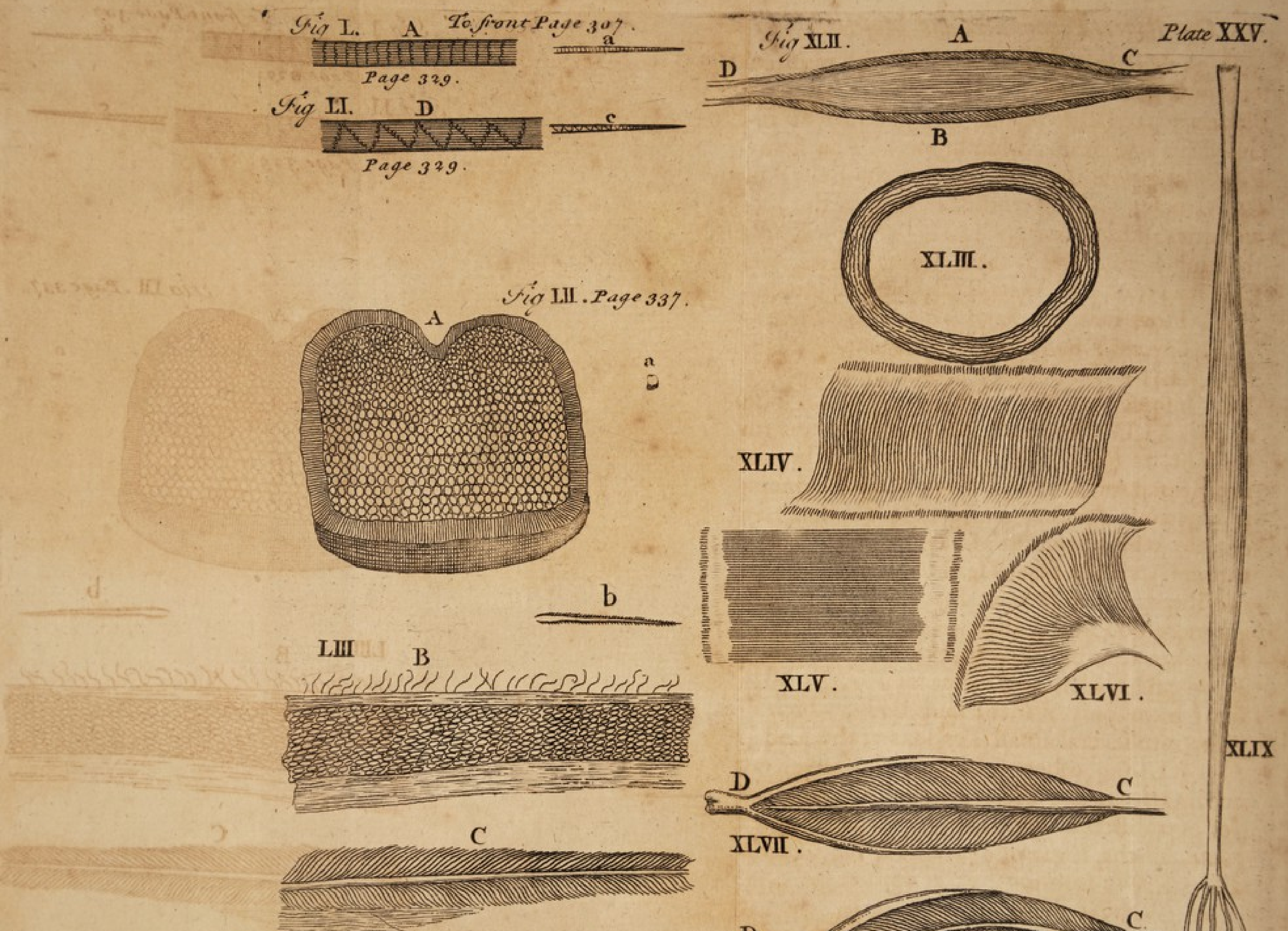


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Plate XXV.
Fig L. A
a
Page 329.
Fig LI. D
c
Page 329.
Fig XLII. A
D
C
B
XLIII.
Fig LII. Page 337.
A
a
b
LIII
B
C
XLIV.
XLV.
XLVI.
XLIX
D
C
XLVII.
D
C.
XLVIII.

B. A *Muſcle* is a Bundle of fleſhy, and often tendinous Fibres: of which all in the ſame Plane are parallel to one another, and are all incloſed by one proper Membrane. The fleſhy Fibres compoſe the Body (called the Belly) of the Muſcle; and the tendinous Fibres, the Extremities: Thus, in *Fig*. XLII, on *Plate* XXV, fronting *p*. 307, AB is the Belly of the Muſcle, C is its Head, and D its Tail, both tendinous.

A. How many *Sorts* of Muſcles are there?

B. Several: Some being long and round, as *Fig*. XLII; ſome plane and circular, as *Fig*. XLIII; ſome broad, whoſe Fibres lie ſpiral-wiſe, as *Fig*. XLIV; ſome broad, whoſe Fibres run ſtraight, as *Fig*. XLV: ſome whoſe Fibres lie divaricated, or converge from their Beginning to a narrow Tendon, as *Fig*. XLVI; ſome are double which conſiſt of a Tendon running through its Body from Head to Tail, and a Row of Fibres on each Side, as *Fig*. XLVII; ſome are yet more double, having two or more tendinous Branches running through them, with various Rows and Orders of Fibres, as *Fig*. XLVIII; ſome have only a ſmall long Body, which divides into ſeveral ſmall Tendons at the End, as *Fig*. XLIX; others alſo have two Bodies proceeding from one Head; and there are others yet of a different Sort from any here deſcribed. Note, all the *Figures* above referred to are on *Plate* XXV, fronting this *p*. 307.

A. What is the *Uſe* of *Muſcles*?

B. 1. They conſtitute the fleſhy Part of our Bodies, and give it that beautiful Form we obſerve over all its Surface. 2. But they principally ſerve for animal Motion; for by their Means all the Parts of the animal Body are moved.

A. How is that Motion performed?

B. Thus; each Muſcle, and every Fibre in a Muſcle, hath *Nerves, Arteries,* and *Veins,* attending it; now by the Rarefaction of the Blood and Spirits in thoſe Veſſels, their Cavities are diſtended; the Muſcle muſt then ſwell of Courſe, and ſwelling, will contract and become ſhorter: Therefore the *Bone,* or Part, into which the Muſcle is inſerted, will, by this Contraction of it, be drawn or pulled towards that Part where the Muſcle ariſes; and this is the general Theory of all *animal Motion.*

A. Pray what *Number of Muſcles* may there be in a human Body?

B. Dr. *Keill* enumerates 446 ſingle Muſcles in the whole Body; but others (leſs knowing) have reckoned different Numbers.

A. Pray what do you underſtand by a *Tendon?*

B. A *Tendon* is a Part conſiſting of nervous Fibres, void of any *parenchymous* or fleſhy Subſtance, inveſted in a Membrane common to all the Muſcles; and form what we call the *Head* C, and *Tail* D, of all Muſcles; or thoſe Parts by which they ariſe from, or are inſerted into the Bones of the ſeveral Limbs of the Body: The Number of Fibres in every Tendon is equal to that of the Fibres of the Muſcle, and are the ſame Fibres with them; they are thoſe white, hard, compacted Bodies, which we vulgarly call *Sinews.*

A. What Part is that you call a *Membrane?*

B. A *Membrane* is a Web of ſeveral Sorts of Fibres, interwoven for the covering and wrapping up of ſome Parts; hence they are elaſtic, and of an exquiſite Senſe; here the innumerable Diviſions, Windings, ſerpentine Progreſſions, and frequent Inoſculations of Veins with Veins, and Arteries with Arteries, make a moſt agreeable Embroidery, and delicate Net-work, covering the whole Membrane.

A. Pray, *Sir*, what is the *Uſe* of *Membranes ?*

B. To cover and wrap up the Parts; to ſtrengthen them; to ſave them from external Injuries; to preſerve the natural Heat; to join one Part to another; to cauſe an exquiſite Senſe; to ſeparate an Humour (by its Glands) for moiſtening the Parts, *&c.*

A. Are there not divers Kinds of Membranes?

B. Yes; as the *Scarf-Skin*, covering the whole Body; the *Skin* of the Body itſelf; the *Meninges* of the Brain; the *Pleura* in the Breaſt; the *Pericardium* involving the Heart; the *Perioſtium* inveſting the Bones: The *Tunicles* or Coats of the Veſſels, as the Stomach, Bladder, Veins, Arteries, Inteſtines, Teſticles, *&c.* are all Membranes of different Kinds.

A. Pray what do you call a *Nerve ?*

B. A *Nerve* is a long and ſmall Bundle of very fine Pipes, or hollow Fibres, wrapped up in the Membranes of the Brain, from whence they have their Beginning.

A. What do you find to be the *Uſe* of the *Nerves ?*

B. It is very probably ſuppoſed, they are the immediate Organs of all Senſation; for to every external Organ of Senſe, as the Eye, the Ear, the Noſe, the Tongue, are detached one or more Pair of thoſe Nerves from the Brain; alſo thoſe Nerves which proceed from the ſpinal Marrow, are ſpread through all Parts of the Muſcles and their Membranes, and to every Point in the Superficies of the Body; and thereby make the whole ſenſible.

A. Pray by what Means do the Nerves render the Parts ſenſible?

B. It is imagined they do it by the Motion of an exceeding fine and inviſible Fluid they contain, called the *animal Spirits*; by which Impreſſions are communicated to the Mind (whoſe Seat is in the Brain) from all Parts of the *animal Body*.

A. How many, or what Quantity of Nerves, may there be in the Body?

B. There be *ten Pair*, which proceed from the medullary Subſtance of the Brain, which are chiefly diſtributed to all the Parts of the Head and Neck; from the ſpinal Marrow there proceeds, through the Vertebræ, *thirty Pair* to all the other Parts of the Body; and thus, in all, there are *forty Pair*; for they come forth originally by *Pairs*.

A. Pray what do you call *Arteries?*

B. Arteries are thoſe Pipes, Tubes, or Channels, which convey the Blood from the Heart to all Parts of the Body.

A. What is their *Compoſition* or *Texture?*

B. They conſiſt, or are compoſed of three Coats, *viz.* The *firſt* ſeems to be a Web of fine Blood-Veſſels and Nerves, for nouriſhing the Coats of the Artery. The *ſecond* is made up of circular, or rather ſpiral Fibres; of which there are more or fewer Lays, according to the Bigneſs of the Artery. The *third* and inmoſt Coat

is

is a fine, denſe, tranſparent Membrane, which keeps the Blood within its Channels. The Arteries branch out into various Ramifications, and become inviſibly ſmall at laſt.

A. Pray whence is that *Pulſation* we find in ſeveral Parts of our Bodies?

B. This is a Motion of the Arteries only; the Blood being thrown out from the left Ventricle of the Heart into the great Artery, ſome and ſome at a Time, preſſeth the Sides of the Artery, and cauſes an intermitting Dilatation thereof; which is continued by the conſtant pulſive Motion of the Blood, and the Spring or Elaſticity of the Artery acting on it; hence therefore enſues a conſtant *alternate Dilatation* and *Contraction* of the Coats of an Artery, and is what we properly call the *Pulſe*.

A. Pray what is the *Difference* between *Arteries* and *Veins*?

B. Veins are only a Continuation of the capillary Arteries at their Extremities, and convey the refluent Blood back again to the Heart; in their Return they unite their Channels as they approach the Heart, and form at laſt the three large Trunks, *viz.* the *Vena Cava Aſcendens, Deſcendens,* and the *Vena Porta,* as they are called.

A. How happens it that veins have no Pulſe?

B. Becauſe the Blood is poured into them at the *Anaſtomoſis* in one continued even Stream; and becauſe it moves from a narrower Channel to a wider: the Preſſure of the Blood againſt the Sides of the Veins being leſs than that againſt the Sides of the Arteries.

A. Pray what do you call thoſe *Ducts*, or *tubular Veſſels*, you mentioned under the laſt Head of ſolid Parts?

B. Thoſe ſmall, fine, hollow Pipes or Tubes diſperſed through all Parts of the Body; which convey, ſome a *Lymph*, called *Lymphæducts*; others a *milky Liquor*, called *lacteal Veins*; and others convey other *Juices* and *Humours* of the Body to their proper Places.

A. Having thus heard you on the Nature and Uſe of the more ſimple Solids, I ſhall be obliged to you for a ſmall Account of the more compound ſolid Parts, which you call the great *Organ of Life*: And, pray, what is the Nature of the *Brain*?

B. The whole Subſtance of the *Brain* is divided into two Parts; that which lies in the Fore-part of the Skull, called the *Cerebrum*; and that lying in the Back-part, called the *Cerebellum*. In the Cerebrum, or Fore-part of the Brain, there are obſerved two Kinds of Subſtances, the external and internal; the external Subſtance is ſoft, glandulous, and of the Colour of Aſhes; this Part receives the capillary to the Brain, and ſendeth from its little oval Glands an infinite Number of Fibres, which all together make up the medullary Subſtance of the internal Part of the Brain and Cerebellum, which going out of the Skull, form the *Nerves* and *ſpinal Marrow*.

A. What is the *Uſe* of the Brain?

B. The Uſe of the Brain is to ſeparate, from the Blood brought thither, the fineſt and ſubtleſt Parts thereof, called *animal Spirits*, by the

Glands in the external Part, which are received from thoſe Glands by the Fibres of the medullary Subſtance, and are from thence conveyed by the Nerves, (which theſe Fibres compoſe) to all Parts of the Body; giving the Faculty of *Senſation* to the whole.

A. Pray what is the Nature of the *Lungs?*

B. The Subſtance of the *Lungs* is compoſed of an infinite Number of little Lobes or Spheres, of various Figures and Magnitudes, whoſe Surfaces are ſo adapted as to leave but few and ſmall Interſtices; theſe ſmall Lobes are diſpoſed like ſo many Branches of Grapes on the Sides of the Branches of the Wind-pipe: Each little Lobe contains, within its own proper Membrane, an infinite Number of ſmall and round Bladders, which leave ſmall Interſtices between, full of ſmall Membranes, like thoſe which bind the Lobes together: The Extremities of the Branches of the Wind-pipe open into the Cavities of theſe ſmall Bladders, which are probably formed by its Membranes; but the fine Blood-Veſſels are only ſpread upon the Bladders like a Net, with frequent and large Inoſculations.

A. What is the *Uſe* of the Lungs?

B. This is the *great Organ of Breathing* or *Reſpiration*; as the Air by its Weight forceth into every Cavity, ſo as ſoon as the Fœtus is born, it ruſhes into the Cavity of the Lungs, and fills the little Veſicles, and by extending them, compreſſes the ſmall Blood-Globules in the Veſſels ſpread upon them; this Compreſſion is much greateſt when the Air is expelled out of the Lungs by the Contraction of the Breaſt; and by this Compreſſion,

preſſion, the red Globules of Blood, which, through their languid Motion in the Veins, were grown too big to circulate, are again broken and divided into the Serum, and ſo the Blood is anew made fit for Nutrition and Secretion. Dr. *Keill* alſo thinks that the Air doth hereby enter and mix with the Blood. Dr. *Cheyne* ſaith, the elaſtic Globules of the Blood are hereby formed. And others hold other Opinions of the Uſe of Reſpiration. But I think it ſtrange that *Etmuller*, amongſt his fourteen Uſes thereof, has not mentioned the *vital Spirit* of the Air, which probably is thereby intermixed with the Blood, and diffuſed through all the Body, and is therein the *Principal of animal Life*; ſince it is well known Animals cannot live in Air deprived of this Spirit. Neither has Mr. *Derham* hinted any Thing concerning it.

A. Pray what is the *Nature* and *Compoſition* of the *Heart*?

B. The *Heart*, (ſaith *Boerhaave)* and its *Auricles*, are real Muſcles, and act with a muſcular Power; for all the Fibres gradually growing ſhorter, diminiſh the Length of the Heart, and increaſe its Breadth; they accurately ſtreighten the Cavities of the Ventricles; dilate the tendinous Mouths of the Arteries; determine the Valves of the Mouths of the Veins for the Stoppage of their Contents; and drive, with great Force, its contained Blood into the dilated Mouths of Arteries, in order to its Circulation through the Body.

A. Pray what is the *principal Service* of the Heart to the human Body?

B. This

B. This wonderful Muſcle has two Motions, which they call *Syſtole*, and *Diaſtole*; the *Syſtole* is when the Fibres contract and ſtreighten the Cavities; the *Diaſtole* is when this Muſcle ceaſeth to act; its Fibres return to their natural Site and Tone, and its Cavities become large and wide. Now the *Vena Cava* returning to the Heart, the exhauſted ſuperfluous Blood, with the Chyle newly mixed herewith, pours it through the right Auricle, whence it is detruded into the right Ventricle or Cavity of the Heart; by its *Syſtole*, it is thence driven into the *pulmonary Artery*, which conveys it to, and diſtributes it through, all the Parts of the Lungs; the Blood being here, by Reſpiration, prepared, reduced, mixed and impregnated with the *vital Spirit*, and *nutritious Principle* of the Air, is remanded back again by the *pulmonary Vein* to the *left Auricle*; thence into the *left Ventricle* of the Heart, which is then in its *Diaſtole*; *laſtly*, in the *Syſtole* of this Ventricle, the Blood now refected is thruſt into the great Artery, called the *Aorta*, which carries it again through all the Body: Thus the *Heart* is the inſtrumental Cauſe of the *Blood's Circulation*.

A. In the next Place, pleaſe to give me ſome Account of the Nature of the *Stomach*.

B. The *Stomach* is compoſed of four Membranes: The *firſt* and *inmoſt* is a large muſcular Coat, lying in Plaits, and containing a great Number of Glands, thence called the *Tunica Glanduloſa*. The *ſecond* Coat is much finer and thinner; is altogether nervous, and therefore of exquiſite Senſe. The *third* Tunicle is made of ſtraight and circular Fibres; ſo that by this muſcular Coat the Ends of the Stomach are drawn towards its Middle, and the Whole is equally contracted. The *fourth* is the common external Cover of the whole Stomach; it proceeds from the *Peritonæum.*

A. To what *Uſe* doth the Stomach ſerve?

B. The Uſe of the Stomach is *Digeſtion*; which is the Diſſolution or Separation of the *Aliments* or Food into ſuch minute Parts as are fit to enter our *lacteal Veſſels*, and circulate with the Maſs of Blood: This is principally effected by the *Saliva*, or Spittle of the Mouth; the fermenting Juice in the Stomach, ſeparated by its aforeſaid Glands; by the Liquors we drink; and, *laſtly*, by the continual Motion of the muſcular Coats of the Stomach, whoſe abſolute Power is, by *Pitcairne*, demonſtrated to be equal to $117088\frac{1}{2}$ Pounds Weight; to which, if the abſolute Force of the Diaphragm and Muſcles of the Abdomen be added, the Sum will amount to 250734 Pounds Weight; which is above 2238 Hundred Weight, or near 112 Tons: No wonder then the very hardeſt Diet, or Bones themſelves, ſhould ſo ſoon be reduced to a liquid Subſtance, we call the *Chyle*, by ſuch prodigious conſpiring Forces!

A. What is the Compoſition of the Liver?

B. The common Membrane being raiſed, the Subſtance of the *Liver* ſeems to be *compoſed of ſmall Glands of a conic Figure*, and bound together by a proper Membrane into ſeveral Heaps or Lobes, which, like Bunches of Grapes, hang to the Branches of the Veſſels, (*viz.* the *Vena*

Portæ,

Portæ, and the *Vena Cava)* from which each ſmall Gland receives a Twig, and the Lobes are tied to one another by fine Membranes, which fill up the Spaces between them; and thus the parenchymous Subſtance of the Liver is formed.

A. What is its Uſe?

B. The *Vena Portæ* brings the Blood to the Liver full of *Bile*, for its Secretion by the Glands of the Liver; and the *Vena Cava* carries back the Blood, which remains, to the Heart. The *Bile* thus ſtrained from the Blood is, by ſmall Veſſels, brought to the *Gall-bladder*, one Part; and the other Part is ſeparated immediately into the Duct, called the *Portus Biliarius*; this Duct going out of the Liver, joins the Neck of the Gall-bladder at ſome Diſtance, and forms one common Duct, called the *Choledochus*, through which both Sorts of Bile mix and paſs to the Lower-end of the *duodenum* Gut, whereinto it flows, in order to mix with the Chyle: Thus the *Uſe* of the Liver is to *ſeparate the Bile from the Blood.*

A. Pray what is the Nature and Make of the *Spleen*.

B. The Subſtance of the *Spleen* (contained within two Membranes) is compoſed of an Infinity of Membranes, which form little Cells and Cavities of different Size and Figure, which communicate with one another, and are always full of Blood.

A. What is the Uſe thereof?

B. The ancients knew nothing of its Uſe; nor can the Moderns do more than conjecture at it. You may ſee Dr. *Keill*'s ingenious Hypotheſis of

its

its being Nature's *Storehouſe*, in which ſhe depoſits the arterial Blood for the Uſe of the Liver, in his *Anatomy*; and the learned Diſquiſitions of the great *Boerhaave* on this Subject, in his *Inſtitutions*, Page 139.

A. What is that you call the *Pancreas?*

B. It is the ſame as is vulgarly called the *Sweet-bread*; it is called *Pancreas* from πᾶν; *all*, and κρέας *Fleſh*; as much as to ſay, *a Part all Fleſh:* It is compoſed of an infinite Number of little Glands, itſelf being only a large Gland of the conglomerate Kind; whence its Subſtance, as we find, is always ſoft and ſupple.

A. Pray what is its *Uſe?*

B. To ſcreen from the Blood, brought thither, a Liquor called the *pancreatic Juice*, which is conveyed by a proper Duct to the *duodenum Gut*, there to dilute the *Chyle*.

A. What is the Subſtance of the *Kidneys?*

B. The *Kidneys* are likewiſe two large Glands, whoſe parenchymous Subſtance is compoſed of an Infinity of very ſmall Glands, every where interwoven in the Net-like Inoſculations of the fine capillary Branches of their Arteries and Veins: From each ſmall Gland proceeds a long ſmall Tube; theſe Tubes approaching towards the Cavity of the Reins gather together in little Bundles, and form the inner Subſtance of each Kidney.

A. Is not their Uſe *to ſeparate the Urine from the Blood?*

B. Yes; the Blood being conveyed to them by the *emulgent Arteries*, hath its ſerous briny Part ſtrained off by their little Glands, and then is is returned again by the *emulgent Veins*; the *Urine*, thus ſeparated, runs down by the *Ureters* into the *Bladder*.

A. Pray what is the *Nature* and *Texture* of the *Glands?*

B. The Moderns have reduced all the Glands of the Body to two Sorts, *viz. Conglobate Glands*, and *Conglomerate Glands*. A *Conglobate Gland* is a little ſmooth Body wrapped up in a fine Skin, by which it is ſeparated from all other Parts, only admitting an Artery to paſs in, and a Vein and excretory Canal to come out: Of this Nature and Sort are the Glands of the *Brain*, of the *Lips*, and of the *Teſticles*. A *Conglomerate Gland* is compoſed of many little *Conglobate Glands*, all tied together, and wrapped up in one common Tunicle or Membrane, whoſe various excretory Ducts uniting, form one or more larger Pipes, or evacuating Veſſels: Of this Sort are the *Breaſts*, the *Sweet-bread*, the *Kidneys*, &c.

A. Their *Uſe* I underſtand is *Secretion of Humours from the Blood?*

B. It is ſo: Thus, the Glands of the Brain ſecern the *Animal Spirits*; thoſe of the Mouth, the *Saliva* or Spittle; thoſe of the Breaſts, *Milk*; thoſe of the *Reins*, Urine; thoſe of the *Liver*, Bile; thoſe of the *Teſticles*, the generative *Semen*; and thoſe of the Skin, the inſenſible Matter of Perſpiration, or Sweat. The Number of theſe ſmall *cuticular Glands* is ſomewhat wonderful; it is ſuppoſed, that one Grain of Sand will cover no leſs than 125000 of them; if then we reckon only 2000 of theſe Grains to an Inch Square, and allow, at a *Medium*, the Surface of a Man's Body to be equal to 14 ſquare Feet; then there will be of thoſe ſmall Glands in the Skin, the Number of 324000000000; each of which contains a *Pore*, or inviſible *Spiracle*, through which we conſtantly perſpire *.

A. Pray what Quantity of Matter goes off by this *inſenſible Perſpiration?*

B. *Sanctorius* tell us, in his *Aphoriſms*, that by weighing himſelf he has found, 1. That a Man *ſleeping* perſpires twice as much as when *awake*. 2. That a ſound Man in one Night of ſeven Hours Sleep, generally perſpires fifty Ounces, or three Pounds *Avoirdupoiſe*, or four Pounds *Troy* Weight. 3. That ſcarce half a Pound of this perſpires in the firſt five Hours. And we cannot wonder hereat, ſince it appears there are above three hundred thouſand Millions of Pores in the Body of a middle-ſized Man; through which there muſt of Neceſſity go off a much greater Quantity than either by *Stool* or *Urine*, or both together.

A. Well, I am wonderfully pleaſed to know this ſurprizing Part of Philoſophy, and do intend for the Sake hereof to buy *Sanctorius*'s Book: But, to go on, pray what is the *Nature* and *Uſe* of the Inteſtines?

* This is upon Truſt from Mr. *Lewenhoek*, who certainly was very happy at theſe Kinds of Invention, for his Eyes, though old, and Microſcopes, though ſingle ones, could in many Caſes diſcover, what I never could with young Eyes, and the beſt double Microſcopes. I have tried in Variety of Subjects to find theſe Pores in the Cuticle, but in vain. And indeed I very much queſtion whether ever he did actually ſee any ſuch Thing.

B. The

B. The *Inteſtines* are a long and large Pipe, which, by ſeveral Circumlocutions and Turnings, reaches from the *Pylorus* of the Stomach to the *Anus*: They are knit all along to the Edge of a Membrane, called the *Meſentery*, and are ſix Times as long as the Body to which they pertain: Their Uſe is, by a peculiar *vermicular Motion* of their ſpiral-fibred Coats, to convey along, and extrude out of the Body, the *Fæces*, or the *recrementitious Part* of the Food, after the *Chyle* is ſtrained from it.

A. Pray how many different *Organs of Senſation* are there?

B. Four particular ones, *viz*. the *Eye*, for *ſeeing*; the *Ear*, for *hearing*; the *Noſe*, for *ſmelling*; and the *Tongue*, for *taſting*: And there is one general Senſe, *viz*. of feeling, common to all the Parts of the Body.

A. What is the *Structure* and *Uſe* of the Eye?

B. The *Eye* is a curious and moſt wonderful Piece of Nature's Work, admirably contrived with various *Coats*, *Muſcles*, *Veſſels*, and *Humours* of three ſeveral Kinds, for the Purpoſe of Viſion: The firſt Humour of the Eye is called the *aqueous Humour*, being in all Reſpects like Water, but of a ſpirituous Nature; for it will not freeze in the greateſt Cold. The ſecond is called the *cryſtalline Humour*, being tranſparent, and more ſolid than either of the other; its Figure reſembles an optic Lens, convex on both Sides, and its Uſe in the Eye is the ſame. Behind this lies the *vitreous* or *glaſſy Humour*; it is very much like the *White of an Egg*; is in greater Abundance than either of the other; it gives the Eye its *ſpherical Form*;

 and

and is thicker than the *aqueous*, but thinner than the *cryſtalline Humour*. Next this Humour, on the Bottom of the Eye, is ſpread a fine curious Membrane, called the *Retina*, through which are expanded the *medullary Fibres* of the *optic Nerve*, which come from the Brain. Now the Rays of Light, which come from all Parts of any Object, falling upon the *aqueous Humour* of the Eye, are through it refracted to the *cryſtalline Humour*, by which as a *double convex Lens* (kept always at a proper Diſtance by the *glaſſy Humour*) they are all converged and united on the *Retina*; the Impreſſion thereof being communicated to the *common Senſory* of the Brain by the optic *Nerves*, doth there preſent to the Mind the *Species* and Image of the Object; and thus *is Viſion performed by Means of the Eye.*

A. Pray how is the Senſe of *Hearing* performed by the *Ear*?

B. I have already told you, that Sounds are brought to the *Ear* from the *ſonorous Body* by Means of the *Air*; and the external Part of the Ear is ſo contrived by its Ridges and Hollow, that Sounds, being gathered into the Ear as into a Tunnel, are thereby directed to the *Meatus Auditorius*, through which they paſs and ſtrike upon a thin tranſparent Membrane of an oval Figure, ſet a little obliquely acroſs the Paſſage of the Ear; behind this Membrane there is a pretty large Cavity, which, with the ſaid Membrane, from its Reſemblance, is called the *Tympanum*, or *Drum of the Ear:* In this Cavity are four ſmall Bones, which from their Form are called *Malleolus*, or the *Hammer*;

the

the *Incus*, or the *Anvil*; the *Stapes*, or *Stirrup*; and the *Os Orbiculare*, or *circular Bone*. Within the *Tympanum* there are ſeveral other Cavities, as the *Veſtibulum*, the *Labyrinth*, and the *Cochlea*; theſe internal Cavities are always full of Air; wherefore the Sounds in the external Air ſtriking on the Drum, move the four little Bones in the *Tympanum*, and theſe in like Manner move the internal Air, which maketh an Impreſſion on the fine Branches of the *auditory Nerve* ſpread through the *Veſtibulum*, the winding Tubes of the *Labyrinth*, and *Cochlea*; and thus all Refractions and Modulations of the external Air become perceptible, and conſequently all the different Sounds they convey become audible, and intelligible to the Mind, by the Communication of theſe Nerves with the Brain, or *common Senſory*.

A. Pray how is the Senſe of *Smelling* effected in the *Noſe*?

B. The Cavity of the *Noſe* is divided into two Parts, we call the *Noſtrils*, by a Partition, of which the upper Part is bony, and the lower cartilaginous: The upper Part of the Cavity is covered with a thick glandulous Membrane, above which the *olfactory Nerve* is finely branched out and ſpread over the Membrane of the ſpongy Bones of the Noſe, and the other ſinous Cavities of the *Noſtrils*: Whence the Exhalations of Odours entering the *Noſtrils* make their Impreſſions on the Fibres of the Nerves, which, by their Communication with the Brain, excite in the Mind the *Smell* or *Senſation of Odours* of every Kind.

A. And thus, I ſuppoſe, you account for the Senſe of *Taſte* in the *Tongue?*

B. The *Tongue* is covered with two Membranes; the external is thick and rugged, eſpecially in Beaſts; the internal Membrane is thin and ſoft; upon it appear ſeveral *Papillæ* or ſmall Riſings, like the Tops of the ſmall Horns of Snails; theſe *Papillæ* are made of the Extremities of the Nerves of the Tongue, and piercing the external Membrane, are conſtantly affected by thoſe Qualities in Bodies, which have their Taſtes excited in the Mind by Means of theſe *nervous Papillæ*; and thus are theſe *Papillæ* the immediate *Organ of Taſting*.

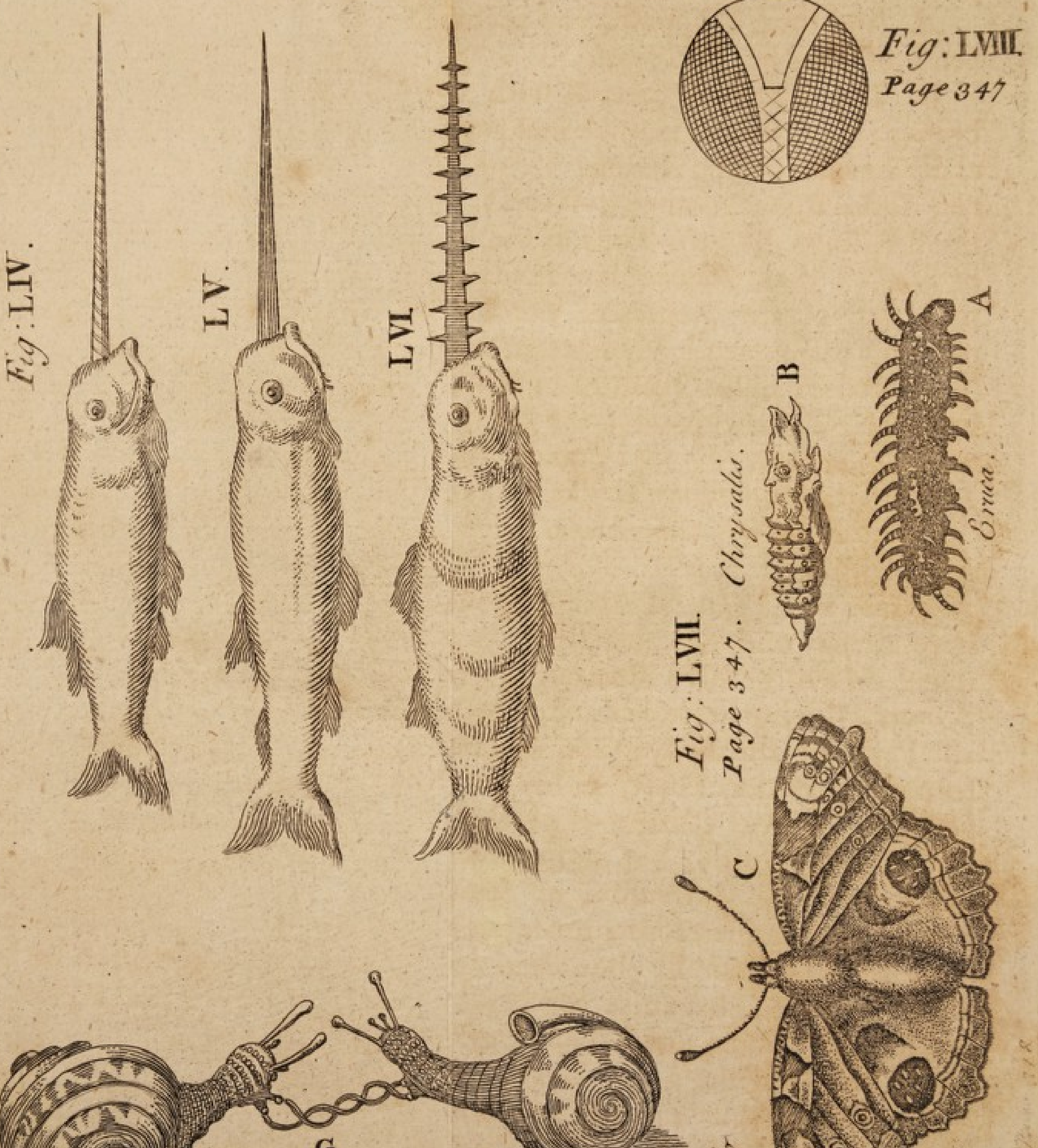
A. Pray how is the *general Senſe of Feeling* performed?

B. Of this a general Account muſt ſerve: I have already told you, that from the Brain and ſpinal Marrow there iſſue out divers *Pairs of Nerves*, which are ramified and diſperſed through all Parts of the Body; and conſequently no Impreſſion on any Point, either on the Superficies, or internal Compages of the Body, can be any way made, but it muſt immediately affect either the Extremity, or ſome Part of a Nerve, and is therefore immediately communicated to the Brain by the *animal Spirits*; and thus the Mind becomes conſcious of every Motion, Affection, or Accident of the Body; and this we call the *Senſation of Feeling*.

A. Having thus obliged me with an Account of the *ſolid Parts*, and of the *Organs* and *Manner of Senſation*, I beg you would now proceed to deſcribe the *Fluids* of the human

Body;

To front Page 342. Plate XXVI.



Body; and firſt, pray, what do you call the *Chyle?*

B. The *Chyle* is a milk-like liquid Subſtance, into which the Food is converted by the *Concoction* and *Digeſtion* of the Stomach, as before I told you; the *Chyle* paſſing by the *Pylorus* out of the Stomach into the firſt of the Inteſtines, called the *Duodenum,* in it and in the next, called the *Jejunum,* it mixeth with the Bile and pancreatic Juice; by which Means the *Chyle* undergoes a further Preparation; the more alimentary Part being hereby refined and ſeparated, is received into the numerous Orifices of the firſt *lacteal Veins,* opening into the ſaid Inteſtines; by theſe it is conveyed to, and ſtrained through, the Glands of the Meſentery; whence it is received by a ſecond Sort of lacteal Veins, and carried to the Baſon, called the *Receptaculum Chyli*; where being duly impregnated with the *Lymph* from the *Lymphæducts* there poured into it, it is thence carried upward by the thoracic Duct, and emptied into the left *ſubclavian Vein,* where it is mixed with the refluent venal Blood, deſcends into the right Ventricle of the Heart, is thence circulated through the Lungs into the left Ventricle, and from thence through all the Parts of the Body: And this is the *animal Oeconomy,* or ordinary Method by which the *Blood is removed,* and *Life continued.*

A. Pray what is the *Blood?*

B. The *Blood* is a vital Stream proceeding from the Fountain of the Heart, and circulating conſtantly through the whole Body by the Canals of the Arteries and Veins. If it be viewed with a *Microscope*, it appears to consist of small red Globules swimming in a thin transparent Serum, and that each Globule is made up of six lesser ones, which, resolved, take upon them the Nature of the *Serum*, whose Colours are various. Dr. *Boerhaave* says, that the *Mixture, Fluidity, Heat,* and *Redness* of the *Blood*, are owing to, and preserved by, the *circulatory Motion* thereof.

A. Pray what is the Rate of the Blood's Motion through the Body?

B. Each Ventricle of the Heart will contain about *an Ounce* of Blood; the Heart contracts about 4000 Times in an Hour; hence there passeth through the Heart every Hour 4000 Ounces of Blood, which is 250lb. Weight. Now an Ounce of Blood is equal in Bulk to $1\frac{66}{100}$ Inch; and if we suppose the Heart contracts 80 Times in a Minute, then 80 Ounces of Blood will be equal to $132\frac{72}{100}$ Inches, which passeth the Heart in one Minute. Now Dr. *Keill* found the Diameter of the *Aorta* to be 0.73 Parts of an Inch, and thence its Orifice 0.4187; by which divide $132\frac{72}{100}$, and the Quotient will be the Length of the Cylinder, or Space through which the Blood will move in a Minute, *viz.* 316 Inches, or 26 Feet. But, because of the *Diastole* of the Heart which takes up half the Time of a Pulsation, there goes out of the Heart 80 Ounces in half a Minute; whence the Blood's Velocity will be double, or it moves at the Rate of 52 Feet in a Minute.

A. Is the Velocity through the Trunk the same as through all the Branches taken together?

B. No;

B. No; for the ſame ingenious *Anatomiſt* found the exact Proportion of the Branches to the Trunk of the Artery to be as 12387 to 10000, and conſequently the greateſt Velocity of the Blood will be to the leaſt, as 5233 to 1; or the Blood moves 5233 Times ſlower in ſome capillary Arteries, than it does in the *Aorta*. The Blood is received from the Arteries into the Veins, where it ſtill moves ſlower as it approaches the Heart. Now the Arteries are to the Veins, as 324 to 441; and therefore the Blood moves in the Veins above 7116 Times ſlower than in the *Aorta*.

A. What Quantity of Blood do you find to be in the *human Body?*

B. You aſk a Queſtion very difficult to be anſwered: At preſent I cannot find any Perſon can certainly tell; *Authors* determine from 10 to 25 lb. and Dr. *Keill* reckons the whole Body conſiſts of near two-thirds Fluids, the greateſt Part of which is Blood.

A. What do the *Chymiſts* find the Blood to conſiſt of?

B. Of much *volatile Salt*, and *Spirits*; ſome *Phlegm* and *Sulphur*; a little *Earth*; and but little or no *fixed Salts*: *Alkalies* diſſolve in it, and *Acids* coagulate it.

A. How are the other *Fluids of the Body* produced?

B. They are all ſeparated from the Blood in ſome Part of the Body or other by the Glands. Thus the *Saliva* or *Spittle* is ſecerned by *parodital Glands* behind the Ears, and *maxillary Glands* of the Mouth; the *Bile* is ſeparated by the

the Liver; the *Milk* is ſtrained off from the Blood by the Gland of the Breaſts; the *Lymph* is a fermenting Liquid ſecerned by the ſmall conglobate Glands in ſeveral Parts; the *Semen* is ſecreted from the Blood by the Teſticles, brought thither through various Circumvolutions and Contortions of the *ſpermatic Arteries*; the *Pancreas,* or *Sweet-bread,* alſo ſeparates a ſweet lymphid Liquor or Juice, to dilute and refine the *Chyle*; the *Urine* is ſecerned by the Reins; it contains *volatile Salt, Spirit,* an *oily Sulphur, Phlegm,* and *Earth*; from *Urine* fermented is diſtilled that luminous Matter called *Phoſphorus,* which is either ſolid or liquid. *Phlegm* is a mucous Matter, ſeparated by the Glands of the Mouth, Noſe, *&c. Serum* is the aqueous Part of the Blood, which is not diſcerned from the Blood itſelf in the Body; but taken out, it ſeparates from the coagulated Blood, by the Action of the Cold; the *aqueous Humour* of the Eye, ſecerned from the *arterial Blood* in the Veſſels of the Eye; the *cryſtalline* and *vitreous Humours* are improperly ſo called, they conſiſting of an infinite Number of ſmall Veſſels filled with circulating *Fluids.*

A. Sir, I am greatly obliged to you for taking ſo much Pains for my Information, yet, as you ſeem to do it with a great deal of Pleaſure, I ſhall be bold to aſk a few Queſtions more; and, pray, what do you ſay of the *Nature of Hair?*

B. When we examine the *Hairs* with a *Microſcope* (ſaith Dr. *Keill)* we find they have each a round bulbous Root lying pretty deep in the Skin,

Skin, and which draw their Nouriſhment from the ſurrounding Humours; that each Hair conſiſts of five or ſix others wrapped up in a common Tegument or Tube: They grow as the Nails do, each Part near the Root, thruſting forwards that which is immediately above it; and not by any Liquor running along the Hair, in Tubes, as Plants grow. Their different Colours depend on the different Quality and Temperament of the Humours producing them; they ſerve for the Covering and Ornament of the Body. Mr. *Derham* gives us the Repreſentation of two Hairs of a Mouſe (the moſt tranſparent of any) the one in *Fig*. L. on *Plate* XV, fronting *p*. 307, where *a* is its Appearance through a ſmall Magnifier, and A as it appears through a large one. *Fig*. LI. on the ſame Plate, *c* and D are the ſame Views of another Hair, to ſhew the different internal Make of the Hair of the ſame Animal *.

A. Pray what are the *Nails*?

B. Our *Nails* are of the ſame Nature as the *Hoofs of Beaſts*; and are nothing but the Covers or Sheaths of *Papilla Pyramidales* of the Skin on the Extremities of the Fingers and Toes, which dry, harden, and lie cloſe upon one another.

A. You have been long telling what thoſe Parts are of which our Bodies conſiſt; but,

* I never could find, by viewing of tranſparent Hairs, that they afforded any other Appearance than that of *clear*, *long*, *round*, or *cylindrical Tubes*; the Hollowneſs of the larger ones being very viſible, but of the ſmaller ones not diſcernible; and their Texture or Subſtance has always appeared to me to be ſimple or uncompounded. So that the Reader is to *believe* or *reject* what Dr. *Keill* and Mr. *Derham* have aſſerted, as he may think reaſonable.

pray, how are our Bodies at firſt generated or formed in the *Womb?* This you have not yet told me.

B. The Learned of late have found by their *Microſcopes*, that not only Man, but all Animals, do really exiſt (in their proper Form compleat in all their Parts) in the Seed of the Male Animal, before Generation, in a ſmall inviſible State, called *Miniature.* It is amazing to ſee the prodigious Number of little Creatures, like ſo many Tadpoles, ſwimming every Way in the Male Sperm of all Animals. Thoſe Animals are ſo ſmall, that 3000000000, *i. e.* three thouſand Millions of them, are not equal to a Grain of Sand, whoſe Diameter is but the 100dth Part of an Inch. The *Animalcule* that has the good Luck to get ſafe into the *Womb*, through the *Fallopian Tubes* in a Kind of Egg, is there foſtered a while ſome how, till, at length, the *Placenta* appears like a little Cloud on one Side of the external Coat of the Egg; and at the ſame Time the Spine of the Embryo is grown ſo big as to be viſible, and a little after, the *Brain* and *Cerebellum* appear like two ſmall Bladders, and the Eyes next ſtand goggling out of the Head; then the *Beating of the Heart*, or *Punctum Saliens*, is plainly to be ſeen, and the Extremities of the Body diſcover themſelves laſt of all; ſo far Dr. *Keill:* And this is the preſent *Theory of Generation*; and very much alike in *Plants* and *Animals* *.

A. Pray

* The Affair of *Impregnation* and *Generation*, even after all the late Diſcoveries, remains ſo very perplexed, obſcure and doubtful, that nothing of Certainty can yet be determined about it. Some aſſerting the *little Animal* to be originally in the Female's Egg; others deny that, and affirm they have no Being there till the Egg is

A. Pray what do you obferve in particular of the *Nature of Beafts* *? *B.* The

is fecundated by the *Semen Mafculinum in Coitu.* See the Controverfy in Mr. *Bradley*'s Phil. Account of the Works of Nature, *Chap.* 9. *Mifcellanea Curiofa*, Vol. I. Page 142. by Mr. *Garden.*

* 1. Mr. *Ray*, in his *Synopfis of Animals*, diftinguifhes *Quadrupeds* into two Kinds, *viz.* (1.) The *ungulated* or *hoofed* Beafts with four Feet; and (2.) The *unguiculated, digitated,* or *clawed* our-footed animals.

2. The *Hoofed Quadrupeds* are either (1.) *Solidipeds*, or Whole-hoofed; as the Horfe, Afs, Mule, *&c.* Of this Tribe none bears Horns. (2.) *Bifulcated*, or Cloven-footed: Of thefe, fome are *Ruminant*, or *chew the Cud*; as the *Ox*, the *Sheep*, the *Goat*, the Deer Kind. Of thefe the three former bear *hollow* and *perpetual Horns*; the latter, *clofe* and *deciduous* Horns. Again, fome of the *Cloven-footed* do not *chew the Cud*, as the *Hog* and *Swine* Kind. (3.) Quadrupeds which have their Hoof cloven into four Divifions, and feem not to be *Ruminant*; as the *Rhinoceros*; the *Hippotamus*, or *River-Horfe*; the *Tapijerote*, and *Capy-Bara* of *Brafil*, &c.

3. Of the fecond or *unguiculate Kind* of *Quadrupeds*, the *Elephant* is fomewhat fingular; his Claws adhere to each other, and are all covered with one common Skin, having only their obtufe Nails fticking out round the Margin of the Foot.

4. The *Camel* and *Dromedary* have only *two Claws*; and, though they have no Horns, they ruminate or chew the Cud, and have the four Stomachs of horned ruminant Animals. Of thefe fome have one *Bunch* on the Back, and another Sort have two.

5. The *Anthropomorpha*, or thofe Quadrupeds which have the Foot divided into many *Claws*, with broad Nails on them, like the Fingers and Toes of Men, make the third Species of this *unguiculate* Kind: As *Apes*, which have no Tails, and *Monkeys* which have Tails, and they of a large Size, called *Baboons.* To this Tribe alfo belong the *Ourang-Outang*, or the Wild Man; the *Caqui* and *Cay* of *Brafil*; and the *Cercopitheci*, or Monkeys of feveral Countries.

6. A *fourth fpecies* of this Kind is when the Claws are many, and have crooked and fharp-pointed Nails, like the Talons of Birds of Prey; and they are of the *Cat*, the *Dog*, the *Vermin*, and the *Hare Kind.*

7. Of the *Cat Kind* of Quadrupeds, are reckoned the *Lion*; the *Tiger*; the *Pardalis* (whofe Male is *Pardus*, Female *Panther*); the *Leopard*; the *Lynx*; the *Cat-a-Mountain*; the *Bear*; and the common *Cat.*

8. Of the *Dog Kind* they account the common *Dog*, the *Wolf*, the *Fox*, the *Jackall*, the *Civet Cat*, as it is erroneoufly called; the *Rackoon*,

B. The Nature of *Beasts* or *Quadrupeds*, is, with Respect to the sensitive Life, or animal Oeconomy, the same with that of Man already described: What I shall here take Notice of then, shall be those Particulars wherein the Brute differs from a Man, and is what he is; the Chief of which are the following: 1. Their external *Form* and *Shape*, which is almost infinite; and is

Rackoon, or *Ratoon*; the *Badger*; the *Otter*; the *Sea-Calf*, or *Seal*; the *Sea Horse*; the *Sea-Cow*; and some other outlandish Animals.

9. Of the *Vermin Kind* are the *Weasel*; the *Ermine*, or *Stoat*, if white; the *wild Stoat*, or *Ferret*; the *Pole Cat*; the *Marten*, or *Martlet*; the *Sable*; the *Genetta*; the *Ichneumon Bellonii*; the *Indian Mungo*; and *Quirpele*, &c.

10. Of the *Hare Kind* are the *Hare*; the *Rabbet*, or *Coney*; the *Porcupine*; the *Bever*; the *Squirrel*; the *Rat*; the *Mouse*; the *Dormouse*; the *Guinea Pig*; the *Tapeta*, *Aperca*, *Agati*, and *Paca*, of *Brasil*; and the *Conies* and *Mice* of various foreign Countries.

11. To these Kinds of Quadrupeds may be added some others more anomalous, as *Viviparous four-footed Animals, having a longish Snout, and their Feet divided into many Claws or Toes, and having Teeth*: As the *Urchin*, or *Hedge Hog*; the several Sorts of *Tatons*, or *Armadillo*'s; the *Mole*; the *Shrew-Mouse*; the white *Indian Erinaceus*, &c.

12. *Others, which have a longish Snout, their Feet divided into many Claws, but have no Teeth*: As the greater and lesser *Ant-Bear*; the *Tamandua Guacu* of *Brasil*, &c.

13. *Flying Quadrupeds*, with a shorter Snout, and their Feet divided as before; as all of the *Bat-Kind*, or *Flutter Mice*; of which there are several Sizes, and different Forms.

14. *Viviparous* and *sanguineous* Quadrupeds, breathing with Lungs, and having only one Ventricle in the Heart; as the *Frog*; the *Toad*; the *Tortoise*; of these there are many different Species both of Land and Water ones in foreign Parts.

15. *Oviparous Quadrupeds* with a long Tail stretched out horizontally; as all of the Lizard Kind; the *Crocodile*; the common *Eft*, or *Newt*; the *Seps*, a Sort of footed Serpent; the *Salamander*; the *Cameleon*; a flying Lizard; with various other Kinds.

Consult Mr. *Ray's Synopsis Animalium. Johnstoni Historiæ Naturalis. Borelli de Motu Animalium. Willis de Anima Brutorum. Aristotle* and *Ælian* among the Ancients; as also *Pliny's Natural History of the World*.

that

that which chiefly diſtinguiſhes the various Species of Brutes. 2. Their Size, of which there are numerous Degrees; the greateſt of all are the *Elephant* and *Rhinoceros.* 3. Their *prone Poſture,* neceſſary to their Way of Living. 4. Their *Motion,* or *Gait,* which is on *four Legs,* and are therefore called *Quadrupeds.* 5. The ſpecial Contrivance and Form of their *Heads,* which is infinitely various. 6. They are ſome of them endued with *Horns* of various Figures and Sizes. 7. They have a ſpecial Form and Structure of their *Ears* externally. 8. The Make of the *Eye* is very different in different Species of Animals. 9. The *Neck* is adapted to the Length of their Legs, except only in the Elephant, which hath his *Proboſcis,* or Trunk, to ſupply that Defect. 10. The Form of their *Legs* is peculiar, yet different in divers Species; whence the ſlow Motion of ſome, and wonderful Agility and Swiftneſs in others. 11. They are all provided with *Tails* of different Length, Size, *&c.* whoſe Uſe is to defend themſelves from the Moleſtation of Flies, *&c.* 12. Their Bodies are clothed with various *Teguments* of *Hair, Wool, Spines, Down,* &c. ſuitable to their particular Occaſions of Life. 13. Their *Feet* are, ſome cloven into *Hoofs,* others divided into *Claws,* with Variety of different *Nails* to anſwer their various Purpoſes of Life. 14. Their *Noſtrils* are ſomewhat differently formed from ours, and from one another. 15. Their *Brain* is conſiderably leſs in Proportion to their Bodies, than Man's. 16. They have ſome of them a peculiar Membrane, called the *nictitating Membrane* of the Eye, by which the Eye, frequently

quently winking and contracting the Pupil, is preſerved from the Annoyance of the Graſs, Stubble, *&c.* in gathering their Meat. 17. They are provided with a ſtrong, tendinous, and inſenſible *Ligament*, braced from the Head to the Middle of the Back, called the *white Leather*, which ſuſpends the weighty Head without Pain, in grazing, *&c.* 18. The *Stomachs* of Brutes are different from ours, and from each other's, both in *Size* and *Number*; for ſome have *ſmall*, others *large Stomachs*; in ſome, *one* only; in others, *two* or more; thus the *Dromedary* hath *four Stomachs.* 19. Some have the wonderful Faculty of *Rumination*, or chewing the *Cud*; for the compleat Maſtication of the Food at the reſting leiſure Times of the Animal. 20 The *Hearts* of Animals are of ſpecial Structure; in ſome it hath but *one Ventricle*, as *Frogs*; in others *two*; and in ſome *three Ventricles*, as in the *Sea-Calf*, &c. 21. Some Animals live only on *Land*; others, called *Amphibious*, live both on Land and in the Water. 22. The *Food* of Brutes is very various, ſome feeding on *Fleſh*, called *Carnivorous*; others on *Graſs*, called *Graminivorous*; ſome on *Grain* and *Seeds*, called *Granivorous*, &c. Beſides innumerable other Differences that might be named, of leſs Note, between a *Man* and a *Brute*.

A. Pleaſe now to oblige me with a ſhort Account of the *Nature of Birds* or *Fowl**.

B. The

* 1. *Birds* are either *Land Fowl*, or *Water Fowl*: Of *Land Fowl*, ſome have crooked Beaks and Talons; of theſe ſome are *carnivorous* and *rapacious*, being called *Birds of Prey*; ſome *frugivorous*, or which feed on Corn, and are called by the general Name of *Parrots*. 2. Of

B. The *Philosophy of Fowl*, or the *feathered Tribe*, is really wonderful, as will appear from a short

2. Of *Birds of Prey*, some are *diurnal*, preying in the Day-time; and of these they reckon a greater and a lesser Sort: The greater are either of a more bold and generous Nature, as the *Eagle-kind*; or of a more cowardly and sluggish, as the *Vulture*.

3. The lesser *diurnal Birds of Prey*, are the *Accipitres*, or of the *Hawk-kind*. And these are of a more bold and generous Nature, and are want to be reclaimed and managed for Fowling, and are called *Hawks:* These the *Falconers* distinguish into *Long-winged*, as the *Falcon*, *Lanner*, &c. and *Short-winged*, as the *Goshawk* and *Sparrow-Hawk*.

4. Those of the Hawk-kind, which are of a Nature more cowardly and sluggish, or else indocile, are neglected by the *Falconers*, and so live at large. And of these there is also a greater Sort, as the *Buzzard-kind*; and a lesser, as the *Butcher-Bird*, or *Shrike*; (about as big as a *Black-bird)* and the *Bird of Paradise*, which is exotic.

5. Of *Birds of Prey* with crooked Beaks and Talons, some are nocturnal, or which fly and prey by Night, as the *Owl-kind*. And these are either horned or eared, as the *Eagle-Owl*, the *Horn-Owl*, &c. or without Horns, as the *Brown-Owl*, the *Grey-Owl*, &c.

6. There is a Sort of *Land-Birds*, which feed on both *Flesh* and *Fruits*, and are distinguished into three Sorts, according to their Bigness; the greatest Size being called *Maccaws*; the middle-sized, and most common, *Parrots* and *Propinjays*; and the least Sort, *Parrakeets*; and all this Kind make use of their Beak in climbing, and move the upper Jaw.

7. Land-Birds that have their Bill and Claws more straight, are also divided into three Sizes. The greatest Sort are such, as by Reason of the Bulk of their Bodies, and the Smallness of their Wings, cannot fly at all; these are exotic Birds of a singular Nature, as the *Ostrich*, the *Cassaware*, the *Dodo*, &c.

8. The middle-sized Kind are divided by their Bills into such as have large, thick, strong, and long ones; some whereof feed promiscuously on *Flesh*, *Insects*, and *Plants*; as the *Crow-kind*, which are wholly black; and the *Pye-kind*, which are *party-coloured*. Some feed on *Flesh* only, as the *King's-Fisher*; and some on *Insects* only, as the *Wood-pecker*. And into such as have a smaller and shorter Bill, whose Flesh is either *white*, as the *Poultry-kind*; or *blackish*, as the *Pigeon* and *Thrush-kind*.

9. The least sized Kind of *Land Birds*, with straight Bills and Claws, are called *Small Birds*; and these are of two Kinds, *viz.* *soft-beaked*, which have sl nder, straight, and pretty longish Bills, most of them, and feed chiefly on *Insects*; or *hard-beaked*, which have thick and hard Bills, and feed mostly on Seeds.

a ſhort Survey thereof: For, 1. with reſpect to their *Generation*, they are produced from *Eggs*, and are therefore called *oviparous Animals.* 2. Their *Motion* is two-fold, *viz. flying* and *walking*; and are thereby rendered, 3. the Inhabitants both of the *Land* and *Air:* For which Purpoſe, 4. they are wonderfully contrived with a

10. *Water-Fowl* are ſuch as frequent *Water* and *watery Places to ſeek their Food*; and theſe are all cloven-footed, and generally have long Legs, naked above their Knees, that they may the more conveniently wade in Waters. Of theſe they reckon two Sorts, *viz.* a *greater*, as the *Crane*, *Jabiru*, &c. and a *leſſer*, which are either *Piſcivorous*, feeding on Fiſh, as the *Heron*, *Spoonbill*, *Stork*, &c. or *Mudſuckers* and *Inſectivorous*, of which ſome have very long and crooked Bills; as the *Curlew* and *Wimbrell*; and others long and ſtraight, as the *Woodcock* and *Godwit.*

11. Others have middle-ſized Bills, as the *Sea-pye* and *Redſhank*; and a third Sort have ſhort Bills, as the *Lapwing* and *Plover*. Thoſe are reckoned *ſhort Bills*, which exceed not *an Inch and a Half*; the *middle-ſized Bills* are betwixt that and two Inches and a Half; and *long Bills* are all above two Inches and a Half.

12. Another Kind of *Water-Fowl* ſwims in Water; ſome of which, as the *Morehen* and *Coot*, are *cloven-footed*, and moſt are *whole-footed*. And of theſe, ſome few have very long Legs, as the *Flammant*, the *Avoſetta*, and *Corrira*; but moſtly they are ſhort-legged; of which ſome few have but three Toes on a Foot, as the *Penguin*, *Raſorbill*, &c. but generally they have four Toes on a Foot; and theſe either all connected together by intervening Membranes, as in the *Pelican*, *Solan-Gooſe*, or more uſually with the back Toe looſe.

13. And this Kind are either *narrow-billed*, or *broad-billed*; thoſe with narrow Bills have them either blunt or hooked at the Top, of which Sort ſome are *ſerrate*, as in the *Diver* Kind; and ſome not *ſerrate* or *toothed*, as in the *Puffin*; or ſharp-pointed or ſtraighter, of which Sort ſome have long Wings, as the *Gull* Kind; and ſome ſhorter, as the Diving Birds, called *Douckers.*

14. Thoſe with *broad Bills* may be divided into the *Gooſe* Kind, which are large; and the *Duck* Kind, which are ſmaller; and theſe latter into *Sea-Ducks*, and *River* or *Pond-Ducks.*

15. Moſt *Water-Fowls* have a ſhort Tail; and none of this Kind have their Feet diſpoſed like *Parrots* and *Woodpeckers* that *have two Toes forward*, and *two Toes backward*, none having more than one back Toe, and ſome none at all.

Pair

Pair of Wings to buoy themſelves up in the fluid elaſtic Sphere of Air, and whereby they keep their Bodies on a due Balance and Equipoiſe in their Motion. 5. The *Tails* of Birds are given them to ſteer their Courſe, keep them ſteady in Flight, and to aſſiſt them in their Deſcents and Aſcents into the Air. 6. The *Plumage* of Birds is a wonderful Thing, their Feathers cloath and beautify them; a Feather is a curious Production in every Part, the *Quill*, the *Rib*, and the *Vanes*, being thoroughly underſtood: The Pith in the *Rib* appears through a *Microſcope* on the tranſverſe Section *a*, as is repreſented in A, *Fig.* LII. on *Plate* XXV, fronting *p.* 307. And a *Vane* of a *Feather* (as *b*) appears like another *Feather* when magnified, as in B, *Fig.* LIII. on the ſame *Plate*, where you obſerve the net-like Texture of its membranous Part, and C is the little End magnified. 7. The *Feet* of Fowl are very particular, being ſpread ſome with Membranes for ſwimming, as *Ducks, Geeſe*, &c. ſome without for ſteady walking, perching, holding their Prey, *&c.* 8. The terrible ſharp-pointed *Talons* in Birds of Prey are very remarkable, as thoſe of the *Eagle, Vulture*, &c. 9. The *Heads* of Birds are admirably ſuited for making Way through the Air, being very near the Figure of Sir *Iſaac Newton*'s Solid of leaſt Reſiſtance. 10. The *Beak*, or *Bill*, is a ſtrange Piece of Art, their very Jaw-bones, as it were, growing out of their Head, and meeting in a Point, wonderfully adapted to pierce the Air, gather Food, and penetrate Wood, Earth, *&c.* for Prey. 11. The *Ears* ſtand not out from the Head to hinder Flight. And, 12. The commodious Situation of the Eyes of *Birds* is ſurprizing; for each of their Eyes takes in very near an *Hemiſphere*, and conſequently with both Eyes they can ſee nearly all around them at once, and ſo the better ſeek their Food and eſcape Dangers. 13. The wonderful *Structure of the Body* of Fowls, in the Form of a Ship, the *Breaſt-bone* ſerving as a Keel, and their Tails as Rudders, to govern them in their *aerial Voyages*, deſerve our Attention and Admiration. 14. The *internal Make of their Bodies*, and the ſeveral Parts, as the *Larynx*, the *Tongue*, the inner *Ear*, the various *Muſcles*, their *Lungs*, the Poſture of the *Heart*, &c. are different for the moſt Part from other Animals. 15. The *Migration* of Birds is an Inſtance of great Amazement: The Stork in the Heaven knoweth מועדיה *her appointed Times*, and the Turtle, and the Crane, and the Swallow, *obſerve the Time of their Coming*, ſaith God himſelf, *Jer.* viii. 7. What ſtrange *Inſtinct* ſhould induce them to change their Place? What ſhould direct ſome to warmer Climes? others to colder Climes? Yea, what ſhould incline Swallows, for Inſtance, to take up their *Winter* Quarters in the Water, under the Ice, in Lumps and Cluſters in the frozen *northern* Seas? as it is well known they do *. 16. The *Incubation*

* Since not only *Olaus Magnus* reports this in his *Breviar. Hiſt. Serpent.* Lib. XIX. Cap. 11. but alſo *Etmuller* affirms he has found Swallows in this Condition among the Reeds of a *Fiſh-Pond*; and the Rev. Mr. *Derham* ſays, that at a Meeting of the Royal Society *Feb.* 12, 1711-12, Dr. *Colas* declared he ſaw 16 Swallows ſo drawn out of the Lake of *Samdrot*, and about 30 out of the King's great Pond in *Roſincilin*; and that at *Schlebitten*, near an Houſe of the Earl of *Dohna*, he ſaw two Swallows juſt come out of the Waters, that could ſcarce ſtand, being very wet and weak, with their Wings hanging on the Ground; and that he hath obſerved the Swallows to be often weak for ſome Days after their Appearance. *Phyſico-Theol.* Book VIII. Chap. 3. Note (4.)

of Fowls is worth our Notice: How (ſays the great *Naturaliſt*, the Rev. Mr. *Derham)* ſhould they be aware that their Eggs contain their Young? or, that their Production is in their Power? 17. Their *Nidification* ought to humble the Pride of Man; with what inimitable Art, Neatneſs, and Propriety, do they contrive and build their *Neſts?* 18. The *Egg* itſelf is a ſtupendous Contrivance of infinite Wiſdom. Moſt Animals are produced from Eggs *within*, but Fowl exclude their Eggs, which therefore are made with hard cruſty Shells to preſerve the included *Embryo* from Accidents, and to contain ſuitable Nouriſhment for it: Chickens are nouriſhed by the White alone till grown great, and then feed on the ſtronger Diet of the Yolk. 19. Though all Fowl are hatched from Eggs; yet it is not always by the Incubation or Brooding of the parent Fowl, but by ſome other Heat or Warmth ſometimes: Thus, *Job* xxxix. (the *Oſtrich*) *leaveth her Eggs in the Earth, and warmeth them in the Duſt*; and at this Time they hatch Chickens in Ovens at *Grand Cairo* in *Egypt*; each Oven containing 80000 Eggs. 20. Some Birds feed on Grain, and are called *Granivorous*; and Birds of Prey are called *Carnivorous*, becauſe they feed on Fleſh. Theſe are a few of the many wonderful Properties of the *Nature of Birds.*

A. Indeed, *Sir*, it affords me unſpeakable Pleaſure to hear you recount the Particulars of the wonderful Nature of different Animals; and, pray, go on if you pleaſe, in the next Place, with the *Nature of Fiſhes* *. *B.* The

* 1. *Ariſtotle* divides Fiſhes into three Kinds, *viz.* *Ceraceous*, *Cartilaginous*,

B. The remarkable Particulars in the Survey of the *Nature* of Fiſhes, which I ſhall juſt ob-
ſerve

tilaginous, and *Spinous*; and to this Diviſion Mr. *Willoughby* conſents, as better than that of *Rondeletius*, who diſtinguiſhes Fiſhes into *Sea-Fiſh*, *River-Fiſh*, *Pond* or *Lake-Fiſh*.

2. The *Cetaceous* Kind, ſometimes called the *Belluæ Marinæ*, have Lungs, and breathe like *Quadrupeds*; they copulate alſo like them, conceive and bring forth their Young alive, and ſuckle them with their Milk.

3. The *Cartilaginous* Sorts are produced from large Eggs like Birds, which are excluded the Womb alſo, like thoſe of Birds.

4. The *Spinous* Kind are alſo *Oviparous*, but their Eggs are ſmaller, and they have *Spinæ*, or ſharp Bones up and down in their Fleſh to ſtrengthen it.

5. But Mr. *Willoughby* thinks it would be yet more proper to diſtinguiſh Fiſh into ſuch as *breathe with Lungs*, and ſuch as *breathe with Gills*; and then to ſubdivide thoſe that *breathe with Gills* into *Viviparous*, and *Oviparous*.

6. The *Viviparous* Kind he ſubdivides into the *long*, as the *Sharks* and *Dog-Fiſh*; and *broad* Kind, ſuch as the *Paſtinacæ*, *Rajæ*, *Squatinæ*, &c.

7. The *Oviparous* Kind are the moſt numerous; and theſe he ſubdivides into the ***Flat-fiſh*** Kind, and ſuch as ſwim with their Backs upright, or at right Angles to the Horizon. He gives us the following Catalogue of our *Engliſh Fiſhes*.

8. Of the long *Cartilaginous* Kind, are the *white and blue Shark*; the *Tope*; the *Prickled Dog*, or *Hound Fiſh*; the *Smooth-Hound-Fiſh*; the *Cornwall-Bounce*; the *Morgay*, or *Leſſer Hound-Fiſh*.

9. Of the *plain Cartilaginous* Kind, are the *Scate* or *Flare*; the *Thornback*; the *White-Horſe*; the *Angel:* or *Monk-Fiſh*; the *Toad-Fiſh*, or *Sea-Devil*.

10. Of the *plain ſpinous* Kind, are the *Turbet*, or *Bret*; the *Cornwall-Lug Aleſe*; the *Plaſe*; the *Dab*; the *Flounder*; *Fluke*, or *Butt*; the *Holy-Butt*, or *Turbot* of the *North*; the *Sole*.

11. Of the *Eel* Kind we have the *Lamprey*; the *Lampern*; the *Conger-Eel*; the common *Eel*; the *Sand-Eel* or *Lancer*; the *Butter-Fiſh*; the *Sea-Loach*; the *Eel Pout*, or *Turbot*; the *Sea-Wolf*; the *Sea-Lark*; the *Creſted-Sea-Lark*; the *Liparis* of *Rondeletius*; the *Miller's-Thumb*; the *Dutch-Poto-Hogs*.

12. Of the Kinds of Fiſh wanting the *Belly Pair of Fins*, we have the *Sun-Fiſh*; the *Acus* of *Ariſtotle*; the *Sea Adder*; the *Saw-Fiſh*; to which may be added the *Mermaid*, or *Syren*.

13. Of the *Non-ſpinous* Kind with *three unprickly ſoft Fins* on the Back, we have the *Cod-Fiſh*; the *Whiting-Pollock*; the *Cole-Fiſh*; the *Whiting-Blands*; the *Haddock*; the *Whiting*.

14. Of the *Non-ſpinous* Kind with only *two ſoft Fins* on the Back, are the *Hake*; the *Ling*; the *Tunny*, or *Spaniſh-Mackrel*; the *Grayling*, or *Umber*; the *Ginnard*; the *Schelly*; the *Salmon*;

the

ſerve to you, are the following: 1. As they were originally made out of the *Water*, ſo that is the only Element in which they can live: And therefore, becauſe, 2. Their Motion is *ſwimming*, they need no Legs; and ſo have none. 3. Inſtead thereof, they are much better provided with *Fins*, and more eſpecially a proper Sort of Tails, which ſerve as *Oars* to waft themſelves about withal in the Water: For, 4. The *Fins* on the Belly principally ſerve to keep them from turning on their Backs, as being the heavier Part; as they would do, were thoſe *BellyFins* cut off. 5. The Fiſhes uſe *Reſpiration* in Water, by paſſing it through their *Mouths* and *Gills*; for their *Gills* ſerve in them the Office of the Lungs in other Animals. 6. The Bodies of Fiſhes are contrived with ſuch divine *Geometry*, as

the *Samlet*, or *Braulin*; the *Gray*; the *Salmon-Trout*; the *Scurf*, or *Bull-Trout*; the *Trout*; the *Red-Chare*; the *Gilt-Chare*; the *Smelt*; the *Rock-Fiſh*, or *Sea-Gudgeon*; the *Lump*, or *Sea-Owl*; the *Dog*, as it is called in the *Weſt* of *England*.

15. Of the *Non ſpinous* Kind with only *one Fin on the Back*, we have the *Herring*; the *Pilchard*; the *Shad*; the *Sprat*, (which is only a *young Herring)*; the *Gar-Fiſh*; the *Sturgeon*; the *Pike*, or *Jack*; the *Carp*; the *Bream*; the *Tench*; the *Oerve*; the *Chub*; the *Barbel*; the *Dace*; the *Roach*; *Bleak*; *Gudgeon*; *Loach*; and *Minow*. Note, the laſt twelve of theſe are called (*Malacoſtomi*) *Leather-mouthed* Fiſhes, becauſe they have no *Teeth* in their Jaws, but only deep down in their Mouths.

16. Of the *ſpinous* Kind with *two Fins on the Back*, of which the foremoſt is *aculeate*, or prickly, we have the *Baſſe*; the *Mullet*; the *Grey-Garnard*; the *Tub-Fiſh*; the *Rotchet*; the *Piper*; the *Sur-Mullet*; the *Spider*; the *Scud*; the *Perch*; the *Dorge*.

17. Of the *aculeate* Kind with only *one Fin on the Back*, whoſe *Radii* are *ſome prickly*, and *ſome ſoft*, we have the *Gilt-Head*; the *Old-Wife*; the *Ruff*; the *Prickle-Back*, or *Banſticle*; the leſſer *Prickle-Back*.

18. Of the *Cetaceous* Kind, there are reckoned only the *Balæna Britannica* of the Ancients, at this Time not known; the common *Whale*; the *Dolphin*; and the *Porpuſs*.

to paſs through the denſe *Medium* of Water with the greateſt Eaſe, and the leaſt poſſible Reſiſtance from it. 7. How wonderouſly are they defended, beautified, and rendered more apt for gliding through the Water, by thoſe hard, ſmooth, poliſhed, numerous *Scales*, with which the Surface of their Bodies is ſo curiouſly overlaid! 8. The great *Author of Nature* has contrived the *Eye* of Fiſhes juſtly ſuitable to the Nature and Refraction of Water, different from that of Air, for their Eyes are flat outwardly, and not protuberant, leſt they ſhould wear and hinder Motion; but the *cryſtalline Humour* is made *ſperical*, and not *lenticular*, or flattiſh, as ours, who live and ſee through Air. 9. Fiſh are contrived with an *Air-bladder*, which makes them buoyant; and according as they dilate or contract their Bladder, by the Means of Air, ſo they are enabled to abide higher, deſcend lower, or remain in what Part of the Waters they pleaſe. 10. Some Fiſhes are wonderfully formed with Inſtruments of Defence, Proviſion, *&c.* What amazing circular Rows of *horrible Teeth* fill the Mouth of a *Shark!* other ſome are endued with *Wings*; ſome have two or more Feet, as the *Male Whale*, &c. See the wonderful *Unicorn-Fiſh* in *Fig.* LIV. on *Plate* XXVI, fronting *p.* 342, whoſe Horn is 10 or 12 Feet in Length. The *Sword-Fiſh* in *Fig.* LV. and the *Saw-Fiſh* in *Fig.* LVI. on the ſame *Plate*, are very ſurprizing; the *Sword* and *Saw*, where they ſhoot from the Head, being ſix, eight, or ten Inches wide, and about five or ſix Feet in Length, as I remember to have ſeen them; the Teeth of the *Saw* at the broad

End

End being as long as one's Finger. 11. The *Size* of Fish, and other Water Animals, is almost infinitely different; the greatest is the *Whale*, (called *Leviathan* in Scripture) being the biggest of all. *Pliny*, *lib*. ix. *cap*. 3. mentions some Whales 960 Feet in Length; and, *lib*. xxxii. *cap*. 1. he mentions *Whales* 600 Feet long, and 360 broad, which came into a River of *Arabia*. 12. The *Species* or *Sorts of Fish* are as various as their Size, and cannot be all known. I could, had I Time, have named to you a far greater Number of remarkable Peculiarities in the *Nature of the finny Tribe*: But, if you desire a farther Account, you may consult the voluminous Writings of the Learned.

A. Sir, this is abundantly better than none; pray proceed to recapitulate some of the chief Things observable next, in the *Nature of Insects*, if you please *. *B*. Nothing

* 1. Mr. *Ray*, in his Method of Insects, distinguishes Insects into two general Kinds, *viz*. such as *change their Form*, and such as do *not change their Form*.

2. *Insects, which change not their Form*, have some six, some eight, some fourteen, others twenty-four Feet, and some many more, which are therefore called *Polypedes*, or *Multipedes*.

3. Those that have but six Feet, are *terrestrial* or *aquatic*; the terrestrial are of various Sorts, as the *Louse*, the *Flea* the *Crab-Louse*, the *Wall-Louse*, the *Tick*, and several others found in the rotten decayed Wood of Trees, old *Books*, in *Meal*, in the *Earth* in *Flowers*, &c. Those in Water, are a Sort of Louse adhering to Fish; and the *Squilla fluviatilis*.

4. Insects with eight Feet are either with a Tail, as the *Scorpion*; or without, as the *Spider*. Of this Sort some *spin no Web*, have but *two Eyes*, and very *long Legs*, as the *Carter* or *Shepherd*. Others *spin a Web*, and have many Eyes, and are of divers Sorts. To this Tribe of *eight-footed Insects* belong several Sorts of *Ticks*, and the *Syrones*, or *Mites*.

5. Insects *not changing Form*, and with 14 Feet, are the *Arselli*, or those of the *Wood-Lice*, or *Chess-bob* Kind, of which some live in

B. Nothing pleaſes me more; therefore with regard to *Inſects*, I obſerve, 1. That though they

in Water, ſome on Land. To this Tribe are alſo referred a Sort of *Water-Gnat*, or *Fly*, and a *Water-Louſe*, found upon Fiſh.

6. Theſe which have 24 Feet, have the eight fore Feet leſſer, and the 16 hinder ones larger. Of theſe there are two Kinds obſerved, both with long Bodies, one larger and of an obſcure Colour, among the Rocks by the Sea-Side; the other of a Silver Colour found in Houſes.

7. There is a Kind with 30 Feet, of an oblong Shape, Cheſnut Colour, and full flattiſh Body, uſually lying under Logs and Trunks of Trees: It is very agile and ſwift.

8. The *Multipede* Inſects, which change not their Form, are found both in Land and in Water; thoſe on Land are either *roundiſh in the Body*, with all their Legs riſing out of the Middle of the Belly nearly, as the *Tulus*; or more flat and compreſſed, with their Legs growing along on each Side, as the *Scolopendra*.

9. And ſome of theſe *Multipedes* are *aquatic*, of which Mr. *Ray* makes three Sorts, *viz.* the *Corniſh Lugs* with 38 Feet, the *Scolopendra Marina*, and a *two-tailed* Animal lying in the Clefts of Stones under the Salt Water.

10. The ſecond Kind of inſects are thoſe *which change their Form*, or undergo a real *Metamorphoſis*. And this is of three Sorts or Species, *viz.* The *firſt* is when the *Tranſmutation* or Change *is ſingle and inſtantaneous*; there being no ſenſible *Stop* or *Reſt* between the *Old* and the *New* Form. The *ſecond Species* is when there is a *double Metamarphoſis*; as firſt into a *Chryſalis*, and then into a *flying Inſect*. The *third Species* is a ſimple Change from a Worm to a flying Inſect, but yet with a ſenſible Reſt or Stop between one Form and the other.

11. Of the *firſt Species* are the *Libellæ* or *Pertæ* produced from an Inſect with ſix Feet; the *Cimices Sylveſtres*, having the Figure of St. *Andrew*'s Croſs on their Backs; the *Locuſts*; the *Gryllo-Talpa*, or *Mole-Cricket*; *Crickets* of all Kinds; the *Graſhopper*; the *Blatta*; the *Ephemera*, which lives but a Day; the *Water-Scorpion*; *Water-Flies* of ſeveral Sorts, *&c.*

12. *Inſects* changing Form of the *ſecond Species*, or which undergo a *double Tranſmutation*, are very numerous; they lie a while before their Change quite ſtill, without Food, or changing Place.

13. In reſpect of their *Wings*, they are either *Vaginipennia*, or ſuch as have *Caſes* within which they withdraw and cover their Wings, as all the *Scarabæi*, or *Beetle* Kind; *Anelytra*, whoſe Wings are open and expanded.

14 The *Scarabs*, or *Beetles*, are divided in reſpect of their Horns into the *Naſicornis*, the *Bucerota*, and *Cervus Volans*, or *Stag-Fly*.

In

they are a small, and deemed a despicable Species of Creatures, yet when well considered, and carefully surveyed with a *Microscope*, they will appear the Pride of Nature, wherein she has bestowed more nice and delicate Art, and displayed more profusely the rich Embroidery, and elegant Beauties and Garniture of Colours, than in any of the larger Species of Animals; though unheeded and unseen by us. 2. *Insects* are so called from the Shape of their Bodies, which seem as it were (*insecta*, i. e.) cut into two Parts or Halves, and joined to one another by a small String or Neck, as in *Ants*, *Flies*, &c. 3. They are all *Oviparous*, that is, they lay Eggs, from whence they are all produced. 4. The different Kinds of *Insects* reposit their Eggs in different Places; some in *Beer*, *Vinegar*, &c. some in *Plums*, *Pease*, *Nuts*, &c. as the *Ichneumon Flies*: In *Pears*, *Apples*, &c. as the *Phalenænæ Kind*: In the *Bark*

In respect of their *Antennæ* they are of many Kinds, of which the most eminent are the *Capricorni*. Some from their Motion are called *Saltatrices*, or Leapers; and others from their Colours are called *Cantharides*.

15. To the Beetle Kind may be referred the *Glow-Worm*; the *Staphylinus*, and the *Oil-Beetle*, so called from its emitting a Sort of Oil from its Joints on being squeezed or pressed.

16. The *Anelytra*, or Insects whose Wings are open, and without Cases, have their Wings either *farinaceous* or *mealy*, as the *Butterfly* Kind; or *membranous* and *transparent*, as the *Fly* Kind.

17. The *Anelytra* with farinaceous or mealy Wings are of two Sorts, *viz. Papiliones*, or *Butterflies*, which fly by *Day*; and the *Phalænæ*, or *Millers*, or *Moths*, which fly by *Night*. The various Sorts of each are so numerous, as scarce to be recounted or methodized.

18. *Anelytra* with *membranous* Wings are a large Species, and comprehends numerous Tribes of the most *perfect Insects*, as the *Hornet*, the *Humble-Bee*, the *Bee*, the *Wasp*, and all the *Fly* and *Gnat* Kind; hitherto is also referred the *Formica*, or *Ant*. Most of this Head come from a *Vermicle* or Maggot by a Metamorphosis of the third Kind.

Wood,

Wood, Buds, Leaves, &c. of *Trees.* The *white Butterfly* lays its voracious Offspring on *Cabbage-leaves:* Some, which require Warmth, lay their Eggs about the *Bodies of Animals,* as in the *Feathers* of *Birds,* the *Hair* of *Beasts,* and even in the very *Scales* of *Fish:* Some go farther, and penetrate the Body itself, and its Cavities, and there lay their Eggs, as in the *Nose, Guts,* the *Kidneys,* the *Bladder,* the *Brain,* in the *Gall-Bladder* itself, and in the *Flesh* in general. 5. Hence the surprizing Production of *Maggots* and *Vermin* in all those Places, and Parts of *Animals* now mentioned. 6. The *Metamorphosis of Insects* is a Thing extremely astonishing; I shall give from Mr. *Geodart* an Instance thereof: See *Fig.* LVII. on *Plate* XXVI, fronting *p.* 342. The *Eruca* or *Caterpillar* A hath its Origin *(saith he)* from the Egg or Seed of a *Butterfly* C, called the *Peacock's Eye*; I took it the 4th Day of *May* 1635, and nourished it with the Leaves of Nettles till the 11th of *June* the same Year; at which Time it began to prepare for its Transformation to the State in which it is called *Chrysalis* or *Aurelia,* as B; in this *aurelian State* it continued changing (with its Head downwards) 19 Days, at the End of which, there proceeded from this *Aurelia* a *Butterfly* C, with four Wings; and from its elegant Colours, called the *Peacock's Eye,* as aforesaid. 7. *Insects* in their first State, as *Maggots* and *Caterpillars,* feed on hard and coarse Diet, as *Leaves, &c.* contrary to other *Animals*; in their *aurelian State,* they subsist without any Food; in their *mature State,* as *Flies,* they live on a more delicate and tender Diet, as Honey from

from Plants, Blood from Animals, *&c.* It is discovered by the *Microscope*, that the elegant Colours of *Butterflies, &c.* are owing to neat and well-made Feathers, set with great Curiosity and Exactness in Rows and good Order. 9. The Eyes of *Insects* are hard, fixed, or immoveable; and some have more than two, as *Spiders* have four, six, or eight Eyes: *Flies, Wasps, &c.* have the Cornea, or outward Coat of their Eye, made of curious Lattice-work, as is represented magnified in *Fig.* LVIII. on *Plate* XXVI, fronting *p.* 342. The Eyes of these *Insects* have this Contrivance to supply the Place of the *crystalline* and *vitreous Humours*, which they (it is thought) have not. 10. The *Antennæ*, or *Feelers*, which grow from the Head of *Insects*, serve them to feel out Obstructions and Annoyances in their Walk or Flight; are a good Guard to the Eyes and Head; and in many, a very beautiful Piece of Garniture to the Body. 11. As to the Motion of *Insects*, some creep, some leap, some walk, some swim, and most of them fly; some fly with Wings, others by Help of their Webs, as *Spiders*; and others by Means as yet unknown. 12. The Wings of many *Insects*, are a most curious Piece of Workmanship, distended and strengthened with the finest Bones, and these covered with the finest, transparent, and lightest Membranes; some adorned with neat and beautiful Feathers, and many provided with the finest Articulations and Foldings, for the Wings to be withdrawn, and neatly laid up in their *Vaginæ* or *Cases*; and again readily extended for Use. 13. Those *Insects* which have four Wings, have their Bodies thereby kept steady and upright in

Flight; and thofe which have but two Wings, have Poifes or Pointils, like little Balls, fet under their Wings on each Side their Bodies for that Purpofe. 14. The Minutenefs, Art, and Curiofity of the Joints, Mufcles, Tendons, Nerves, *&c.* neceffary to perform the Motion of the Wings, Legs, and other Parts, is a furprizing Thing to all who confider it. 15. The *Nidification* of *Infects* far excels the moft exquifite human Art, witnefs the nice geometrical Combs of fome, or earthen Cells of others, or the Webs, Nets, and Cafes woven by the admirable *Textrine Art* of fome others. 16. Again, what ftrange *Inftinct* leads others of thofe fmall Creatures to make even Nature itfelf fubfervient to their Defigns, by making the *Vegetation of Trees* and *Plants* the Means of building their little *Nefts* or *Cells*; fuch as thofe Cafes, *Galls* and *Balls*, found on the Leaves and Branches of Vegetables of many different Sorts; fome being hard Shells, fome tender *Balls*, fome fcaly, fome fmooth, fome hairy, fome long, round, conical, *&c.* 17. They have Parts analogous to the *Brain, Stomach, Entrails, Arteries, Veins, Nerves, Lymphæducts, &c.* yet being fo wonderfully fine and tender, are, as it were, included within the hard Cafe of their outward Body; wherewithal they are cloathed and defended, as with a *Coat of Mail.* 18. Again, how curioufly are thofe outward Teguments, or hard Cafes of *Infects* Bodies, contrived? How are they fet with *Briftles*, fharp *Spines, &c.* for Defence? How are they adorned with neat Imbrications, and many other Beauties and Fineries? 19. As the Magnitude of fome Species of Animals is very wonderful, on the contrary, the Minuteness of some *Insects* is far more amazing: Mr. *Lewenhoeck* has observed more of these *Animalcules* in the *Melt* of a *Cod-Fish*, at one Time, than there are People living on the Face of all the Earth at once. It is also found, that in a Drop of Pepper-water are contained above 8280000 of those small Creatures; and some are yet discovered smaller than these, so that Millions of Millions might be contained in one Drop of Water. 20. It is the infinite Number of these invisible Animals that makes stagnating Waters appear of so many different Hues, as *green*, *brown*, *reddish*, *&c.* But I cannot farther enlarge, for want of Time.

A. Well, these Things loudly declare the wondrous Skill and Wisdom of their Maker; and great Pity it is they are not more attended to: But, pray, continue this pleasing Survey next in the Nature of those Creatures you call *Reptiles**.

B. In

* 1. *Reptiles* are either *terrestrial* or *aquatic*. *Terrestrial Reptiles*, or such as are found on Land, or in the Earth; among these the *Serpent Kind* are the principal; of which some are *venomous* in their Bite, as the *Rattle-Snake*, the *Viper* or *Adder*; and, some think, the *Sloe Worm*; but that, as well as its *Blindness*, is thought by others to be an Error. Some are not *venomous*, as the *common Snake*, and many other Sorts of Snakes in foreign Countries.

2. The next considerable Species of *Reptiles*, are *Snails* of all Sorts: Of these some bear *Shells* of various Forms, Sizes, and beautiful Colours. Others have *no Shells*, as the large *black Snail*, and others of a greenish and yellow Colour; with all that Sort we call *Slugs*, found under Boards on moist Ground, and on the Leaves of Plants, *&c.*

3. To the Head of *Reptiles* also many refer the *Multipede* Kind; for as they cannot, without great Impropriety, be called *Insects*; and as their Motion, though performed with Legs, is yet a Sort of *Creeping* or *Crawling*, so they may be very fitly called *Reptiles*; but as I have, according to Mr. *Ray*'s Method, mentioned them in the last Note as a Species of *Insects*, I shall say nothing more of them here.

4. The

B. In the *Reptile Species* ſeveral Things are common to other Animals, and have been already obſerved; and ſome Things are ſomewhat parti-

4. The *Lumbrici*, or *Earth-Worms*, are a moſt conſpicuous Part of the *Reptile* Kind: Of theſe ſome are of a *larger Sort*, called *Dew Worms*; ſome of a *leſſer Sort*, of theſe there are *red* and *green*, with *yellow* Tails; which latter are called *Gilt-Tails*.

5. *Worms* found in the Bodies of Animals make another large Species; as the *Teretes*, the *Lati*, the *Aſcarides* in the Bowels of Men; the *Vermiculi Setiformes*, and the *Botts* in the Inteſtines of Horſes and other Beaſts.

6. *Aquatic* or *Water-Reptiles* are of various Species; of which, in regard of their Motion, *Eels* make the firſt Diſtinction: But, from their more general Nature, they have always been conſidered among the *Fiſh Kind*, where of Courſe I was obliged to take Notice of them in this Survey. See Note, *Page* 340. *Art.* 11.

7. The *Leaches* make the next Claſs of *Water-Reptiles*: Of theſe there are three Sorts, *viz.* the *Medicinal Leach*, or *Sanguiſuge*; the common black *Horſe-Leach*, and the Aſh-coloured *Sea-Leaches*. There is alſo a Sort of this Kind that is *ſmaller* and *flatter*, which is found ſticking to Stones at the Bottom of Brooks.

8. Beſides this, there is another leſſer Sort of *Water-Reptiles*, of which ſome are round, long, and *black*, and others *red*; the Black hath two ſmall Horns on its Head; the Red is about a Finger's Length, with a Forceps at the Tail. To theſe may be added, thoſe very ſmall and ſlender *Anguiculæ* which lie in Cluſters in ſtagnant Waters, and from a Veſſel of a *red Fluid* which appears thro' the Body of each, they make the Water look red in divers Places.

9. There is another Sort of this Kind which is *flat*, and very ſmall and thin, and are called *Flukes*; they are ſometimes found in Waters, and ſometimes in the Branches of the *porus Bilarius* in Sheep. Beſides theſe, there are many other Species without Name or Diſtinction.

10. I think thoſe *Water-Animals* which are covered with a *Theca*, or Sort of Caſe, are to be referred to the Claſs of *Reptiles*. This *Theca* is either *immoveable*, being fixed to the Stones, and is of a Figure round, or elſe more compreſſed and flat; or *moveable* and *portable*; which *Theca* is commonly called *Phryganea*; and is either *ſtraight* or *crooked*.

11. The ſtraight *Theca* is compoſed either of *Straws* and little *Feſtucæ*, lying parallel one to another, of which there are two Sorts, a *greater*, where the *Feſtucæ* are two Inches long; and a *leſſer*, which is very common, and are called *Straw-Worms*. Or elſe the *Feſtucæ* lie tranſverſely, and are ſhorter, having ſometimes Pieces of *Shells* or *Stones* mixed with them.

12. Others, whoſe *Theca* or Caſes are ſtraight alſo, have no *Feſtucæ*, but always either *Sand* or *Gravel*; and of theſe, ſome have the *Theca* round, and are called *Cod-Baits*; others are flat and compreſſed.

13. Others

particular and peculiar to them, which I ſhall remark in the following Order: 1. Their *ſinuous, vermicular,* or *creeping Motion* is very curious, and contrived with the niceſt Art, and geometrical Neatneſs. 2. The whole Body of a Worm is, as it were, but a Chain of *annular* or *ſpiral Muſcles*, whoſe orbicular Fibres by contracting render each Ring (at firſt wide and extended) more ſtraight and long; and thus the foremoſt attracting the next behind, the Action is continued through the Length of their Body, and produceth their vermicular or ſpiral Motion. 3. The *Serpent Kind* move by means of *annular Scales* lying ſtraight acroſs their Bellies, contrary to what they do on the Back, and other Parts of their Bodies. Now the Edges of the foremoſt Scales lying over the Edges of the hinder from Head to Tail, run out a little beyond them, ſo that when each Scale is drawn back, or ſet a little upright by its Muſcle, the outer Edge thereof (or Foot) is raiſed alſo a little from the Body, to take hold on the Earth, and ſo producing, by the ſucceſſive Action of all, the ſinous Motion of the *Serpent*. 4. The *Motion of Snails* is performed by the *undulatory Action* of a long broad Skin along each Side of their Belly; and they are enabled, partly by a ſlimy glutinous Matter emitted from their Body, and partly by the Preſſure of the *Atmoſphere*, to adhere firmly

13. Others have the *Theca crooked* or *horned*, which runs tapering; of theſe there are reckoned four Kinds, a greater and a leſſer *black* Sort; and a greater and leſſer *Aſh-coloured one*. The *Theca* or Caſes of all theſe Sorts of *Cados Worms* are admirably contrived, being cemented or glued together in ſuch a Manner, as not to be eaſily ſeparated one Part from another; and by that Means theſe Creatures ſecure themſelves from the Voracity of ſuch Fiſh as would otherwiſe make them their Prey.

to all Kinds of Superficies, and in all Poftures. 5. *Caterpillars*, while in their *vermicular State*, are curioufly provided with little Feet, the foremoft fhort and hooked, to draw Leaves, *&c.* to them; the hindermoft are broad Palms, befet around with fmall fharp Nails, by which they ftick to, and grafp whatever they are upon: Whereas, in their *Nympha* or *Aurelia State*, they have neither Feet nor Motion, but a little in their hinder Parts, and in their *mature* or *infect State*, they have motive Parts proper to that *Species of Animals*. 6. It is a wonderful pretty *Mechanifm* obfervable in the going of *Millepedes*, (or *Multipedes*) that on each Side of their Bodies every Leg hath its Motion, one very regularly following the other from End to End of the Body; fo that their Legs in going make a Kind of *Undulation*, and give the Body a fwifter Progreffion than one would imagine it fhould have, where fo many fhort Feet are to take fo many fhort Steps. 7. The *Spine* or *Back-bone* of *Serpents* is really wonderful: How thick are they fet with Joints, or *Vertebræ!* How numerous and ftrong are their co-operating fmall *Mufcles!* By what curious *Articulation* of the *Vertebræ* can they turn and wind their Bodies any Way! 8. Some of the *Reptile Kind* are provided with a *poifonous Matter*, ferving to the more eafy Conqueft and fure *Capture* of their Prey; and probably may ferve to the Digeftion of their Food. 9. The *Poifon* of the *Viper* lieth in a *Bag* in the Gums at the End of a certain fharp Tooth, conveyed thither by a Duct from a conglomerate Gland lying

lying in the Side of the Fore-part of the Head, by which it is ſeparated from the Blood. This Tooth is *tubulated* or hollow, through which, when the *Serpent* biteth therewith, the Poiſon is conveyed to the Wound. 10. The *Size*, or rather Length, to which ſome of theſe *Serpents* grow, is very ſurprizing. I have ſeen the perfect Skin of a *Rattle-ſnake* 22 Feet long; and there are others from 30 to 40 Feet in Length. 11. Thoſe Creatures of the *Serpentine Kind* are the moſt *vivacious*, or tenacious of Life, of all other Animals. Thus we ſee *Eels*, *Adders*, &c. live, have Motion, yea, are very ſtrong, for a great while after they are beheaded, fleaed, and diſboweled: The Reaſon of which is owing to the greater Firmity, Solidity, and Compactneſs of their Fleſh above that of other Creatures; ſo that the Action of the vital Springs, or Cauſes of Motion, continue longer in them than in other Creatures. 12. Mr. *Redi* relates, that *Serpents* and *Vipers* will live not only ſome *Days* or *Weeks*, but *many Months*, without Food, ſhut up in a Box, yea, that they will be able to *bite*, and emit a *deadly Poiſon*, after eight, nine, or more months. But if the Veſſel be open, and they perſpire much, they die, without Food, in a ſhort Time. 13. Some of thoſe *Reptiles*, as *Earth-Worms*, *Snails*, &c. are *Hermaphrodites*; that is, have the *genital* Parts of both Sexes, the ſame *Worm* being Male and Female, ſo that they mutually copulate with each other; and the Parts of Generation are placed in the Necks of Snails, juſt under their Heads. And would you ſee more of the wonderful Nature, Kinds, and

Peculiarities of the *Reptile Species*, you may be ſatisfied, by reading the Natural Hiſtory of the ſeveral Parts of *Aſia*, *Africa*, and *America*.

A. Sir, I thank you; I do not know but that I may, when I have Opportunity and Leiſure: But, pray, what have you to obſerve in the Nature of thoſe you call *Shell-Animals* * ?

B. My

* 1. The Kinds and ſeveral *Species* of *Conchilious* or *Shell-Animals* are not well known, nor ſufficiently digeſted by Naturaliſts; nor is it poſſible they ſhould, ſince their *Number* and *Variety* are ſo exceeding great, and the Bottom of the *Sea* their principal Place of *Habitation*.

2. However, ſome of the more common and diſtinguiſhed of this Tribe I ſhall enumerate and methodize in the following Order. Of *Shell-Fiſh*, ſome are *univalve*, or have only *one Shell*; others are *bivalve*, or have *two Shells*.

3. Of ſingle Shell-Fiſh there is great Variety, both with reſpect to Fiſh itſelf, and the Make and Form of the *Shells*. Some Fiſh having divers and diſtinct Parts, as *Head*, *Legs*, *Claws*, *Antennæ*, &c. without the Shell, as in the *Lobſter* and *Crab* Kind. Others are contained entirely within the Shell, except when they exert themſelves for Motion; at leaſt, they have no Parts growing without the Shell, as in the *Snail*, *Periwinkle*, &c. Kind.

4. The *Lobſter* is the Principal of *Shell-Fiſh*. His Habitation is in Holes among the Rocks. They have four Legs on a Side, by Means of which, with their two great Claws and broad Tail, they move with great Nimbleneſs. It is ſaid, that if one of the large Claws be broken off, it will grow again, or be renewed, though no other Animal hath the Power of renewing a loſt Limb. Some ſay, the *Lobſter* is *androgynous*, i. e. hath both Sexes in itſelf; but others doubt it. It is reported there are near thirty ſeveral Sorts of *Lobſters*, all clothed with Shells; of the *Lobſter* Kind are the *Craw-Fiſh*, the *Prawn*, the *Shrimp*, &c.

5. The *Crab* is the next Shell-Fiſh of Note; its Legs and Claws are like thoſe of the Lobſter for Number, Parts and Texture, nearly; but their Motion is *latitudinal*, or ſide-ways; their Eyes are more prominent than thoſe of Lobſters, and therefore want not their *Antennæ*, or long *Feelers*. They live among the Stones and Rocks like Lobſters, and are never found uncovered by the Waters, except when very young and ſmall, on the Shores at low Water. Their *Spawn*, like that of *Lobſters*, conſiſts of ſmall Eggs, and the Time of Spawning in both is the ſame. The *Crab* Kind hath alſo its *Species*, as the *Spider-Crab*, the *Soldier-Crab*, &c.

6. The

B. My Survey of them will be very brief; and I ſhall obſerve to you, 1. That thoſe Creatures have

6. The *Star-Fiſh* is another Species of the *Univalves:* They have five pointed *Rays*, which proceed from the Body in the Centre, and by bending theſe backward and forward, move in all Directions indifferently. The Mouths of all this Kind are in the Centre of their Bodies, and armed with Teeth: they have ſeveral little fleſhy Trunks, which they dart into the *Mud*, through which they ſuck their Food. Their Organs of *Digeſtion*, *Generation*, or for voiding of *Excrement*, are not yet diſcovered.

7. The moſt wonderful Fiſh of this Kind is the *Stella-Arboreſcens*, ſo called, becauſe from its ſmall Body, as a Centre, proceed a prodigious Number of Branches all around, whoſe numerous and minute Ramifications make a ſurprizing Kind of *Net-Work*, which the little Animal, floating about in the Water, caſts over its Prey, which it then catches as Fiſh are caught in a *Caſting-Net*. There is a Fiſh of this Sort to be ſeen in the *Muſeum* of the Royal Society in *Crane-Court*, *Fleet-Street*, whoſe Ramifications are reckoned more than twenty Thouſand in Number.

8. Beſides theſe are divers others, whoſe Natures are very wonderful; as the *Limpets*; the *Venus-Ear*; *Sea-Urchins*, or Button-Fiſhes; *Centre-ſhells*, which are Cells for ſmall Fiſhes of the Oyſter-Kind; the *Sea-Horſe*; the *Pipe Worm*; with many others.

9. There are ſeveral *Univalve-Shells*, which are *wreathed*, or of a *ſpiral* Form. As the *Nautilus*, or *Sailor*; the *Turbinatæ*, or *Whirls* of ſeveral Sorts, great and ſmall; the *Sea-Spider*, and *Fingered-Whirl*; the *Mitre*; the *Harp*; the *Top-Whirl*; the *Blackmore-Teeth*; the *Unicorn Shell*; the *Purple-Shell*; the *Spider-Shell*; the *Buccina*, or *Trumpet*; the great muricated *Whirl*; the Golden *Trochus*; with ſeveral others. Theſe Shells are ſome ſo large, as to weigh near ten Pounds; and the *wonderful Colouring* of others ſurpaſſes that of Birds, both for the *Variety*, *Order*, and *Intenſity* thereof. From that called the *Purpura*, the Ancients extracted their Purple Colour, with which they dyed their Stuffs; though *Cochineal* and *Kermes Cods* dye a *Scarlet* incomparably better, and more laſting.

10. The ſecond Kind of Shell-Fiſhes are *bivalvous*, or whoſe Shells conſiſt of two Pieces, or open with two ſimilar Parts. Among theſe the *Oyſter* obtains the firſt Place; the *Muſcle* next; then the *Scallop*; and, laſtly, the *Cockles* of every Kind.

11. Theſe are called *immoveable Shell Fiſh*, as not being able to remove themſelves from their firſt Situation; they are alſo ſaid to be *Hermaphrodite*, as not having the Power to ſeek at any Diſtance one of a contrary Sex for Copulation, which therefore is a neceſſary Proviſion of Nature.

have a Sort of middle Nature between Plants and Animals, and therefore the moſt imperfect of all the animal Creation. 2. They are therefore called *Zoophyta*, from ζῶον *an Animal*, and φυλὸν *a Plant*; as much as to ſay, *animal Plants*, or *vegetable Animals*, becauſe they gather Food, and feed with a Mouth like other Animals; but grow or adhere immoveably to a Shell by the Membrane, as Plants grow or adhere to the Earth by their Roots: Such as *Snails*, *Oyſters*, *Cockles*, and all the *conchilious Kind*. 3. The *Shells* of theſe moſt con-

12. The *Oyſter* abides at ſuch a Depth of Waters, as not to be left uncovered by them: But the *Muſcle* has generally its Situation in ſuch Places on the Shore or Rocks, as, by the Fall of the Tides, they become expoſed to the open Air. The *Cockle* is always bedded in the Sand, upon thoſe Shores which are uncovered at low Tides.

13. The Food of Oyſters and Muſcles are ſome Kinds of *Sea-Weeds*, and the fineſt Parts of Mud and Sand, and the Waſh of the Sea. The Cockle ſeems likewiſe to draw its Nouriſhment from Earth, which paſſes through its Body like *Earth-Worms*.

14. Mr. *Lowenhoek* ſays, that Muſcles lay their Eggs in Strings on the Outſide of their Shells, and that theſe *Eggs* or *Spawn* continually increaſe in Strength, till they become perfect Muſcles; at which Time, Part of the *Egg-ſhell* is diſcoverable upon the outward Covering of the Fiſh, till that Coat is hardened or changed into a firm Shell. *Philoſ. Tranſ.* N° 336.

15. Mr. *Strachan* tells us, he ſaw on the Coaſt of *Ceilan* an Oyſter of a Foot Diameter; and that the Shell of one of theſe did grow till it was three Feet in Diameter broad, and a Foot thick, after the Fleſh was putrified. *Philoſ. Tranſ.* N° 282.

16. There are very commonly found *Pearls* of different Sizes in the Bottom of the Shells of *Oyſters*, *Scallops*, and eſpecially in that called the *Naker*, or *Mother of Pearl*, where they are generally found in Abundance. The Pearls which are ſometimes found in the Bodies of thoſe Fiſhes, ſeem rather to be *Gravel-Stones* than true *Pearls*, and therefore not ſo valuable.

17. Beſides theſe Shell-Fiſh now mentioned, there are many others to be met with in the Works of *Naturaliſts*, but infinitely more in the Works of *Nature* herſelf; which muſt be left to the Search and Induſtry of future Time, which poſſibly may arrive by Degrees to a more accurate Knowledge, and give a more perfect Hiſtory of them, than is now to be had.

temptible Creatures are yet made with wondrous *Art*, *Beauty*, and *Finery*; in ſome particular Species of *Snails*, *Cockles*, &c. what artful curious Spirals, Circles, and other Divarications, and diametrical Diviſions, do we obſerve therein? How are they covered to pleaſe the Fancy, and ſerve the Luxury, even of the human Species? 4. Theſe *Shells*, or *cruſty Houſes*, ſerve the poor ſoft and boneleſs Inhabitants for Defence and Security againſt outward Accidents, from which they can ſafely retreat therein 5. A wonderful Thing in *Snails* is, that they have their *Eyes* placed (not in their Heads as other Animals, but) on or at the *Top of their Horns*; which therefore they can move farther or nearer from their Head, and circumvolve them here and there, or one this Way, the other that, at Pleaſure. 6. The *Bodies* of *Shell-Animals* are contrived without Bones, or any Thing that I know of like them; they conſiſt of a tough membranous Subſtance, analogous to Fleſh and Muſcles; and their internal Organs of Life are ſeveral, and diſtinctly appear on being diſſected; but what the particular *Shape* and *Function* of many of them may be, is not ſo eaſy to aſcertain; the *Bowels* and *Inteſtines* of theſe Creatures bearing but ſmall Analogy to thoſe of more perfect Animals, I ſhall end my Reflections on them, by giving you a Cut, ſhewing the mutual Copulation of Snails, by their Genitals G, in *Fig.* LIX. on *Plate* XXVI, fronting *p.* 342.

A. It is very wonderful indeed; as are moſt of the other Particulars which you have related of the divers Species of Animals: But, pray, (before we leave this Survey of the animal Creation) let me aſk your Opinion of *Griffins*, the *Phœnix*, *Dragons*, *Satyrs*, *Syrens*, *Unicorns*, *Mermaids*, *Fairies*, &c. Do you think there really are any ſuch Things in Nature *?

B. The

* 1. It makes but little for the Credit of the Hiſtories of *Dragons*, *Unicorns*, *Mermaids*, &c. that their Names are not to be found in the Tranſactions of our celebrated Royal Society, who, it is well known derive their Intelligence at the beſt Hand from almoſt all Parts of the World. At leaſt, I can find no Mention of any ſuch Creatures in the ſeven Volumes of Abridgments by *Lowthorpe*, *Eames*, and *Jones*.

2. The *Hiſtoire Naturelle de l'Univerſe* gives an Account of ſeveral Perſons who have deſcribed the *Unicorn*; and particularly Father *Lobos*, in his Voyage to the *Abyſſine Empire*, ſays, that this Animal is of the Shape and Size of a fine-made and well-proportioned Horſe, of a bay Colour, with a black Tail and Extremities; he adds, that the Unicorns of *Tuacua* have very ſhort Tails; and thoſe of *Ninina* (a Canton in the ſame Province) have theirs very long, and their Manes hanging over their Heads. *Vol.* IV. *Page* 3.

3. *Du Mons* ſays, he ſaw the Head of a Dragon which was ſet up over the *Water Gate* in the City of *Rhodes*; this Dragon was 23 Feet long, and waſted all the Country round, till it was ſlain by *Deodate de Gozon*, a Knight of *St. John*. He ſays, the *Head* was like that of an Hog, but much larger; its Ears were like a Mule's, but cut off; the *Teeth* were extraordinary ſharp and long; the *Throat* wide; its *Eyes* hollow, and burning like two Coals. It had two little Wings on its Back; its *Legs* and *Tail* like thoſe of a Lizard, but ſtrong, and armed with ſharp and venomous Talons. His Body was covered with Scales, which was Proof againſt Arms. See the Manner of his being killed in the *Atlas Geographicus*, Vol. III. Page 43, 44.

4. *Ludolphus*, in his *Ethiopic* Hiſtory, tells us, that in the *Abyſſine Empire*, there are voracious ſcaly Dragons of the largeſt Size, though not venomous or hurtful otherwiſe than by the Bite, and they look like the Bark of an old Tree. *Atlas Geographicus*, Vol IV. Page 614.

5. The *Stories* of *Mermaids*, *Satyrs*, &c. had undoubtedly their Original from ſuch Animals as have in ſome Reſpects a Likeneſs to the *human Shape* and *Features*. Among theſe the *Monkey* Kind the *Orang Outang*, and the *Quoja Morron*, are the chief on Land; and the Fiſh called the *Mermaid*, (though it has nothing of the *human Form*) and ſome other unuſual Animals in the Sea.

6. The

B. The *Phœnix* is mentioned by *Pliny*, and other Ancients, more credulous than ſkilful; but has long ſince been rejected as a vulgar Error. The *Griffin* and *Harpy* have had a Place given them in Modern Hiſtories of Nature, but not without great Reproach and Ridicule to the Authors. *Satyrs*, *Syrens*, and *Fairies*, are all Poetical Fictions. The *Scripture* makes Mention of the *Dragon* and the *Unicorn*, and moſt *Naturaliſts* have affirmed that there have been ſuch Creatures, and given Deſcriptions of them; but the Sight of theſe Creatures, or credible Relations of them, having been ſo very rare, has occaſioned many to believe there never were any ſuch Animals in Nature; at leaſt it has made the Hiſtory of them very doubtful. As to

6. The Story of the *Quoja Morron* being very uncommon and curious, I ſhall here inſert it from *Dapper*, who ſays they are found in *Quoja* in *Guinea*, and *Angola* in *Ethiopia*. The *Negroes* call them *Satyrs*, and believe they ſprang from the *human Race*. They have large Heads, thick heavy Bodies, nervous Arms, no Tails, walk ſometimes erect, ſometimes on all-four; they feed on Fruit and wild Honey; fight continually with one another; they dare attack armed Men, and will ſometimes force Women. The *Portugueſe* call them *Savages*.

7. *Dapper* tells us, that thirty Years before he wrote, a Female of this Kind was brought to *Holland*, and preſented to Prince *Frederick-Henry*. It was as big as a Child of three Years old, but twice as thick, well ſet, ſtrong and nimble; it lifted Things of great Weight, and carried them from Place to Place. Her Breaſts and Belly were naked, but her Back covered with Hair. Her Face was ſomewhat human, but her Noſe flat and turned up. Her Ears, Breaſt, Nipples, Elbow, Legs, Feet, Belly, and *Pudenda*, were altogether like a Woman's. She often ſtood and walked upright on her two hind Feet. She would take the Cup in one Hand, ſupport it with the other, and drink very neatly. She alſo lay down to ſleep with her Head on a *Bolſter*, and ſpread the Coverlet over her, as if ſhe had been a human Creature. It is ſuppoſed this Species of Creatures firſt gave Riſe to the poetical Kind of Satyrs. See *Atlas Geogr.* Vol. IV. Page 376, and 561.

Z 4 *Mer-*

Mermen and *Mermaids*, there certainly are ſuch Creatures in the Seas as have ſome diſtant Reſemblance of ſome Parts of the *human Shape*, *Mien*, and *Members*; but not ſo perfectly like them, it is very probable, as has been repreſented. In all ſuch ambiguous Pieces of Hiſtory it is better not to be poſitive, and ſometimes to ſuſpend our Belief, rather than credulouſly embrace every current Report, or vulgar Aſſertion, which may perhaps expoſe us to Ridicule, but cannot procure us any ſolid Reputation for Wiſdom and Learning.

A. Well, leaving theſe uncertain Subjects, let us conclude this ſhort View of the Creation with what you called the *Accidents* of animal Life; pray what do you reckon ſuch?

B. They are ſuch as follow, *viz.*

Health: This ariſeth from an apt Conſtruction and due Temperament of the Parts, whereby they are capable of performing all the natural Actions and Functions of Life.

Diſeaſe: This is that State of an animal Body, which deprives it of the Faculty of exerting every Action proper for it.

Vigilance, or the *State of being awake:* This ariſeth from the Preſence and Action of a due Quantity of animal Spirits through all the Parts of the Body; by Means of which the Organs of the external and internal Senſes, and all the Inſtruments of Motion depending on the Will, are properly affected by external Objects, and eaſily perform all their Actions and Motions.

Sleep: The State contrary to *Vigilance*; but what is the Cauſe, or wherein it doth conſiſt, the

greateſt

greatest *Physiologists* differ in their Determinations, and are puzzled to account for it.

Dream: This is an Action of the *reflective Faculty* of the Mind, which is always active even in Sleep, and doth therein recollect and review the *Ideas* which were present to it when the Body was waking: But the Body asleep not admitting the Exercise of the *rational Faculty* of the Mind, it rangeth those Ideas for the most Part in a confused, unnatural, and imperfect Manner; and this Vision of Things we call a *Dream.*

Hunger: This is that Quality which ariseth from a *Vellication* of the inner Coats of the Stomach, by the Action of the digesting Juice; which, having no Food whereon to spend its Force, gnaws on the Stomach itself, and thereby excites in our Minds the *Desire*, or *Appetite of Food.*

Thirst: This is somewhat analogous to *Hunger*; for a due Quantity of Moisture being wanting in the Stomach, and Parts of the Throat and Mouth, produceth that *molesting Sensation*, which creates in us a *Necessity of drinking*, to remove it.

Death: This brings an Animal to its last State; and is nothing but a final Obstruction or natural Cessation of all the animal and vital Faculties and Functions of the Body, which then remains in a State of perfect Quiescence, and is entirely passive to all other Changes and Conditions it meets withal in this World. And, as *Death puts an End to all Things*, so I judge it most natural to end this long Reflection on the wonderful Works of God, the great Author of Nature, with the *awful Subject of Death*, which alſo, ere long, will intercept all ſuch delightful and agreeable Converſe, as hath hitherto paſſed between you and me.

A. Ah! Were it not for the Proſpect of a better, and a more perfect State of Life and Being hereafter, how dreadful would be the Thought of parting with our *dear*, *our friendly* and *agreeable Company* and Acquaintance, even in this Life of Troubles? I am heartily ſorry that our Knowledge extends no farther in the Nature of Things, ſince it is a Topic, which, of all others, gives me the moſt ſerious and perfect Pleaſure in the Contemplation of it. And, ſince you have taken abundant Pains to repleniſh my Mind with the beſt Treaſure of this Sort of Science, I can but love you, and return you my ample Thanks for the ſame.

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