
M. Vdr. Gucht Sculp:

Miſcellanea Curioſa.

CONTAINING A

COLLECTION

Of ſome of the Principal

PHÆNOMENA

IN

NATURE,

Accounted for by the Greateſt Philoſophers of this Age;

BEING THE

Moſt Valuable DISCOURSES, Read and Delivered to the ROYAL SOCIETY, for the Advancement of Phyſical and Mathematical Knowledge.

As alſo a Collection of Curious *Travels*, *Voyages*, *Antiquities*, and *Natural Hiſtories* of Countries; Preſented to the ſame *Society*.

In Three VOLUMES.

The Second Edition; To which is added, A Diſcourſe of the *Influence* of the *Sun* and *Moon* on *Humane Bodies*, &c. By R. *MEAD*, M. D. F. R. *S.* And alſo *Fontenelle's Preface* of the *Uſefulneſs* of *Mathematical Learning*.

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TO THE

READER.

SOME of the Principal Diſcoveries and Enquiries, both in *Phyſical* and *Mathematical* Learning, being regiſter'd in the Voluminous Journals of the *Royal Society*, are amongſt a multitude of leſs uſeful Matters, ſo Obſcurely hid, that but very few inquiſitive Gentlemen ever ſo much as heard of them.

The Deſign therefore of the enſuing Collection, is to digeſt in a convenient Method, all the moſt curious *Philoſophical* and *Mathematical* Diſcoveries, as they are to be met with, which may any way tend to the Uſe of Life or Advancement of Arts and Sciences.

And on this Occaſion, it will be convenient to intimate to the Reader;

Firſt, That the Theories and Diſcourſes here collected, have already paſt the Cenſure of the *Learned World*: Who have acknowleg'd them the moſt ſatisfactory Accounts of Nature's Proceedings, wherein ſome of her greateſt Depths are fathom'd, and a Foundation laid for Poſterity to build an infinite *Superſtructure.*

Secondly, That they are related (*Verbatim*) juſt as they were delivered in, or read before the *Royal Society*: For it has been the Opinion of the moſt Judicious among thoſe *Honourable Members*, that it is impoſſible ſo to abridge them, (which are but Abridgments themſelves) as not to render them obſcure and unintelligible.

A
TABLE
OF THE
Discourses contain'd in this *Volume.*

A

A

APPENDIX.

A

A Translation of Part of Monsieur Fontenelle's *Preface to the Memoirs of the Royal Academy at* Paris, *in the Year* 1699. *treating of the Usefulness of Mathematical Learning.*

BUT to what purpose should People become fond of the Mathematicks and Natural Philosophy. Of what use are the Transactions of the Academy? These are common Questions, which most do not barely propose as Questions; and it will not be improper to clear them.

People very readily call useless, what they do not understand. It is a sort of Revenge; and as the Mathematicks and Natural Philosophy are known but by few, they are generally look'd upon as useless. The reason of this is; because they are crabbed and not easily learnt.

We have a Moon to light us in the Night; What is it to us, say they, whether *Jupiter* hath four? Why so many laborious Observations, so many tedious Calculations to know exactly their Course? They'll not afford us the more Light for it; and Nature, which hath plac'd these little Planets without the reach of our Eyes, doth not seem to have made them for us. According to this plausible Argument they ought not to have

been

been obſerv'd with a Teleſcope, nor ſtudy'd. But it is certain, that we had been conſiderable Looſers by it: For thoſe who have ſome inſight into the Principles of Geography and Navigation know, that ſince theſe four Moons about *Jupiter* have been diſcover'd, they have been more uſeful to thoſe Sciences than our own Moon; and that they ſerve, and ſhall more and more ſerve to make new Sea-Charts, infinitely more exact than the Old; and are likely to ſave the Lives of a vaſt many Seamen. Did we reap no other advantage from Aſtronomy than this from theſe Satellites of *Jupiter*, that wou'd be ſufficient to juſtifie thoſe prodigious Calculations, thoſe aſſiduous and nice Obſervations, this great number of elaborate Inſtruments, and this Noble Edifice built only for this Science. However the greateſt part of Mankind know nothing of theſe Satellites of *Jupiter*, unleſs perhaps by hear-ſay, and that too confuſedly; or elſe they are ignorant of what Affinity they have with Navigation, or of the great Improvements which have been lately made in it.

This is the Fate of Sciences, which are ſtudy'd and improv'd by few. Moſt People are not ſenſible of their Progreſs, and eſpecially when made in ſome mean Callings. But what doth it ſignifie, that we can now more eaſily direct the Courſe of Rivers, cut out Canals, and ſettle new Navigations; becauſe our Method of taking the Level and making Sluces is infinitely better than heretofore? Some Maſons and Seamen have thereby found their Buſineſs eaſier, but they themſelves were not ſenſible of the Skill of the Geometrician who directed them. They were mov'd, as the Body by a Soul, it doth not know. Others are

yet

yet leſs ſenſible of the Genius that preſided over the Undertaking; and the World is the better for its ſucceeding well, but not altogether free from Ingratitude.

Anatomy, which is ſome time ſince ſo carefully ſtudy'd, can't become more exact, but Chyrurgical Operations muſt alſo be more ſure. Surgeons know this; but thoſe who receive the Benefit of their Art know nothing of it. And indeed how ſhould they? They would be oblig'd to compare Old with Modern Surgery; and this wou'd take too much Time, and go againſt the Grain: So that ſince the Operation hath ſucceeded well, they do not think it material to know whether it had ſucceeded as well in another Century.

It is ſtrange that ſo many things are before our Eyes, and that we do not ſee them. Your Handycraft Shops are full of ingenious Works; but yet we hardly mind them: And very uſeful and well contriv'd Inſtruments and Experiments want Spectators, who wou'd be wonderfully pleas'd, wou'd they take the pains to admire them.

If a Learned Society have made ſome Improvements in Geometry, Anatomy, Mechanicks, or any other uſeful Science, it muſt not be expected, that the World will go back to ſo remote a Spring to thank and applaud them for the Uſefulneſs of their Productions: For it will be more eaſie to enjoy the Benefit of their Diſcoveries and Improvements than to know them. The Determination of Longitude by the Satellites, the Diſcovery of the *Ductus Thoracicus*, a more convenient, and more exact Level, are not Novelties ſo fit to make a noiſe as a pleaſant Poem, or a handſome Piece of Oratory.

Altho' the Usefulness of Mathematicks and Natural Philosophy is obscure, yet it is real. To consider Mankind in their Natural State, nothing is more useful to them, than what may preserve their Lives, and produce those Arts, which are both great Helps and Ornaments to Publick Societies.

As for what concerns the Preservation of Life, it peculiarly belongs to Physick; which for that reason is divided in the Academy into three Branches, which make three different sorts of Members of this Society, Anatomy, Chymistry, and Botanicks. Every Body knows of what Importance it is to have an exact Knowledge of Human Body, and of what Medicines may be extracted from Minerals and Plants.

As for Arts, too tedious to be reckon'd, they depend some upon Natural Philosophy, others upon Mathematicks.

One wou'd think at first, that if the Mathematicks were to be confin'd to what is useful in them, they ought only to be improv'd in those things, which have an immediate and sensible affinity with Arts, and the rest ought to be neglected as a Vain Theory. But this wou'd be a very wrong Notion. As for Instance, the Art of Navigation hath a necessary Connexion with Astronomy, and Astronomy can never be too much improv'd for the Benefit of Navigation. Astronomy cannot be without Opticks by reason of Perspective Glasses; and both, as all other Parts of Mathematicks, are grounded upon Geometry, and to go as far as you can, even upon Algebra.

Geometry

Geometry, and eſpecially Algebra, are the Keys of all the Inquiries, that can be made concerning Magnitude. Theſe Sciences which are only converſant about abſtruſe Relations, and ſimple Ideas, may ſeem dry and barrén, whilſt they keep within the Verge of the Intellectual World; but mixt Mathematicks, which ſtoop to Matter, and conſider the Motion of the Stars, the Augmentation of moving Forces, the different Paſſages of the Rays of Light through different Mediums; the different Effects of Sound by the Vibration of Things; to conclude all thoſe Sciences, which diſcover the particular Relations of Senſible Magnitudes go on farther and more ſecurely, when the Art of diſcovering Relations in General is more perfect. The Univerſal Inſtrument cannot be too extenſive, too handy, or too eaſily apply'd: It is uſeful to all the Sciences, and they cannot be without it: And therefore among the Mathematicians of the Academy, who are deſign'd to be uſeful to the Publick, the Geometricians and Algebriſts make a Claſs, as well as the Aſtronomers and Mechanicks.

However, it is certain, that Speculations purely of Geometry, or of Algebra, are not about uſeful things: But it is certain too, that thoſe that are not, either lead or belong to thoſe that are. It is in it ſelf a very barren thing to know, that in a Parabola a Subtengant is double the correſponding Abſciſſæ; but yet it is a Degree of Knowledge neceſſary to the Art of throwing Bombs, ſo exactly as they can do now. There are not by far ſo many evident Uſes as Propoſitions or Truths in the Mathematicks: Yet it is enough if the Concourſe of ſeveral Truths is generally of ſome uſe.

Farther, a Geometrical Speculation, which was not at first applicable to any use, becomes so afterwards. When the greatest Geometricians in the Seventeenth Century set about to study a new Curve, which they call'd a Cycloide, they only engag'd themselves in a meer Speculation out of Vanity, striving to outdo one another by the Discovery of difficult Theorems. They did not even pretend that this was for the Publick Good; however by diving into the Nature of the Cycloide it was found, that it was destin'd to make Pendulums as perfect as may be, and carry the Measure of Time as far as it can go.

It is the same thing with Natural Philosophy as with Geometry. The Anatomy of Animals seems insignificant; and it only concerns us to know that of Human Body. But yet some Parts of it, which are of so nice, or so confus'd a Make, that they are invisible, are sensible and manifest in the Body of an Animal. Hence it is, that Monsters themselves are not to be neglected. The Mechanism conceal'd in a particular Kind or in a common Make, is unfolded in another kind, or in an extraordinary Make; and one wou'd be almost apt to say, that Nature by multiplying and varying so much her Works, can't sometimes forbear betraying her Secrets. All that the Antients knew of the Load-stone, was, that it attracts Iron. But whether they did not value a Curiosity, which promis'd them nothing; or that their Genius did not lead them to make Experiments, they have not examin'd this Stone as carefully as they might. One Experiment taught them, that it turns of its self towards the Poles of the World, and did put into their Hands the inestimable Treasure of the Mariners Compass. They might easily have made

made this Diſcovery important, and yet they did not do it; and if they had ſpent a little more time upon a Curioſity which ſeem'd uſeleſs to them, the Latent uſe of it had ſoon appear'd.

Let us always make a Collection of Mathematical and Phyſical Truths; happen what it will we can't hazard much by it. It is certain, that they ſhall be drawn from Springs, whence a great many uſeful ones have already been drawn. We have reaſon to preſume, that we ſhall draw from thence, ſome that ſhall ſhine as ſoon as they are diſcover'd, and convince us of their Uſefulneſs. Other Truths ſhall ſtay ſome time till a piercing Meditation, or ſome happy Accident diſcovers their Uſe. Some Truths being conſider'd by themſelves ſhall be barren, till they are conſider'd with reference to one another. Laſtly, let the worſe come to the worſe, ſome ſhall be eternally uſeleſs.

I mean uſeleſs with reference to ſenſible and groſs Uſes; for otherwiſe they ſhall not be ſo. An Object upon which alone you caſt your Eyes is the clearer and brighter, when the neighbouring Objects, which however you do not look upon, are alſo enlighten'd; becauſe it hath the Benefit of the Rays, which are reflected from them. Thus thoſe Diſcoveries, which are palpably uſeful, and deſerve our chiefeſt Attention, are in ſome meaſure enlighten'd by thoſe, which may be call'd uſeleſs. For all Truths make one another more lucid.

It is always uſeful to have right Notions, even of uſeleſs Subjects. And tho' we cou'd reap no benefit by the Knowledge of Numbers and Sines, yet it wou'd ſtill be the only certain Knowledge granted to our Natural Light, and they wou'd ſerve to give our Reaſon the firſt Habit of and Inclination to Truth. They wou'd teach us to operate upon Truths; to take the Thread of them, which is generally very fine and almost imperpeceptible; and to follow it as far as it reaches: In a word, they wou'd make Truth so familiar, that we might on other Occasions know it at first sight, and almost by Instinct.

A Geometrical Genius is not so confin'd to Geometry, but that it may be capable of learning other Sciences. A Tract of Morality, Politicks, or Criticism, and even a Piece of Oratory, supposing the Author qualify'd otherwise for those Performances, shall be the better for being compos'd by a Geometrician. That Order, Perspicuity, *Precision* and Exactness, which some time since are found in good Books, may originally proceed from that Geometrical Genius, which is now more common than ever, and in some manner is communicated by one Relation to another, nay even to those that do not understand Geometry. Sometimes a Great Man draws all his Cotemporaries after him; and he who hath the justest Claim to to the Glory of having settled a new Art of Arguing, was an Excellent Geometrician.

Lastly, whatever raises us to Great and Noble Reflexions, tho' they be purely Speculative, afford a Spiritual and Philosophical *Utility*. The Wants of the Mind are perhaps as many as those of the Body. She desires to extend her Knowledge: All that can be known, is necessary to her, and there can be no better Proof than this, that she is design'd for Truth. Nothing perhaps can redound more to her Glory, than the Pleasure that is felt sometimes, in spight of ones

self,

ſelf, in the dry and crabbed Queſtions of Algebra.

But without running counter to the common Notions, and recurring to Advantages which may ſeem too far fetch'd and refin'd, it may fairly be own'd, that the Mathematicks and Natural Philoſophy have ſome things which are only ſubſervient to Curioſity; and ſo have thoſe Sciences which are moſt generally acknowledg'd to be uſeful, as Hiſtory, *&c.*

Hiſtory doth not in every Part of it ſupply us with Examples of Vertue and Rules for our Behaviour. For beſides theſe, therein you have a View of the perpetual Revolutions of Human Affairs, of the Beginning and Fall of Empires, of Manners, Cuſtoms, and Opinions which continually ſucceed one another; and in a word, of all that rapid, tho' inſenſible, Motion that carries all before it, and inceſſantly alters the Face of the Earth.

Had we a mind to oppoſe Curioſity to Curioſity, we ſhou'd find that inſtead of the Motion, which agitates Nations, and gives birth to, and deſtroys States; Natural Philoſophy conſiders that Great and Univerſal Motion, which hath put the whole Frame of Nature in Order, and ſuſpended the Cœleſtial Bodies in ſeveral Spheres, and which illuminates and extinguiſhes ſome Stars; and by following always unalterable Laws, diverſifies its effects *ad infinitum.* If the ſurpriſing difference of Manners and Opinions of Mankind is ſo entertaining; there is too a great deal of Pleaſure to ſtudy the prodigious diverſity of the Structure of the different Species of Animals, with reference to their different Functions, to the Elements they live in, to the Climates they inhabit, and the Aliments they are to take, *&c.* The moſt curious ſtrokes of Hiſtory ſhall hardly be more curious than the *Phoſphorus*, the cold Liquors which being mixt together, break out into a flame; Silver Trees, the almoſt Magical Operations of the Load-Stone, and a vaſt number of Secrets, which Art hath diſcover'd by a near and diligent Scrutiny of Nature.

Laſtly, Natural Philoſophy doth as much as it is poſſible unravel the Footſteps of that Infinite Intellect and Wiſdom, who hath made all things: Whereas the Object of Hiſtory are the diſorderly Effects of the Paſſion, and of Humane Caprices; and ſo odd a Series of Events, that ſome formerly fancy'd that a Blind and Senſeleſs Deity had the Direction of them.

We muſt not look upon the Sublime Reflexions which Natural Philoſophy leads us to make concerning the Author of the Univerſe, as meer Curioſities. For this ſtupendous Work, which appears always more wonderful the more we know it, gives us ſuch exalted Notions of its Maker, that they fill our Minds with Admiration and Reſpect. But above all, Aſtronomy and Anatomy are the two Sciences which more palpably lay before us two grand Attributes of our Creator; one his Immenſity by the diſtance, Magnitude and Number of Cœleſtial Bodies; the other his Infinite Knowledge by the Mechaniſm of Animals. True Natural Philoſophy is a kind of Theology.

The

The different views of Humane Underſtanding are almoſt infinite; and Nature is really ſo. So that we may every day expect ſome Diſcoveries, either in Mathematicks or Natural Philoſophy, which ſhall be of a new ſort of Utility or Curioſity. Make a Collection of all the different Advantages which the Mathematicks afforded a Hundred Years ago, and you'll find nothing to be compar'd to the Perſpective Glaſſes they have furniſh'd ſince that time, and which are a new Organ to the Sight, and cou'd not be expected from Art. How ſurpriz'd had the Ancients been, if they had been told that their Poſterity, by the help of ſome Inſtruments, ſhou'd one day ſee a vaſt number of Objects which they did not ſee; a Heaven that was unknown to them; and Plants and Animals they did not even ſuſpect it was poſſible to exiſt. Naturaliſts had already a great many curious Experiments; but within about half a Century, the Air-Pump hath produced a prodigious quantity of them wholly new, and which by ſhewing Bodies in a Space void of Air, ſhews them as tranſported in a World different from ours, where they undergo Alterations whereof we had no Notion. The Excellency of Geometrical Methods, which are every day invented and improv'd, may perhaps at laſt exhauſt Geometry; that is, The Art of making Geometrical Diſcoveries, and that is all: Whereas Natural Philoſophy, which contemplates an Object of an unlimited Variety, and *Fœcundity*, ſhall always find room for new Obſervations, and opportunities to increaſe its vaſt Stock, and ſhall have the Advantage of never being a compleat Science.

There

There are so many things to be discover'd, whereof a great part, in all likelyhood shall never be known; that they give an opportunity to those who will not encounter with the Thorns and Difficulties of Natural Philosophy, to affect a sort of Discouragement. A great many to vilify this Natural Science, pretend a mighty veneration for the works of Nature, and that they are absolutely incomprehensible. However, Nature is never so admirable, nor so admir'd as when known. True it is, that what is known is inconsiderable in comparison of what is not yet known. Nay, Sometimes what is not known, is exactly what seems shou'd be the soonest known. As for instance, it is not at least certainly known, why a Stone thrown up into the Air falls down again; but we certainly know the cause of the Rainbow, why it doth not exceed a certain height; why its breadth is always the same; why when there are two Rainbows at the same time, the Colours of the one are overset with reference to the Colours of the other; and yet the fall of a Stone in the Air appears a more simple Phænomenon, than the Rainbow. But in a word, altho' we do not know every thing, we are not neither ignorant of every thing. And altho' we are ignorant of the most simple Events, yet we have a knowledge of what seems the most Complex. So that if we have on the one hand reason to fear, lest our Vanity shou'd flatter us with the hopes of attaining to the knowledge of things above our reach; on the other we ought to dread, lest our Slothfulness should also flatter us that we are condemn'd to a greater degree of Ignorance than really we are.

People

People may think that the Sciences do not begin to exert themſelves, either becauſe they cou'd be but imperfect among the Ancients; or becauſe we have almoſt loſt the Footſteps of them during the gloomy Darkneſs of Barbarity; or becauſe a better method hath been taken about 100 Years ago. Was the Progreſs Hiſtorically examin'd, they have already made in ſo ſhort a time, notwithſtanding the ſtrong, but falſe Prejudices they had long to encounter with, even ſometimes the foreign Obſtacles they have met with from Authority and Power; the want of Zeal for Sciences ſo remote from common uſe, thoſe few who apply'd themſelves to this Work, and the weak Motives which engag'd them in it; a Man would wonder at the Greatneſs and Rapidity of the Progreſs of the Sciences, and even we might obſerve ſome new ones to ſtart out of nothing, and perhaps be tempted to have too great hopes of future Improvements.

The greater reaſon we have of future Succeſs, the greater we have to look upon the Sciences as in their Cradles, at leaſt Natural Philoſophy. And therefore the Academy is only now employ'd to make an ample Proviſion of Obſervations, and Facts well atteſted, which may one day be the foundation of a Syſtem. For before the Syſtematical Natural Philoſophy can raiſe ſolid Edifices; Experimental Natural Philoſophy muſt be in a condition to ſupply it with good Materials.

None

None but Societies, or those too countenanc'd and encourag'd by the Prince, can successfully make and prepare this Collection of Materials. All the Learning, Care, Life and Wealth of one Private Man can never answer this Design. There are too many different Experiments to be made, which are to be too much vary'd, and a long time prosecuted with the same Temper and Mind. The Cause of the least Effect is so wrap'd up, that unless you very carefully open all the various Foldings, you cannot come at it.

Hitherto the Academy of Sciences hath consider'd Nature but by parcels: They have fix'd upon no general System, for fear of falling into the inconveniency of hasty Systems, which are very grateful to the impatience of Humane Understanding; and being once settled, are Obstacles to what Truths are afterwards discover'd. This day we are sure of a Fact, to morrow we shall be sure of another that hath no relation with the former. However some Conjectures are ventur'd at upon Causes; but they are only Conjectures. So that this Collection, which the Academy gives to the Publick, is compos'd of separate Fragments, independant of one another; whereof every one who is the Author, warrants the Facts and Experiments; and whose Arguments are approv'd by the Academy, but with Restrictions becoming Wise and Wary Scepticks.

Time perhaps will come, when these scatter'd Fragments shall be united into one regular Body; and if they be such as they are wish'd, they may of themselves Unite. A great many Truths, when their Numbers is considerable,

rable, ſhew ſo near a Relation to, and ſo mutual a Dependance upon one another, that it ſeems, that notwithſtanding their violent Separation, they have a natural Tendency to be re-united.

MISCELLANEA CURIOSA.

An Estimate of the Quantity of the Vapours raised out of the Sea derived from Experiment: Together with an Account of the Circulation of the watry Vapours of the Sea, and of the Cause of Springs, presented to the Royal Society.

By Mr. E. Halley, F. R. S.

THAT the Quantity of Aqueous Vapours contain'd in the Medium of the Air, is very considerable, seems most evident from the great Rains and Snows which are sometimes observ'd to fall, to that degree, that the Water thus discharg'd out of the Interstices of the Particles of Air, is in weight a very sensible part of the incumbent Atmosphere: But in what proportion these Vapours rise, which are the Sources not only of Rains, but also of Springs or Fountains (as I design to prove) has not, that I know of, been any where well examin'd, tho' it seem to be one of the most necessary Ingredients of a

Real and Philoſophical Meteorology, and, as ſuch; to deſerve the Conſideration of this Honourable Society. I thought it might not be unacceptable to attempt by Experiment to determine the Quantity of the Evaporations of Water, as far as they ariſe from Heat, which upon Trial ſucceeded as follows.

We took a Pan of Water, adout 4 Inches deep, and 7 Inches $\frac{9}{10}$ Diameter, in which we placed a Thermometer, and by means of a Pan of Coals, we brought the Water to the ſame degree of Heat, which is obſerved to be that of the Air in our hotteſt Summer; the Thermometer nicely ſhewing it: This done, we affixed the Pan of Water, with the Thermometer in it, to one end of the Beam of a Pair of Scales, and exactly counterpois'd it with weights in the other Scale; and by the application or removal of the Pan of Coals, we found it very eaſie to maintain the Water in the ſame degree of Heat preciſely. Doing thus we found the weight of the Water ſenſibly to decreaſe; and at the end of two hours we obſerved that there wanted half an Ounce *Troy*, all but 7 grains, or 233 grains of Water, which in that time had gone off in Vapour; tho' one could hardly perceive it ſmoke, and the Water were not ſenſibly warm. This Quantity in ſo ſhort a time ſeem'd very conſiderable, being little leſs than 6 ounces in 24 hours, from ſo ſmall a Surface as a Circle of 8 Inches Diameter. To reduce this Experiment to an exact Calculus, and determine the thickneſs of the Skin of Water that had ſo evaporated, I aſſume the Experiment alledg'd by Dr. *Edward Bernard* to have been made in the *Oxford* Society, *viz.* That the Cube-foot *Engliſh* of Water weighs exactly 76

Pounds

Pounds *Troy*; this divided by 1728, the number of Inches in a Foot, will give $253\frac{1}{3}$ grains, or $\frac{1}{2}$ ounce $13\frac{1}{3}$ grains for the weight of a Cube-inch of Water; wherefore the weight of 233 grains is $\frac{233}{253\frac{1}{3}}$ or 35 Parts of 38 of a Cube-inch of Water. Now the Area of the Circle whose Diameter is $7\frac{9}{10}$ Inches, is 49 square Inches: by which dividing the Quantity of Water evaporated, *viz.* $\frac{35}{38}$ of an Inch, the Quote $\frac{35}{1862}$ or $\frac{1}{53}$ shews that the thickness of the Water evaporated was the 53d part of an Inch; but we will suppose it only the 60th part, for the Facility of Calculation. If therefore Water as warm as the Air in Summer, exhales the thickness of a 60th part of an Inch in two hours from its whole Surface, in 12 hours it will exhale the $\frac{1}{10}$ of an Inch; which Quantity will be found abundantly sufficient to serve for all the Rains, Springs, and Dews; and account for the *Caspian* Sea, being always at a stand, neither wasting nor overflowing; as likewise for the Current said to set always in at the Streights of *Gibralter*, tho' those Meditterranean Seas receive so many and so considerable Rivers.

To estimate the Quantity of Water arising in Vapours out of the Sea, I think I ought to consider it only for the time the Sun is up, for that the Dews return in the Night, as much if not more Vapours than are then emitted; and in Summer the Days being no longer than 12 hours, this Excess is ballanc'd by the weaker Action of the Sun, especially when rising before the Water be warmed: So that if I allow $\frac{1}{10}$ af an Inch of the Surface of the Sea, to be raised *per diem* in Vapours, it may not be an improbable Conjecture.

Upon this Suppoſition, every 10 ſquare Inches of the Surface of the Water, yields in Vapour *per diem* a Cube-inch of Water; and each ſquare Foot half a Wine-pint; every Space of 4 Foot ſquare, a Gallon; a Mile ſquare, 6914 Tons; a ſquare Degree ſuppoſe of 69 *Engliſh* Miles, will evaporate 33 Millions of Tons: And if the Mediterranean be eſtimated at forty degrees long and four broad, allowances being made for the Places where it is broader, by thoſe where it is narrower (and I am ſure I gueſs at the leaſt) there will be 160 Square degrees of Sea; and conſequently, the whole Mediterranean muſt loſe in Vapour, in a Summer's day, at leaſt 5280 Millons of Tons. And this Quantity of Vapour, tho' very great, is as little as can be concluded from the Experiment produced: And yet there remains another Cauſe, which cannot be reduced to Rule, I mean the Winds, whereby the Surface of the Water is licked up ſome times faſter than it exhales by the heat of the Sun; as is well known to thoſe that have conſider'd thoſe drying Winds which blow ſometimes.

To eſtimate the Quantity of Water, the Mediterranean Sea receives from the Rivers that fall into it, is a very hard Task, unleſs one had the Opportunity to meaſure their Chanels and Velocity; and therefore we can only do it by allowing more than enough; that is, by aſſuming theſe Rivers greater than in all probability they be, and then comparing the Quantity of Water voided by the *Thames*, with that of thoſe Rivers, whoſe Waters we deſire to compute.

The Mediterranean receives theſe conſiderable Rivers; the *Iberus*, the *Rhone*, the *Tiber*, the *Po*, the *Danube*, the *Neiſter*, the *Boryſtenes*, the

the *Tanais*, and the *Nile*; all the rest being of no great Note, and their Quantity of Water inconsiderable: These nine Rivers, we will suppose each of them to bring down ten times as much Water as the River *Thames*; not that any of them is great in reality, but to comprehend with them all the small Rivulets that fall into the Sea, which otherwise I know not how to allow for.

To calculate the Water of the *Thames*, I assume that at *Kingston* Bridge where the Flood never reaches, and the Water always runs down, the breadth of the Chanel is 100 Yards, and its Depth 3, it being reduced to an Equality (in both which Suppositions I am sure I take with the most) hence the Profil of the Water in this Place is 300 square Yards: This multitplied by 48 Miles (which I allow the Water to run in 24 hours, at 2 Miles an hour) or 84480 Yards, gives 25344000 Cubick-yards of Water to be evacuated every Day; that is, 20300000 Tons *per diem*; and I doubt not, but in the excess of of my Measures of the Chanel of the River, I have made more than sufficient allowance for the Waters of the *Brent*, the *Wandel*, the *Lea*, and *Darwent*, which are all worth notice, that fall into the *Thames* below *Kingston*.

Now if each of the aforesaid 9 Rivers yield 10 times as much Water as the *Thames* doth, 'twill follow that each of them yields but 203 Millions of Ton *per diem*, and the whole 9, but 1827 Millions of Tons in a day; which is but little more than $\frac{1}{3}$ of what is proved to be raised in vapour out of the Mediterranean in 12 hours time. Now what becomes of this Vapour when rais'd, and how it comes to pass that the Current always ſets in at the Mouth, of the Streights of *Gibralter*, ſhall immediately be ſhew'd: But firſt it is neceſſary to advertiſe the Reader, that in making the Experiment herein mention'd, the Water uſed had been ſalted to the ſame degree as is the common Sea-water, by the Solution of about a 40th part of Salt.

HAving thus ſhew'd by Expetiment the Quantity of Water raiſed in Vapour from the Surface of the Sea in a Days time, which was ſo far approv'd of by ſome Honourable Members of this Society, that I receiv'd their Commands to proſecute theſe Enquiries; and particularly, in relation to the Method uſed by Nature, to return the ſaid Vapours again into the Sea; which is ſo juſtly perform'd, that in many hundred of Years we are ſufficiently aſſured that the Sea has not ſenſibly decreaſed by the loſs in Vapour; nor yet abounded by the immenſe Quantity of freſh it receives continually from the Rivers. To demonſtrate this Equilibre of Receipt and Expence in the whole Sea, is a Task too hard for me to undertake, yet in obedience to thoſe whom I have the Honour to ſerve, I ſhall here offer, what to me has hitherto ſeem'd the moſt ſatisfactory Account of this grand *Phænomenon*: I have in another place attempted to explain the manner of the riſing of Vapour by Warmth, by ſhewing, that if an Atom of Water were expanded into a Shell or Bubble, ſo as to be ten times as big in Diameter as when it was Water; ſuch an Atom would become ſpecifically lighter than Air, and riſe ſo long as that *Flatus* or warm Spirit that firſt ſeparated it from the Maſs of Water, ſhall continue to diſtend it to the ſame Degree;

Degree; and that Warmth declining, and the Air growing cooler and alſo ſpecifically lighter, the Vapours conſequently ſhall ſtop at a certain Region of the Air, or elſe deſcend, which may happen upon ſeveral accounts, as I ſhall by and by endeavour to make out; yet I undertake not that this is the only principal of the riſe of Vapours, and that there may not be a certain ſort of Matter, whoſe *Conatus* may be contrary to that of Gravity; as is evident in Vegitation, where in the Tendency of the Sprouts is directly upwards, or againſt the Perpendicular. But what ever is the true Cauſe, it is in Fact certain, that warmth does ſeparate the Particles of Water, and emit them with a greater and greater Velocity, as the heat is more and more intenſe; as is evident in the Steam of a boiling Cauldron, wherein likewiſe the Velocity of the aſcent of the Vapours does viſibly decreaſe till they diſappear, being diſperſed into and aſſimulated with the Ambient Air. Vapours being thus raiſed by warmth, let us for a firſt Suppoſition put, that the whole Surface of the Globe were all Water very deep, or rather that the whole Body of the Earth were Water, and that the Sun had its diurnal courſe about it: I take it, that it would follow, that the Air of it ſelf would imbibe a certain Quantity of aqueous Vapours, and retain them like Salts diſſolved in Water; that the Sun warming the Air, and raiſing a more plentiful Vapour from the Water in the day-time, the Air would ſuſtain a greater proportion of Vapour, as warm Water will hold more diſſolved Salts, which upon the abſence of the Sun in the Nights would be all again diſcharged in Dews, analogous to the Precipitation of Salts on the cooling of the Liquors; nor is it to be believed that in ſuch Caſe there would be any diverſity of Weather, other than periodically, every Year alike; the mixture of all terreſtrious, ſaline, heterogenious Vapours being taken away, which as they are variouſly compounded and brought by the Winds, ſeem to be the Cauſes of thoſe various Seaſons which we now find. In this caſe the Aiery Regions every where, at the ſame height, would be equally repleniſhed with the Proportion of Water it could contain, regard being only to be had to the different degree of warmth, from the nearneſs or diſtance of the Sun; and an eternal Eaſt-wind would blow all round the Globe, inclining only to the ſame ſide of the *Eaſt*, as the Latitude doth from the Equator; as is obſerved in the Ocean between the Tropicks.

Next let us ſuppoſe this Ocean interſperſed with wide and ſpacious Tracts of Land, with high Ridges of Mountains, ſuch as the *Pyrenean*, the *Alps*, the *Apennine*, the *Carpathian* in *Europe*, *Taurus*, *Caucaſus*, *Imaus*, and ſeveral others in *Aſia*; *Atlas* and the *Montes Lunæ*, with other unknown Ridges in *Africa*, whence came the *Nile*, the *Nigre*, and the *Zaire*: And in *America*, the *Andes* and the *Apalatean* Mountains; each of which far ſurpaſs the uſual height to which the Aqueous Vapours of themſelves aſcend, and on the tops of which the Air is ſo cold and rarified, as to retain but a ſmall part of thoſe Vapours, that ſhall be brought thither by Winds. Thoſe Vapours therefore that are raiſed copiouſly in the Sea, and by the Wind, are carried over the low Land to thoſe Ridges of Mountains, are there compelled by the Stream of the Air to mount up with it to the tops of the Mountains, where the Water preſently precipitates,

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gleeting down by the Crannies of the Stone; and part of the Vapour entering into the Caverns of the Hills, the Water thereof gathers as in an Alembick into the Basons of Stone it finds; which being once fill'd, all the overplus of Water that comes thither 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 Valleys or Guts between the Ridges of the Hills, and coming to unite, form little Rivulets, or Brooks: Many of these again, meeting in one common Valley and gaining the plain Ground, being grown less rapid, become a River; and many of these being united in one common Channel, make such Streams as the *Rhine*, the *Rhone*, the *Danube*; which latter, one would hardly think the Collection of Water condensed out of Vapour, unless we consider how vast a Tract of Ground that River drains, and that it is the Sum of all those Springs which break out on the South side of the *Carpathian* Mountains, and on the North side of the immense Ridge of the *Alps*, which is one continued Chain of Mountains from *Switzerland*, to the *Black-Sea* And it may almost pass for a Rule, that the magnitude of a River, or the quantity of Water it evacuates, is proportionable to the length and height of the Ridges from whence its Fountains arise. Now this Theory of *Springs* is not a bare *Hypothesis*, but founded on Experience, which it was my luck to gain in my abode at St. *Helena*, where in the Night-time, on the tops of the Hills, about 800 Yards above the Sea, there was so strange a condensation, or rather precipitation of the Vapours, that it was a great Impediment to my Cœlestial Observations; for in the clear Sky, the Dew would

would fall ſo faſt, as to cover, each half quarter of an Hour, my Glaſſes with little drops; ſo that I was neceſſitated to wipe them ſo often, and my Paper on which I wrote my Obſervations would immediately be ſo wet with Dew, that it would not bear Ink: By which it may be ſuppos'd how faſt the Water gathers in thoſe mighty high Ridges I but now nam'd.

Thus is one part of the Vapours blown upon the Land return'd by the Rivers into the Sea, from whence they came; another part by the cool of the Night falls in Dews, or elſe in Rains, again into the Sea before it reaches the Land, which is by much the greateſt part of the whole Vapours, becauſe of the great extent of the Ocean, which the motion of the Wind does not traverſe in a very long ſpace of Time; and this is the Reaſon why the Rivers do not return ſo much into the *Mediterranean*, as is extracted into Vapour. A third part falls on the Low-Lands, and is the *Pabulum* of Plants, where yet it does not reſt, but is again exhaled in Vapour by the action of the Sun, and is either carried by the Winds to the Sea to fall in Rain or Dew there, or elſe to the Mountains to be there turn'd into Springs; and tho' this does not immediately come to paſs, yet after ſeveral Viciſſitudes of riſing in Vapour, and falling in Rain or Dews, each Particle of the Water is at length return'd to the Sea from whence it came. Add to this, that the Rain-waters after the Earth is fully ſated with moiſture, does, by the Vallies or lower parts of the Earth, find its way into the Rivers, and ſo is compendiouſly ſent back to the Sea, After this manner is the Circulation perform'd, and I doubt not but this Hypo-

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thesis is more reasonable than that of those who derive all Springs from the Rain-waters, which yet are perpetual and without diminution, even when no Rain falls for a long space of time; or that derive them from a Filtration or Percolation of the Sea-waters, thro' certain imaginary Tubes or Passages within the Earth wherein they lose their Saltness. This, besides many others, labouring under this principal Absurdity, that the greatest Rivers have their most copious Fountains farthest from the Sea, and whether so great quantities of fresh Water cannot reasonably be deriv'd any other way than in Vapour. This, if we may allow final Causes, seems to be the design of the Hills, that their Ridges being plac'd thro' the midst of the Continents, might serve, as it were, for Alembicks to distil fresh Water for the use of Man and Beast, and their heights to give a descent to those Streams to run gently, like so many Veins, of the *Macrocosm* to be the more beneficial to the Creation. If the difference between Rain and Dew, and the cause why sometimes 'tis Cloudy, at other times Serene, be inquir'd, I can offer nothing like a proper Solution thereof, only with submission to propose Conjectures, which are the best I can find, *viz.* That the Air being heaped up by the meeting of two contrary Winds, when the *Mercury* is high, the Vapours are the better sustain'd and kept from Co-agulating or Condensing into Drops, whereby Clouds are not so easily generated, and the Night the Vapours fall down single, as they rose in imperceptible Atoms of Water: Whereas, when the *Mercury* is low, and the Air rarified by the Exhaustion thereof, of, by two contrary Winds blowing from the place; the Atoms of Air keep the Vapours not so well separated, and they coalesce into visible Drops in the Clouds, and from thence are easily drawn into greater Drops of Rain; to which 'tis possible and not improbable, that some sort of Saline or Angular Particles of Terrestrial Vapour being immix'd with the Aqueous, which I take to be Bubbles, may cut or break their Skins or Coats, and so contribute to their more speedy Condensation into Rain.

The

The True Theory of the Tides, extracted from that admired Treatise of Mr. Isaac Newton, *Intitled,* Philosophiæ Naturalis Principia Mathematica; *Being a Discourse presented with that Book to the late King* James, *by Mr.* Edmund Halley.

IT *may, perhaps, seem strange, that this Paper, being no other than a particular Account of a Book long since published, should now appear here; but the Desires of several honourable Persons, which could not be withstood, have obliged us to insert it here, for the sake of such, who being less knowing in Mathematical Matters, and therefore not daring to adventure on the Author himself, are notwithstanding, very curious to be inform'd of the Causes of Things; particularly of so general and extraordinary* Phænomena, *as are those of the Tides. Now this Paper having been drawn up for the late King* James's *Use, (in whose Reign the Book was publish'd) and having given good Satisfaction to those that got Copies of it; it is hoped the Savans of the higher Form will indulge us this Liberty we take to gratifie their Inferiours in point of Science; and not be offended, that we here insist more largely upon Mr.* Newton's Theory of the Tides, *which, how plain and easie soever we find, is very little understood by the common Reader.*

THE

THE sole Principle upon which this Author proceeds to explain most of the great and surprizing Appearances of Nature, is no other than that of *Gravity*, whereby in the Earth all Bodies have a tendency towards its Centre; as is most evident: And from undoubted Arguments it's proved, that there is such a Gravitation towards the Centre of the Sun, Moon, and all the Planets.

From this Principle, as a necessary Consequence, follows the Sphærical Figure of the Earth and Sea, and of all the other Cœlestial Bodies: And tho' the tenacity and firmness of the Solid Parts, support the Inequalities of the Land above the Level; yet the Fluids, pressing equally and easily yielding to each other, soon restore the *Æquilibrium*, if disturbed, and maintain the exact Figure of the Globe.

Now this force of Descent of Bodies towards the Centre, is not in all places alike, but is still less and less, as the distance from the Center encreases: And in this Book it is demonstrated, that this Force decreases as the Square of the distance increases; that is, the weight of Bodies, and the Force of their Fall is less, in parts more removed from the Center, in the proportion of the Squares of the Distance. So as for Example, a Ton weight on the Surface of the Earth, if it were raised to the height of 4000 Miles, which I suppose the Semidiameter of the Earth, would weigh but $\frac{1}{4}$ of a Ton, or 5 Hundred weight: If to 12000 Miles, or 3 Semidiameters from the Surface, that is 4 from the Center, it would weigh but $\frac{1}{16}$ part of the Weight on the Surface, or a Hundred and Quarter: So that it would be as easie for the Strength

Strength of a Man at that height to carry a Ton weight, as here on the Surface a $100\frac{1}{4}$. And in the ſame Proportion does the Velocities of the fall of Bodies decreaſe: For whereas on the Surface of the Earth all things fall 16 Foot in a ſecond; at one Semidiameter above, this fall is but four Foot; and at three Semidiameters, or four from the Centre, it is but $\frac{1}{16}$ of the Fall at the Surface, or but one Foot in a ſecond: And at greater Diſtances both Weight and Fall become very ſmall, but yet at all given Diſtances is ſtill ſome thing, tho' the Effect become inſenſible. At the diſtance of the Moon (which I will ſuppoſe 60 Semidiameters of the Earth) 3600 Pounds weigh but one Pound, and the fall of Bodies is but $\frac{1}{3600}$ of a Foot in a ſecond, or 16 Foot in a Minute; that is, a Body ſo far off deſcends in a Minute no more than the ſame at the Surface of the Earth would do in a Second of Time.

As was ſaid before, the ſame force decreaſing after the ſame manner is evidently found in the Sun, Moon, and all the Planets; but more eſpecially in the Sun, whoſe Force is prodigious; becoming ſenſible even in the immenſe diſtance of *Saturn*: This gives room to ſuſpect, that the force of Gravity is in the Cœleſtial Globes proportional to the quantity of Matter in each of them: And the Sun being at leaſt ten Thouſand times as big as the Earth, its Gravitation or attracting Force, is found to be at leaſt ten Thouſand times as much as that of the Earth, acting on Bodies at the ſame diſtance.

This Law of the decreaſe of Gravity being demonſtratively proved, and put paſt contradiction; the Author with great Sagacity, inquires into the neceſſary Conſequences of this Sup-

Suppoſition; whereby he finds the genuine Cauſe of the ſeveral Appearances in the Theory of the Moon and Planets, and diſcovers the hitherto unknown Laws of the Motion of Comets, and of the Ebbing and flowing of the Sea. Each of which are Subjects that have hitherto taken up much larger Volumes; but Truth being uniform, and always the ſame, it is admirable to obſerve how eaſily we are enabled to make out very abſtruſe *and difficult Matters*, when once true and genuine Principles are obtain'd: And on the other hand it may be wondred, that, notwithſtanding the great facility of truth, and the perplexity and nonconſequences that always attend erroneous Suppoſitions, theſe great Diſcoveries ſhould have eſcaped the acute Diſquiſitions of the beſt Philoſophical Heads of all paſt Ages, and be reſerv'd to theſe our Times. But that wonder will ſoon ceaſe, if it be conſider'd how great improvements Geometry has receiv'd in our Memory, and particularly from the profound Diſcoveries of our incomparable Author.

The Theory of the Motion of the primary *Planets* is here ſhewn to be nothing elſe, but the contemplation of the Curve Lines which Bodies caſt with a given Velocity, in a given Direction, and at the ſame time drawn towards the Sun by its gravitating Power, would deſcribe. Or, which is all one, that the Orbs of the Planets are ſuch Curve Lines as a Shot from a Gun deſcribes in the Air, being caſt according to the direction of the Piece, but bent in a crooked Line by the ſupervening Tendency towards the Earths Centre: And the Planets being ſuppoſed to be projected with a given Force, and attracted towards the Sun, after the aforeſaid

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manner, are here proved to describe such Figures, as answer punctually to all that the Industry of this and the last Age has observed in the Planetary Motions. So that it appears, that there is no need of solid Orbs and Intelligences, as the Antients imagin'd, nor yet of *Vortices* or Whirlpools of the Cœlestial Matter, as *Des Cartes* supposes; but the whole Affair is simply and mechanically performed, upon the sole Supposition of a Gravitation towards the Sun; which cannot be denied.

The Motion of *Comets* is here shewn to be compounded of the same Elements, and not to differ from Planets, but in their greater swiftness, whereby overpowering the Gravity that should hold them to the Sun, as it doth the Planets, they flie off again, and distance themselves from the Sun and Earth, so that they soon are out of our sight. And the imperfect Accounts and Observations Antiquity has left us, are not sufficient to determine whether the same Comet ever return again. But this Author has shewn how Geometrically to determine the Orb of a Comet from Observations, and to find his Distance from the Earth and Sun, which was never before done.

The third thing here done is the Theory of the Moon, all the Inequalities of whose Motion are proved to arise from the same Principles, only here the effect of two Centers operating on, or attracting a projected Body, comes to be considered; for the Moon, though principally attracted by the Earth, and moving round it, does together with the Earth, move round the Sun once a Year, and is, according as she is nearer or farther from the Sun, drawn by him more or less than the Center of the Earth, about

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which ſhe moves; whence ariſe ſeveral Irregularities in her Motion, of all which, the Author in this Book, with no leſs Subtility than Induſtry, has given a full account. And though by reaſon of the great Complication of the Problem, he has not yet been able to make it purely Geometrical, 'tis to be hoped, that in ſome farther Eſſay he may ſurmount the difficulty: And having perfected the Theory of the Moon, the long deſir'd Diſcovery of the Longitude (which at Sea is only practicable this way) may at length be brought to light, to the great Honour of your Majeſty, and Advantage of your Subjects.

All the ſurpriſing Phænomena of the Flux and Reflux of the Sea, are in like manner ſhewn to proceed from the ſame Principle; which I deſign more largely to inſiſt on, ſince the Matter of Fact is in this Caſe much better known to your Majeſty than in the foregoing.

If the Earth were alone, that is to ſay, not affected by the Actions of the Sun and Moon, it is not to be doubted, but the Ocean, being equally preſs'd by the force of Gravity towards the Center, would continue in a perfect Stagnation, always at the ſame height, without either Ebbing or Flowing; but it being here demonſtrated, that the Sun and Moon have a like Principle of Gravitation towards their Centers, and that the Earth is within the Activity of their Attractions, it will plainly follow, that the Equality of the preſſure of Gravity towards the Center will thereby be diſturb'd; and though the ſmallneſs of theſe Forces, in reſpect of the Gravitation towards the Earth's Center, renders them altogether imperceptible by any Experiments we

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can deviſe, yet the Ocean being fluid and yielding to the leaſt force, by its riſing ſhews where it is leſs preſs'd, and where it is more preſs'd by its ſinking.

Now if we ſuppoſe the force of the Moon's Attraction to decreaſe as the Square of the Diſtance from its Center increaſes (as in the Earth and other Cœleſtial Bodies) we ſhall find, that where the Moon is perpendicularly either above or below the Horizon, either in Zenith or Nadir, there the force of Gravity is moſt of all diminiſhed, and conſequently that there the Ocean muſt neceſſarily ſwell by the coming in of the Water from thoſe parts where the Preſſure is greateſt, *viz.* in thoſe places where the Moon is near the Horizon: But that this may be the better underſtood, I thought it needful to add the following Figure, *(Vide Fig.* 1. *Plate* 1.) where *M* is the Moon, *E* the Earth, *C* its Center, and *Z* the place where the Moon is in the Zenith, *N* where in the Nadir.

Now by the Hypotheſis it is evident, that the Water in *Z*, being nearer, is more drawn by the Moon, than the Center of the Earth *C*, and that again more than the Water in *N*; wherefore the Water in *Z* hath a tendency towards the Moon, contrary to that of Gravity, being equal to the exceſs of the Gravitation in *Z*, above that in *C*: And in the other caſe, the Water in *N*, tending leſs towards the Moon than the Center *C*, will be leſs preſſed, by as much as is the difference of the Gravitation towards the Moon in *C* and *N*. This rightly underſtood, it follows plainly, that the Sea, which otherwiſe would be Spherical, upon the Preſſure of the Moon, muſt form it ſelf into a Spheroidal or Oval Figure, whoſe longeſt Diameter is where the Moon is vertical, and shortest where she is in the Horizon; and that the Moon shifting her Position as she turns round the Earth once a Day, this Oval of Water shifts with her, occasioning thereby the two Floods and Ebbs observable in each 25 Hours.

And this may suffice, as to the general Cause of the Tides; it remains now to shew how naturally this Motion accounts for all the Particulars that have been observ'd about them; so that there can be no room left to doubt, but that this is the true cause thereof.

The Spring Tides upon the New and Full Moons, and Neap Tides on the Quarters, are occasion'd by the attractive Force of the Sun in the New and Full, conspiring with the Attraction of the Moon, and producing a Tide by their united Forces: Whereas in the Quarters, the Sun raises the Water where the Moon depresses it, and the contrary; so as the Tides are made only by the difference of their Attractions. That the force of the Sun is no greater in this Case, proceeds from the very small Proportion the Semidiameter of the Earth bears to the vast distance of the Sun.

It is also observ'd, that *cæteris paribus*, the Æquinoctial Spring Tides in *March* and *September*, or near them, are the Highest, and the Neap Tides the lowest; which proceeds from the greater Agitations of the Waters, when the fluid *Spheroid* revolves about a great Circle of the Earth, than when it turns about in a lesser Circle; it being plain, that if the Moon were constituted in the Pole, and there stood, that the *Spheroid* would have a fix'd Position, and that it would be always high Water under the Poles, and low Water every where under the Æquinoctial:

noctial: And therefore the nearer the Moon approaches the Poles, the leſs is the agitation of the Ocean, which is of all the greateſt, when the Moon is in the Æquinoctial, or fartheſt diſtant from the Poles. Whence the Sun and Moon, being either conjoined or oppoſite in the Æquinoctial, produce the greateſt Spring Tides; and the ſubſequent Neap Tides, being produc'd by the Tropical Moon in the Quarters, are always the leaſt Tides; whereas in *June* and *December*, the Spring Tides are made by the Tropical Sun and Moon, and therefore leſs vigorous; and the Neap Tides by the Æquinoctial Moon, which therefore are the ſtronger: Hence it happens, that the difference between the Spring and Neap Tides in theſe Months, is much leſs conſiderable than in *March* and *September*. And the reaſon why the very higheſt Spring Tides are found to be rather before the Vernal and after the Autumnal Equinox, *viz.* in *February* and *October*, than preciſely upon them, is, becauſe the Sun is nearer the Earth in the Winter Months, and ſo comes to have a greater effect in producing the Tides.

Hitherto we have conſider'd ſuch Affections of the Tides as are Univerſal, without relation to particular Caſes; what follows from the differing Latitudes of places, will be eaſily underſtood by the following Fig. (*Vide Fig.* 2. *Plate* 1.)

Let *A p E P* be the Earth cover'd over with very deep Waters, *C* its Center, *P*, *p*, its Poles, *A E* the Æquinoctial, *F*, *f*, the parallel of Latitude of a Place, *D*, *d*, another Parallel at equal diſtance on the other ſide of the Æquinoctial, *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 deſcrib'd upon *H h*, and *K k*, ſhall nearly repreſent the Figure of the Sea, and *C f*, *C D*, *C F*, *C d*, ſhall be the heighths of the Sea in the places *f*, *D*, *F*, *d*, in all which it is High-water: And ſeeing that in twelve Hours time, by the diurnal Rotation of the Earth, the Point *F* is transferr'd to *f*, and *d* to *D*: The height of the Sea *C F* will be that of the 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 *C F*. 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 produc'd by the Moon declining ſenſibly from the Æquinoctial; 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: Whence it is, that the Moon in the Northern Signs, in this part of the World, makes the greateſt Tides when above the Earth, and in 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 obſerv'd to hold true on the Coaſt of *England*, at *Briſtol* by Captain *Sturmy*, and at *Plymouth* by Mr. *Colepreſſe*.

But the Motions hitherto mentioned are ſomewhat alter'd by the Libration of the Water, whereby, though the Action of the *Luminaries* ſhould ceaſe, the Flux and Reflux of the Sea would for ſome time continue: This Conſervation of the impreſs'd Motion diminiſhes the differences that otherwiſe would be between two conſequent Tides, and is the reaſon why the

highest

highest Spring-Tides are not precisely on the New and Full Moons, nor the Neaps on the Quarters; but generally they are the third Tides after them, and sometimes later.

All these things would regularly come to pass, if the whole Earth were cover'd with Sea very deep; but by reason of the shoalness of some places, and the narrowness of the Streights, by which the Tides are in many cases propagated, there arises a great diversity in the Effect, and not to be accounted for, without an exact Knowledge of all the Circumstances of the Places, as of the Position of the Land, and the Breadth and Depth of the Channels by which the Tide flows; for a very slow and imperceptible Motion of the whole Body of the Water, where it is (for Example) 2 Miles deep, will suffice to raise its Surface 10 or 12 Feet in a Tides time; whereas, if the same quantity of Water were to be convey'd up a Channel of 40 Fathoms deep, it would require a very great Stream to effect it, in so large Inlets as are the Channel of *England*, and the *German* Ocean; whence the Tide is found to set strongest in those places where the Sea grows narrowest; the same quantity of Water being to pass through a smaller Passage: This is most evident in the *Streights*, between *Portland* and *Cape de Hague* in *Normandy*, where the Tide runs like a Sluce; and would be yet more between *Dover* and *Calais*, if the Tide coming about the Island from the North did not check it. And this force being once impress'd upon the Water, continues to carry it above the level of the ordinary height in the Ocean, particularly where the Water meets a direct Obstacle, as it is at St. *Malo's*; and where it enters into a long Channel, which running far into the Land, grows very ſtreight at its Extremity; as it is in the *Severn-Sea* at *Chepſtow* and *Briſtol.*

This ſhoalneſs of the Sea, and the intercurrent Continents are the reaſon, that in the open Ocean the time of High water is not at the Moons appulſe to the Meridian, but always ſome Hours after it; as it is obſerv'd upon all the Weſt Coaſt of *Europe* and *Africa*, from *Ireland* to the *Cape of Good-Hope*: In all which a S. W. Moon makes High-water, and the ſame is reported to be on the Weſt ſide of *America*. But it would be endleſs to account all the particular Solutions, which are eaſie Corollaries of this *Hypotheſis*; as why the *Lakes*, ſuch as the *Caſpian Sea*, and *Mediterranean Seas*, ſuch as the *Black Sea*, the *Streights*, and *Baltick*, have no ſenſible Tides: For *Lakes* having no Communication with the Ocean, can neither increaſe nor diminiſh their Water, whereby to riſe and fall; and Seas that communicate by ſuch narrow Inlets, and are of ſo immenſe an Extent, cannot in a few Hours time receive or empty Water enough to raiſe or ſink their Surface any thing ſenſibly.

Laſtly, to demonſtrate the Excellency of this Doctrine, the Example of the Tides in the Port of *Tunking* in *China*, which are ſo extraordinary, and differing from all others we have yet heard of, may ſuffice. In this Port there is but one Flood and Ebb in 24 Hours; and twice in each Month, *viz.* when the Moon is near the Æquinoctial there is no Tide at all, but the Water is ſtagnant; but with the Moons Declination there begins a Tide, which is greateſt when ſhe is in the Tropical Signs: Only with this difference, that when the Moon is to the Northward of the Æquinoctial, it Flows when ſhe is above

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the Earth, and Ebbs when ſhe is under, ſo as to make High-water at Moons-ſetting, and Low-water at Moons-riſing: But on the contrary, the Moon being to the Southward, makes High-water at riſing, and Low-water at ſetting; it Ebbing all the time ſhe is above the Horizon. As may be ſeen more at large in the *Philoſophical Tranſactions*, Numb. 162.

The Cauſe of this odd Appearance is propos'd by Mr. *Newton*, to be from the concurrence of two Tides; the one propagated in ſix Hours out of the great *South-Sea* along the Coaſt of *China*; the other out of the *Indian-Sea*, from between the Iſlands in twelve Hours, along the Coaſt of *Malacca* and *Cambodia*. The one of theſe Tides, being produc'd in North Latitude, is, as has been ſaid, greater, when the Moon being to the North of the Equator is above the Earth, and leſs when ſhe is under the Earth. The other of them, which is propagated from the *Indian Sea*, being raiſed in South-Latitude, is greater when the Moon declining to the South, is above the Earth, and leſs when ſhe is under the Earth: So that of theſe Tides alternately greater and leſſer, there comes always ſucceſſively two of the greater and two of the leſſer together every Day; and the High-water falls always between the times of the arrival of the two greater Floods; and the Low-water between the arrival of the two leſſer Floods. And the Moon coming to the Æquinoctial, and the alternate Floods becoming equal, the Tide ceaſes, and the Water ſtagnates: But when ſhe has paſs'd to the other ſide of the Equator, thoſe Floods which in the former Order were the leaſt, now becoming the greateſt, that That before was the time of High-water, now becomes the Low-water, and the

the Converſe. So that the whole appearance of theſe ſtrange Tides, is without any forcing naturally deduc'd from theſe Principles, and is a great Argument of the Certainty of the whole *Theory*.

A

A Theory of the Variation *of the* Magnetical Compaſs. *By Mr*. Ed. Halley, *Fellow of the Royal Society.*

THE Variation of the Compaſs (by which I mean the Deflection of the Magnetical Needle from the true Meridian) is of that great Concernment in the Art of Navigation, that the neglect thereof, does little leſs than render uſeleſs one of the nobleſt Inventions Mankind ever yet attained to. And for this cauſe all Ships of Conſequence (eſpecially thoſe bound beyond the Equator) carry with them Inſtruments on purpoſe to obſerve this Variation: That ſo the Courſe ſteer'd by the Compaſs, may be reduc'd to the true Courſe in reſpect of the Meridian.

Now although the great utility that a perfect Knowledge of the Theory of the Magnetical Direction would afford to Mankind in general, and eſpecially to thoſe concern'd in Sea Affairs, ſeems as ſufficient incitement to all Philoſophical and Mathematical Heads, to take under ſerious Conſideration the ſeveral *Phænomena*, and to endeavour to reconcile them by ſome general Rule: Yet ſo it is; that almoſt all the Authors, from whom a Diſcourſe of this kind ought to have been expected, paſs by in ſilence the Difficulties they here Encounter. And thoſe that mention this Variation: By affirming it to proceed from Cauſes altogether uncertain (as are the caſual ly-

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ing of Iron Mines and Loadſtones in the Earth) put a ſtop to all further Contemplation; and give diſcouragement to thoſe that would otherwiſe undertake this Enquiry. 'Tis true, that not long ſince one Mr. *Bond*, an old Teacher of Navigation, put forth a ſmall Treatiſe, wherein he pretends to calculate the Variation: But he limits his Hypotheſis to the City of *London*, affirming himſelf (as he had a great deal of reaſon) that the ſame *Calculus* is not ſufficient for other Places; whereby it appears that this Rule is far ſhort of the ſo much deſir'd general one.

Now although (through want of ſufficient Obſervations, and ſome other Difficulties, which I ſhall anon ſhew) I cannot pretend perfectly to eſtabliſh the Numbers and Rules of a *Calculus*, which ſhall preciſely anſwer to the Variations of all parts of the World: Yet I ſuppoſe it will not be unacceptable to the Curious to propoſe ſomething of a Light into this abſtruſe Myſtery; which, if no other, may have this good Effect, to ſtir up the Philoſophical *Genii* of the Age to apply themſelves more attentively to this uſeful Speculation. But before I proceed, 'twill be neceſſary to lay down the Grounds upon which I raiſe my Concluſions; and at once to give a Synopſis of thoſe Variations, which I have reaſon to look upon as ſure, being moſtly the Obſervations of Perſons of good Skill and Integrity.

A TABLE OF VARIATIONS.

Names of Places.	*Longitude from* Lon.	*Latitude.*	*Anno Dom.*	*Variation Observ'd.*
	d m	*d m*		*d m*
London	0 0	51 32 N	1580	11 15 E
			1622	6 0 E
			1634	4 5 E
			1672	2 30 W
Paris	2 25 E	48 51 N	1683	4 30 W
			1640	3 00 E
			1666	0 0
			1681	2 30 W
Uraniburg	13 0 E	55 54 N	1672	2 35 W
Copenhagen	12 53 E	55 41 N	1649	1 30 E
			1672	3 35 W
Dantzick	19 0 E	54 23 N	1679	7 00 W
Mompelier	4 0 E	43 37 N	1674	1 10 W
Brest	4 25 W	48 23 N	1680	1 45 W
Rome	13 0 E	41 50 N	1681	5 0 W
Bayonne	1 20 W	43 30 N	1680	1 20 W
Hudson's Bay	79 40 W	51 00 N	1668	19 15 W
In *Hud.* Straights	57 00 W	61 00 N	1668	29 30 W
In *Baffin*'s Bay at Sir *Thomas Smith's* Sound	80 00 W	78 00 N	1616	57 00 W

Names

Names of Places.	Longitude.	Latitude.	Anno Dom.	Variation.
	d m	d m		d m
At Sea	50 0 W	38 40 N	1682	7 30 W
At Sea	31 30 W	43 50 N	1682	5 30 W
At Sea	42 0 W	21 0 N	1678	0 40 E
Cape St. *Aug.* of *Brazile*	35 30 W	8 0 S	1670	5 30 E
Cape *Frio*	41 10 W	22 40 S	1670	12 10 E
At Sea off of the Mou. of the River *Plate*	53 00 W	39 30 S	1670	20 33 E
At the East Entrance of *Magellan* Straits	68 00 W	52 30 S	1670	17 00 E
At the W. Entrance of the *Magellan* Straits	75 00 W	53 00 S	1670	14 10 E
Baldivia	73 00 W	40 00 S	1670	8 10 E
At Cape d' *Agulhas*	16 30 E	34 50 S	1622	2 00 W
			1675	8 00 W
At Sea	1 0 E	34 30 S	1675	0 00
At Sea	20 0 W	34 0 S	1675	10 30 E
At Sea	32 0 W	24 0 S	1675	10 30 E
At St. *Helena*	6 30 W	16 00 S	1677	0 40 E
At *Ascension*	14 30 W	7 50 S	1678	1 00 E
At *Johanna*	44 00 E	12 15 S	1675	19 30 W
At *Monbasa*	40 00 E	4 00 S	1675	16 00 W
At *Zocatra*	56 00 E	12 30 N	1674	17 00 W
At *Aden*, at the Mo. of the *Red Sea*	47 30 E	13 00 N	1674	15 00 W
At *Diego Roiz*	61 0 E	20 0 S	1676	20 30 W
At Sea	64 30 E	0 0	1676	15 30 W
At Sea	55 0 E	27 0 S	1676	24 00 W
At *Bombay*	72 30 E	19 0 N	1676	12 00 W
At Cape *Comorin*	76 00 E	8 15 N	1680	8 48 W
At *Ballafore*	87 00 E	21 30 N	1680	8 20 W
At Fort St. *George*	80 00 E	13 15 N	1680	8 10 W
At the W. Point of *Java*	104 00 E	6 40 S	1676	3 10 W

At

Names of Places.	Longitude.	Latitude.	Anno Dom.	Variation.
	d m	d m		d m
At Sea	58 00 E	39 0 S	1677	27 30 W
At the Iſle of St. *Paul*	72 0 E	38 0 S	1677	23 30 W
At *Van Dimen*'s Land	142 0 E	42 25 S	1642	0 0
At *New Zealand*	170 0 E	40 50 S	1642	9 0 E
At *Three Kings Iſle* in *New Zealand.*	169 30 E	34 35 S	1642	8 40 E
At the Iſle *Rotterdam* in the South Sea	184 00 E	20 15 S	1642	6 20 E
On the Coaſt of *N.Guin.*	149 00 E	4 30 S	1643	8 45 E
At the W.P. of *N.Guin.*	126 00 E	0 26 S	1643	5 30 E

Tho' I could wiſh we could obtain from the *Spaniards* what Variations they find in their Voyages from the *Manilhas* towards *Acapulco*, thorough the North part of the South Sea; as likewiſe what it is at *Japan* from the *Dutch*: Yet (conſidering the number of theſe Obſervations I have collected, and that they are made in parts of the World ſo remote from *Europe*, and from one another) I ſuppoſe that the Theory that anſwers theſe will ſcarce fail in thoſe Regions from whence we have as yet no account. But firſt we muſt make ſome Remarks upon the foregoing Table: And, Firſt,

That in all *Europe* the Variation at this time is Weſt, and more in the Eaſtern Parts thereof than the Weſtern: As likewiſe, that it ſeems throughout to be upon the increaſe that way.

Secondly, That on the Coaſt of *America*, about *Virginia*, *New-England* and *New-Foundland*, the Variation is likewiſe Weſterly; and that it increaſes all the way as you go Northerly along the Coaſt, ſo as to be above 20 Degrees at *New-Found-Land*, nearly 30 gr. in *Hudſon*'s *Straights*, and not leſs than 57 Degrees in *Baffin*'s *Bay*; alſo, that as you Sail Eaſt-

ward

ward from this Coaſt, the Variation diminiſhes. From theſe two it is a Legitimate Corollary: That *Somewhere between* Europe, *and the North part of* America, *there ought to be an Eaſterly Variation, or at leaſt no Weſterly.* And ſo I conjecture it is about the Eaſtermoſt of the *Tercera Iſlands.*

Thirdly, That on the Coaſt of *Braſile* there is Eaſt Variation, which increaſes very notably as you go to the Southward, ſo as to be 12 Degrees at *Cape Frio*, and over againſt the River of *Plate* 20½ Degrees: And from thence Sailing Southweſterly to the Straits of *Magellan* it decreaſes 17 Degrees, and at the Weſt Entrance but 14 Degrees.

Fourthly, That at the Eaſtward of *Braſile*, properly ſo call'd, this Eaſterly Variation decreaſes, ſo as to be very little at St. *Helena* and *Aſcenſion*, and to be quite gone, and the Compaſs Point true about 18 Degrees of Longitude Weſt from the Cape of *Good-hope*.

Fifthly, That to the Eaſtward of the aforeſaid Places a Weſtward Variation begins, which Reigns in the whole *Indian* Sea, and ariſes to no leſs than Eighteen Degrees under the Equator it ſelf, about the Meridian of the Northern part of *Madagaſcar*; and near the ſame Meridian, but in 39 Degrees South Latitude it is found full 27½ Degrees: From thence Eaſterly the Weſt Variation decreaſes, ſo as to be little more than eight Degrees at *Cape Comorin*, and than three Degrees upon the Coaſt of *Java*; and to be quite extinct about the *Molucca Iſlands*, as alſo a little to the Weſtwards of *Van*

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Diemens Land found out by the *Dutch* in 1642.

Sixthly, That to the Eaſtward of the *Molucca's* and *Van Diemens* Land in South Latitude there ariſes another Eaſterly Variation, which ſeems not ſo great as the former, nor of ſo large Extent; for that at the Iſland *Rotterdam* it is ſenſibly leſs than upon the Eaſt Coaſt of *New Guinea*; and, at the rate it decreaſes, it may well be ſuppos'd, that about 20 Degrees farther Eaſt, or 225 Degrees Eaſt Longitude from *London*, in the Latitude of 20 Degrees South, a Weſterly Variation begins.

Seventhly, That the Variations obſerv'd by the Honourable Sir *John Norborough* at *Baldivia*, and at the Weſt Entrance of the *Straights* of *Magellan* do plainly ſhew, that That Eaſt Variation, noted in our third Remark, is decreaſing apace; and that it cannot reaſonably extend many Degrees into the South Sea from the Coaſt of *Peru* and *Chili*, leaving room for a ſmall Weſterly Variation, in that Tract of the unknown World that lies in the mid-way between *Chili* and *New-Zealand*, and between *Hounds-Iſland* and *Peru*.

Eighthly, That in Sailing North-Weſt from St. *Helena* by *Aſcenſion*, as far as the Equator, the Variation continues very ſmall Eaſt, and as it were conſtantly the ſame: So that in this part of the World the Courſe, wherein there is no Variation, is evidently no Meridian, but rather North-Weſt.

Ninthly, That the Entrance of *Hudſon's Straights*, and the Mouth of the River of *Plate*, being nearly under the ſame Meridian, at the one place the Needle varies $29\frac{1}{2}$ Degrees to the *Weſt*; at the other $20\frac{1}{2}$ Degrees to the *Eaſt.* This plainly demonſtrates the impoſſibility of reconciling theſe Variations by the Theory of *Bond; which is by two Magnetical Poles and an Axis, inclin'd to the Axis of the Earth*; from whence it would follow, That *under the ſame Meridian the Variation ſhould be in all places the ſame way.*

Theſe things being premiſed may ſerve as a ſure Foundation to raiſe the Superſtructure of a Theory upon. But firſt it would not be amiſs to ſhew hereby the miſtake of *Gilbert* and *Des Cartes*: The firſt whereof ſuppoſes; that *the Earth it ſelf being in all its parts Magnetical, and the Water not; whereſoever the Land is, thither alſo ſhould the Needle turn, as to the greater quantity of Magnetical Matter.* But this in many Inſtances is not true; but moſt remarkably upon the Coaſt of *Brazile*, where the Needle is ſo far from being attracted by the Land, that it turns the quite contrary way, leaving the Meridian to lye N b E, which is juſt along the Coaſt. As to the Poſition of *Des Cartes, that the Iron and Loadſtones hid in the Bowels of the Earth and the Bottom of the Sea, may be the Cauſes that the Needle varies*; if we conſider for how great a part of the Earths Surface, *ex gr.* in the whole *Indian* Sea, the Needle declines the ſame way, and that regularly, 'twill follow that the attracting Subſtance that occaſions it, muſt be very far diſtant. Now by Experience we find the little force that Iron Guns have upon the Compaſs in Ships (their Vertue, though they be Demiculverin, or greater Cannon, being not perceptible at four or five Yards diſtance) and the

the Experiments now before the *Royal Society* do plainly ſhew, how little a Magnetiſm there is in moſt crude Iron Oars: What quantity thereof muſt be then ſuppos'd to make ſo powerful a Diverſion at two or three Thouſand Miles diſtance? Yet I cannot deny that in ſome places near the Shoar, or in Shoal-Water, the Needle may be irregularly directed from the aforeſaid Cauſes, and that not a little, as *Gaſſendus* gives a notable inſtance of the Iſland *Elba* in the Mediterranean Sea: But theſe differences from the general Direction are always ſigns of the nearneſs of thoſe Magnetical Subſtances, for the Production whereof that Iſland *Elba* has been famous from all Antiquity. Beſides, againſt both *Des Cartes* and *Gilbert*, the change of the Variation, which has been within theſe Hundred Years laſt paſt more than 15 gr. at *London*, is an entire Demonſtration; tho' *Des Cartes* does not ſtick to ſay, that the tranſportation of Iron from place to place, and the growth of new Iron within the Earth, where there was none before, may be the cauſe thereof. The ſame holds likewiſe againſt the *Hypotheſis* of *Magnetical Fibres*, which *Kircher* maintains.

Now to propoſe ſomething that may anſwer the ſeveral appearances, and introduce nothing ſtrange in Philoſophy, after a great many cloſe Thoughts, I can come to no other Concluſion than that, *The whole Globe of the Earth is one great Magnet, having four Magnetical Poles, or Points of Attraction, near each Pole of the Equator Two; and that, in thoſe parts of the World which lie near adjacent to any one of thoſe Magnetical Poles, the Needle is govern'd thereby, the neareſt Pole being always predominant over the more remote.* The parts of the Earth wherein theſe

Magnetical *Poles* lie, cannot as yet be exactly determin'd for want of sufficient *Data* to proceed Geometrically; but, as near as Conjecture can reach, I reckon that the *Pole*, which is at present nearest to us, lies in or near the Meridian of the Lands-end of *England*, and not above seven Degrees from the Pole Arctick; by this *Pole* the Variations in all *Europe* and *Tartary*, and the *North Sea* are principally govern'd, though with regard to the other Nothern Pole, whose situation is in a *Meridian* passing about the middle of *California*, and about 15 gr. from the North Pole of the World; to this the Needle has chiefly respect in all the North *America*, and in the two Oceans on either side thereof, from the *Azores* Westward to *Japan*, and farther. The two Southern Poles are rather farther distant from the South Pole of the World: The one about sixteen Degrees therefrom, is in a Meridian, some twenty Degrees to the Westward of *Magellan Straights*, or ninety five Degrees West from *London*: This commands the Needle in all the *South-America*, in the *Pacifick Sea*, and the greatest part of the *Ethiopick* Ocean. The Fourth and last *Pole* seems to have the greatest Power, and largest Dominions of all, as it is the most remote from the *Pole* of the World, being little less than 20 Degrees distant therefrom in the Meridian, which passes through *Hollandia Nova*, and the Island *Celebes* about one hundred and twenty Degrees East from *London*; this *Pole* is predominant in the South part of *Africa*, in *Arabia* and the *Red Sea*, in *Persia*, *India*, and its Islands, and all over the *Indian Sea*, from the Cape of *Good-Hope* Eastwards to the middle of the great South Sea, that divides *Asia* from *America*. This seems

ſeems to be the preſent Diſpoſition of the Magnetical Vertue throughout the whole Globe of the Earth; it remains to ſhew how this Hypotheſis makes out all the Variations that have been obſerv'd of late; and how it anſwers to our ſeveral Remarks drawn from the Table. And firſt it is plain, that (our *European* North *Pole* being in the Meridian of the Lands-end of *England*) all places more Eaſterly than that will have it on the Weſt ſide of their Meridian, and conſequently the Needle, reſpecting it with its Northern Point, will have a Weſterly Variation, which will ſtill be greater as you go to the Eaſtwards, till you come to ſome Meridian of *Ruſſia*, where 'twill be greateſt, and from thence decreaſe again. Thus at *Breſt* the Variation is but $1\frac{3}{4}$ Degrees, at *London* $4\frac{1}{2}$ Degrees; but at *Dantzick* ſeven Degrees Weſt. To the Weſtward of the Meridian of the Lands-end, the Needle ought to have an Eaſterly Variation; were it not that (by approaching the *American* Northern *Pole*, which lies on the Weſt ſide of the Meridian, and ſeems to be of greater force than this other) the Needle is drawn thereby Weſtwards, ſo as to counterballance the Dirì-ection given by the *European Pole*, and to make a ſmall Weſt Variation in the Meridian of the Lands-end it ſelf. Yet I ſuppoſe that about the Meridian of the Iſle *Tercera*, our neareſt *Pole* may ſo far prevail as to give the Needle a little turn to the Eaſt, though but for a very ſmall ſpace: The Counterballance of thoſe two *Poles* permitting no conſiderable Variation in all the Eaſtern Parts of the *Atlantick* Ocean; nor upon the Weſt Coaſts of *England* and *Ireland*, *France*, *Spain* and *Barbary*. But to the Weſtwards of the *Azores* the Power of the *American*

 Pole

Pole overcoming that of the *European*, the Needle has chiefly respect thereto, and turns still more and more towards it as you approach it. Whence it comes to pass, that on the Coast of *Virginia*, *New-England*, *New-found-Land*, and in *Hudson*'s-*Straights* the Variation is Westward; that it decreases as you go from thence towards *Europe*, and that it is less in *Virginia* and *New-England*, than in *New-found-Land*, and *Hudson*'s-*Straights*. This Westerly Variation again decreases, as you pass over the *North America*; and about the Meridian of the middle of *California* the Needle again points due North; and from thence Westward to *Yedzo* and *Japan*, I make no doubt but the Variation is Easterly, and half the Sea over no less than fifteen Degrees, if there be any truth in this Hypothesis of mine. Therefore I propose this as a Trial, that the whole may be scann'd thereby; and I conceive it will not be hard to know of the *Spaniards* how it is, who so frequently sail through that Ocean, in their return from the *Manilha* Isles. This East Variation extends over *Japan*, *Yedzo*, *East-Tartary*, and part of *China*, till it meet with the Westerly, which is govern'd by the *European* North Pole, and which I said was greatest some where in *Russia*.

Towards the Southern Pole the effect is much the same, only that here the South Point of the Needle is attracted. Hence it will follow, that the Variation on the Coast of *Brazile*, at the River of *Plate*, and so on to the Straights of *Magellan*, should be Easterly (as in our third Remark); if we suppose a Magneticul Pole situate about twenty Degrees more Westerly than the Straights of *Magellan*. And this Easterly Variation doth extend Eastward over the greatest

part

part of the *Ethiopick* Sea, till it be counterpoised by the Vertue of the other Southern *Pole*; as it is about mid-way between the Cape of *Good-Hope*, and the Isles of *Tristan d' Acuntia*. From thence Eastwards, the *Asian* South Pole (as I must take the liberty to call it) becoming prevalent, and the South point of the Needle being attracted thereby, there arises a West Variation, very great in quantity and extent, because of the great distance of this Magnetical Pole of the World. Hence it is, that in all the *Indian* Sea as far as *Hollandia Nova*, and farther, there is constantly West Variation; at that under the Equator it self it arises to no less than eighteen Degrees, where 'tis most. About the Meridian of the Island *Celebes*, being likewise that of this Pole, this Westerly Variation ceases, and an Easterly begins; which reaches, according to my Hypothesis, to the middle of the *South-Sea*, between *Zelandia Nova*, and *Chili*, leaving room for a small *West Variation* govern'd by the *American* South Pole, which I shew'd to be in the *Pacifick Sea*, in the sixth and seventh Remark.

What I have now said, does plainly shew the sufficiency of this Hypothesis for solving the Variations that are at this time observ'd in the temperate and frigid *Zones*, where the Direction of the Needle chiefly depends upon the Counterpoise of the forces of two Magnetical Poles of the same Nature; and I suppose I have shewn how it comes to pass, that under the same Meridian the Variation should be in one place $29\frac{1}{2}$ West, and another $20\frac{1}{2}$ East; as I have noted in my ninth Remark.

In the *Torrid Zone*, and particularly under the Equinoctial, respect must be had to all four

Poles, and their Poſitions well conſider'd, otherwiſe it will not be eaſie to determine what the Variations ſhall be; the neareſt *Pole* being always the ſtrongeſt; yet not ſo, as not to be counterballanc'd ſometimes by the united forces of two more remote; a notable Inſtance whereof is in our eighth Remark, where I took notice, that in ſailing from St. *Helena* by the Iſle of *Aſcenſion*, to the Equator, on a *N. W.* Courſe, the Variation is very little Eaſterly, and in that whole Tract unalterable; for which I give this Reaſon, That the South *American* Pole (which is conſiderably the neareſt in the aforeſaid Places) requiring a great Eaſterly Variation, is counterpoiſed by the contrary Attraction of the *North-American* and the *Aſian-South-Pole*; each whereof ſingly are in theſe Parts, weaker than the *American-South-Pole*; and upon the North Weſt Courſe, the Diſtance from this latter is very little varied; and as you recede from the *Aſian-South-Pole*, the Ballance is ſtill preſerv'd by the acceſs towards the *North-American-Pole*. I mention not in this Caſe the *European-North-Pole*, its Meridian being little remov'd from thoſe of theſe places; and of it ſelf requiring the ſame Variations we here find. After the ſame manner we might proceed to conclude the Variations in other places under and near the Equator; but I purpoſely leave it for an Exerciſe to the Thoughts of the ſerious Reader, who is deſir'd to help his Imagination, by having before him a Map or Globe of the Earth: And to mark thereon the Magnetical *Poles* in the *Longitudes* and *Latitudes* I aſſign them. (*Vide Plate* 2.)

Thus

Thus, I hope, I have not loſt my Pains and Study in this difficult Subject; believing that I have put it paſt doubt, *That there are in the Earth four ſuch Magnetical Points or Poles, which occaſion the great variety and ſeeming irregularity which is obſerv'd in the Variations of the Compaſs.* But to calculate exactly what it is, in any place aſſign'd, is what I dare not yet pretend to, though I could wiſh it were my happineſs to be able to oblige the World with ſo uſeful a piece of Knowledge; there are Difficulties that occur, that render the thing as yet not feaſible; for firſt there are a great many Obſervations requiſite, which ought to be made at the ſame time; not at Sea, but aſhore, with greater Care and Attention than the generality of Sailors apply. And beſides, it remains undetermin'd in what proportion the attractive Power decreaſes, as you remove from the *Pole* of a Magnet, without which it were a vain attempt to go about to calculate. There is yet a further Difficulty, which is the Change of the Variation, one of the Diſcoveries of this laſt Century; which ſhews, that it will require ſome hundreds of Years to eſtabliſh a compleat Doctrine of the Magnetical Syſtem. From the foregoing Table it ſhould ſeem, that all the Magnetical *Poles* had a motion Weſtward: But if it be ſo, 'tis evident, that it is not a Rotation about the Axis of the Earth; for then the Variations would continue the ſame, in the ſame parallel of *Latitude* (the *Longitude* only chang'd) as much as is the motion of the Magnetical *Poles*, but the contrary is found by Experience; for there is no where in the Latitude of $15\frac{1}{2}$ North between *England* and *America*, a Variation of eleven Degrees Eaſt at this time;

as

as it was once here at *London*; it ſeems therefore, that our *European* Pole is grown nearer the Pole *Arctick* than it was heretofore, or elſe that it has loſt part of its Vertue. But whether theſe Magnetical Poles move altogether with one motion, or with ſeveral; whether equally or unequally; whether Circular or Libratory: If Circular, about what Center; if Libratory, after what manner; are Secrets as yet utterly unknown to Mankind, and are reſerv'd for the Induſtry of future Ages.

An

An Account of the Cauſe of the Change of the Variation of the Magnetical Needle, with an Hypotheſis of the Structure of the Internal Parts of the Earth; as it was propoſed to the Royal Society *in one of their late Meetings. By Mr.* Edmund Halley.

HAving in the precedent Diſcourſe delivered a Theory of the Variation of the Magnetical Compaſs, wherein I did collect as many Obſervations as at that time I could procure, and having carefully compar'd them together, I came at length to this general concluſion, *That the Globe of the Earth might be ſuppoſed to be one great Magnet, having four Magnetical Poles or Points of Attraction, near each Pole of the Equator two; and that in thoſe parts of the World which lie near adjacent to any one of thoſe Magnetical Poles, the Needle is chiefly govern'd thereby; the neareſt Pole being always predominant over the more remote.* And I there have endeavour'd to ſtate and limit the preſent Poſition of thoſe Poles in the Surface of our Globle, which the Reader pleaſing to conſult, will ſave us the pains of repeating. But after all, tho' that Diſcourſe was favourably receiv'd both at home and abroad, as ſeeming to render a tolerable account of the obſerv'd Variations

Variations, yet I found two Difficulties not easie to surmount; the one was, that no Magnet I had ever seen or heard of, had more than two opposite *Poles*, whereas the Earth had visibly four, and perhaps more. And secondly, it was plain that these *Poles* were not, at least all of them, fixt in the Earth, but shifted from place to place, as appear'd by the great Changes in the Needles Direction within this last Century of Years, not only at *London*, (where this great Discovery was first made) but almost all over the Globe of Earth; whereas it is not known or observ'd that the *Poles* of a Load-stone ever shifted their place in the Stone, nor (considering the compact hardness of that Substance) can it easily be suppos'd; though the Matter of Fact be too notorious and universal, not to be accounted for.

These Difficulties had wholly made me despond, and I had long since given over an Inquiry I had so little hopes of, when in accidental Discourse, and least expecting it, I stumbl'd on the following Hypothesis; in delivering whereof, if I shall seem to advance any thing that looks like Extravagant or Romantick, the Reader is desir'd to suspend his Censure, till he have consider'd the force and number of the many Arguments which concur to make good so new and so bold a Supposition.

Though it be sufficiently known and allow'd, that the Needles Variation changes, it will be necessary however to give a few Instances, whereby it may appear that this Change is gradual and universal, and the effect of a great and permanent motion: For which take the following Examples.

At

At *London*, in the Year 1580, the Variation was obſerv'd by Mr. *Burrows* to be 11° 15′ Eaſt. In *Anno* 1622, the ſame was found by Mr. *Gunter* to be but 6° 0′ Eaſt. In the Year 1634, Mr. *Gellibrand* found it 4° 5′ Eaſt. In 1657, Mr. *Bond* obſerv'd that there was no Variation at *London*. *Anno* 1672, my ſelf obſerv'd it 2° 30′ to the Weſt; and in the Year 1692, I again found it 6° 00′ Weſt. So that in 112 Years the Direction of the Needle has chang'd no leſs than ſeventeen Degrees.

At *Paris*, *Orontius Finæus* about the Year 1550, did account it about eight or nine Degrees Eaſt Variation. *Anno* 1640, it was found three Degrees Eaſt. *Anno* 1660, there was no Variation there, and *Anno* 1681, I found it to be 2° 30′ to the Weſt.

At *Cape d' Agulhas*, the moſt Southerly Promontary of *Africa*, about the Year 1600, the Needle pointed due North and South without Variation, whence the *Portugueze* gave its name. *Anno* 1622, there was two Degrees Weſt Variation. *Anno* 1675, it was 8° 50′ Weſt; and in the Year 1691, it was curiouſly obſerv'd not leſs than eleven Degrees Weſt.

At St. *Helena*, about the Year 1600, the Needle declin'd eight Degrees to the Eaſt. *Anno* 1623, it was but 6° 0′ Eaſt. *Anno* 1677, when I was there, I obſerv'd it accurately on Shoar to be 0°. 40′ Eaſt; and in 1692 it was found about 1° to the Weſtward of the North.

At *Cape Comorine* in *India*, in the Year 1620, there was 14° 20′ Weſt Variation. In the Year 1680, there was 8° 48′, but now lately in the Year 1688, it was no more than 7° 30′, ſo that here the Needle has return'd to the Eaſt about ſeven Degrees in ſeventy Years.

In

In all the other Examples the Needle has gradually mov'd towards the West, and the places are too far asunder to be influenc'd by the removal of any Magnetical Matter, which may by accident be transplac'd within the Bowels, or on the Surface of the Earth. If more Examples are desir'd, the Reader may be furnish'd with them in the *Portugueze Routier* of *Aleixo de Motta* (written about the Year 1600) and in the Voyage of *Beaulieu*, both publish'd in Mr. *Thevenot*'s first Collection of curious Voyages, Printed at *Paris*, *Anno* 1663; which he is to compare with the Journals of our late *East India* Voyagers, and I am assur'd, that it will be thereby evident, that the Direction of the Needle is in no place fix'd and constant, tho' in some it change faster than in others: And where for a long time it has continu'd as it were unalter'd, it is there to be understood, that the Needle has its greatest Deflection, and is become Stationary in order to return, like the Sun, in the Tropick. This, at present, is in the *Indian-Sea*, about the Island *Mauritius*, where is the highest West Variation, and in a Tract tending from thence into the N. N. W. towards the *Red-Sea* and *Egypt*. And in all Places to the Westward of this Tract, all over *Africa* and the Seas adjoining, the West Variation will be found to have encreas'd; and to the Eastwards thereof, as in the Example of *Cape Comorine*, to have decreased, *viz.* all over the *East-Indies*, and the Islands near it.

After the like manner in that Space of East Variation, which, beginning near St. *Helena*, is found all over the South *America*, and which at present is highest about the Mouth of *Rio de la Plata*, it has been observ'd, that in the Eastern Parts

Parts thereof, the Variation of the Needle gradually decreases; but whether on the contrary it increases in those places which lie more Westerly than that Tract wherein the highest East Variation is found; or how it may be in the vast *Pacifick Sea*, we have not Experience enough to ascertain, only we may by Analogy infer, that both the East and West Variations therein do gradually increase and decrease after the same Rule.

These *Phænomena* being well understood and duly consider'd, do sufficiently evince, That the whole Magnetical System is by one, or perhaps more motions translated, whether Eastwards or Westwards, I shall anon discuss; that this moving thing is very great, as extending its effects from Pole to Pole, and that the motion thereof is not *per saltum*, but a gradual and regular motion.

Now considering the Structure of our *Terraqueous* Globe, it cannot be well suppos'd that a very great part thereof can move within it, without notably changing its Center of Gravity and the Equilibre of its Parts, which would produce very wonderful Effects in changing the Axis of diurnal Rotation, and occasion strange alteration in the Seas Surface, by Inundations and Recesses thereof, such as History never yet mention'd. Besides, the solid parts of the Earth are not to be granted permeably by any other than fluid Substances, of which we know none that are any ways Magnetical. So that the only way to render this motion intelligible and possible, is to suppose it to turn about the Center of the Globe, having its Center of Gravity fix'd and immoveable in the same common Center of the Earth: And there is yet requir'd,

that

that this moving internal Subſtance be looſe and detached from the external Parts of the Earth whereon we live; for otherwiſe, were it affix'd thereto, the whole muſt neceſſarily move together.

So then the External Parts of the Globe may well be reckon'd as the Shell, and the Internal as a *Nucleus* or inner Globe, included within ours, with a fluid Medium between, which having the ſame Common Center and Axis of diurnal Rotation, may turn about with our Earth each twenty four Hours; only this outer Sphere having its turbinating motion ſome ſmall matter either ſwifter or ſlower than the internal Ball: And a very minute Difference in length of time, by many Repetitions becoming ſenſible, the Internal Parts will by degrees recede from the External, and not keeping pace with one another, will appear gradually to move either Eaſtwards or Weſtwards by the difference of their motions.

Now ſuppoſing ſuch an Internal Sphere having ſuch a motion, we ſhall ſolve the two great Difficulties we encounter'd in my former Hythеſis: For if this exteriour Shell of Earth be a Magnet, having its Poles at a diſtance from the Poles of diurnal Rotation; and if the Internal *Nucleus* be likewiſe a Magnet, having its Poles in two other places, diſtant alſo from the Axis; and theſe latter by a gradual and ſlow motion change their place in reſpect of the External; we may then give a reaſonable account of the four Magnetical Poles I preſume to have demonſtrated before; as likewiſe of the Changes of the Needles Variations, which till now hath been unattempted.

The

The Period of this Motion being wonderful great, and there being hardly an hundred Years ſince theſe Variations have been duly obſerv'd, it will be very hard to bring this Hypotheſis to a Calculus, eſpecially ſince, though the Variations do increaſe and decreaſe regularly in the ſame place, yet in differing places, at no great diſtance, there are found ſuch caſual Changes thereof as can no ways be accounted for by a regular Hypotheſis; as depending upon the unequal and irregular diſtribution of the Magnetical Matter within the Subſtance of the External Shell or Coat of the Earth, which deflect the Needle from the Poſition it would acquire from the effect of the general Magnetiſm of the whole. Of this the Variations at *London* and *Paris* give a notable Inſtance, for the Needle has been conſtantly about 1°½ more Eaſterly at *Paris* than at *London*; though it be certain that according to the general effect, the Difference ought to be the contrary way: Notwithſtanding which, the Variations in both places do change alike.

Hence, and from ſome other of like Nature, I conclude, That the two Poles of the External Globe are fixt in the Earth, and that if the Needle were wholly govern'd by them, the Variations thereof would be always the ſame, with ſome little Irregularities upon the account I but juſt now mention'd: But the Internal Sphere having ſuch a gradual tranſlation of its Poles, does influence the Needle, and direct it variouſly, according to the reſult of the attractive or directive Power of each Pole; and conſequently there muſt be a Period of the Revolution of this Internal Ball, after which the Variations will return again as before. But if it ſhall in future Ages be obſerv'd otherwiſe, we muſt then conclude that there are more of theſe Internal Spheres, and more Magnetical Poles than Four, which at preſent we have not a ſufficient number of Obſervations to determine, and particularly in that vaſt *Mar del Zur*, which occupies ſo great a part of the whole Surface of the Earth.

If then two of the Poles be fixt and two moveable, it remains to aſcertain which they are that keep their place; and though I could wiſh we had the Experience of another Century of Years to found our Concluſions upon, yet I think we may ſafely determine, That our *European North Pole* (which in the precedent Diſcourſe I ſuppos'd near the Meridian of the Lands-end of *England*, and about ſeven Degrees therefrom) is that That is moveable of the two Northern Poles, and that That has chiefly influenc'd the Variations in theſe parts of the World: For in *Hudſon's* Bay, which is under the Direction of the *American* Pole, the Change is not obſerv'd to be near ſo faſt as in theſe parts of *Europe*, though that Pole be much farther remov'd from the Axis.

As to the South Poles, I take the *Aſian* Pole, which I place about the Meridian of the Iſland *Celebes* to be the fixt, and conſequently the *American* Pole to move; from the like Obſervation of the ſlow Decreaſe of the Variation on the Coaſt of *Java*, and near the Meridian of the *Aſian* Pole; though I muſt confeſs to have no account of the effects of the other beyond *Magellan's* Streights.

If this be allow'd me, 'tis plain that the fixt Poles are the Poles of this External Shell or Cortex of the *Earth*, and the other two the Poles of a Magnetical *Nucleus* included and moveable

moveable within the other. It likewiſe follows, that this Motion is Weſtwards, and by conſequence that the aforeſaid *Nucleus* has not preciſely attained the ſame degree of Velocity with the exteriour Parts in their diurnal Revolution; but ſo very nearly equals it, that in 365 Revolves the the difference is ſcarce ſenſible. This I conceive to ariſe from the Impuſe whereby this diurnal Motion was impreſt on the Earth, being given to the External Parts, and from thence in time communicated to the Internal; but not ſo as perfectly to equal the Velocity of the firſt Motion impreſs'd on, and ſtill conſerv'd by the ſuperficial Parts of the Globe.

As to the quantity of this Motion it is almoſt impoſſible to define it, both from the Nature of this kind of Obſervation, which cannot be very accurately perform'd, as alſo from the ſmall time theſe Variations have been obſerv'd, and their Change diſcover'd. It appears by all Circumſtances, that its Period is of many Centuries of Years, and as far as may be collected from the Change of the Place, where there was no Variation, by reaſon of the Equilibre of the two Southern Magnetical Poles, *viz.* from *Cape d' Agulhas* to the Meridian of St. *Helena* (which is about 23 *degr.* in about ninety Years) and of the place where the Weſterly Variation is in its ἀκμῇ or greateſt Deflection, being about half ſo much, *viz.* from the Iſle of *Diego Roiz* to the South Weſt Parts of *Madagaſcar.* We may with ſome Reaſon conjecture, that the *American* Pole has mov'd Weſtwards forty ſix Degrees in that time, and that the whole Period thereof is perform'd in ſeven hundred Years, or thereabouts; ſo that the nice Determination of this, and of ſeveral other Particulars in the

Magnetick System is reserv'd for remote Posterity; all that we can hope to do, is to leave behind us Observations that may be confided in, and to propose an Hypothesis which after Ages may examine, amend or refute. Only here I must take leave to recommend to all Masters of Ships, and all others, Lovers of Natural Truths, that they use their utmost Diligence to make, or procure to be made, Observations of these Variations in all parts of the World, as well in the North as South Latitude (after the laudable Custom of our *East India* Commanders) and that they please to communicate them to the *Royal Society*, in order to leave as compleat a History as may be to those that are hereafter to compare all together, and to compleat and perfect this abstruse Theory.

And by the way it will not be amiss to amend a receiv'd Error in the Practice of observing the Variation, which is, to take it by the Amplitude of the Rising and Setting Sun, when his Center appears in the visible Horizon; whereas he ought to be observ'd when his under Limb is still above the Horizon about $\frac{2}{3}$ of his Diameter, or twenty Minutes, upon the score of the Refraction, and the height of the Eye of the Observer above the Surface of the Sea: Or else they are to work the Amplitudes as they do the Azimuth, reckoning the Suns Distance from the Zenith 90° 36': This, though it be of little consequence near the Æquinoctial, will make a great Error in high Latitudes, where the Sun rises and sets obliquely.

But to return to our Hypothesis, In order to explain the Change of the Variations, we have adventur'd to make the Earth hollow, and to place

place another Globe within it; and I doubt not but this will find Oppoſers enough. I know 'twill be Objected, That there is no Inſtance in Nature of the like thing; that if there was ſuch a middle Globe it would not keep its place in the Center, but be apt to deviate therefrom, and might poſſibly chock againſt the Concave Shell, to the ruin, or at leaſt endammaging thereof; That the Water of the Sea would perpetually leak through, unleſs we ſuppoſe the Cavity full of Water; That were it poſſible, yet it does not appear of what uſe ſuch an inward Sphere can be of, being ſhut up in Eternal Darkneſs, and therefore unfit for the Production of Animals or Plants; with many more Objections, according to the Fate of all ſuch new Propoſitions.

To theſe, and all other that I can foreſee, I briefly Anſwer, That the Ring environing the Globe of *Saturn* is a notable Inſtance of this kind, as having the ſame common Center, and moving along with the Planet, without ſenſibly approaching him on one ſide more than the other. And if this Ring were turn'd on one of its Diameters, it would then deſcribe ſuch a Concave Sphere as I ſuppoſe our External one to be. And ſince the Ring, in any Poſition given, would, in the ſame manner, keep the Centre of *Saturn* in its own, it follows, that ſuch a Concave Sphere may move with another included in it, having the ſame common Centre. Nor can it well be ſuppos'd otherwiſe, conſidering the Nature of Gravity; for ſhould theſe Globes be adjuſted once to the ſame common Centre, the Gravity of the parts of the Concave would preſs equally towards the Centre of the inner Ball, which equality muſt neceſsarily continue till some External Force disturb it, which is not easie to imagine in our Case. This perhaps I might more intelligibly express, by saying that the inner Globe being posited in the Centre of the Exteriour, must necessarily ascend which way soever it move; that is, it must overcome the force of Gravity pressing towards the common Centre, by an impulse it must receive from some outward Agent; but all outward Efforts being sufficiently fenc'd against by the Shell that surrounds it, it follows, that this *Nucleus* being once fixt in the common Centre, must always there remain.

As to the leaking of the Water through this Shell, when once a passage shall be found for it to run through, I must confess it is an Objection seemingly of weight; but when we consider how tightly great Beds of Chalk or Clay, and much more Stone do hold Water, and even Caves arch'd with Sand; no Man can doubt but the Wisdom of the Creator has provided for the Macrocosm by many more ways than I can either imagine or express, especially since we see the admirable and innumerable Contrivances wherewith each worthless Individual is furnish'd both to defend it self, and propagate its Species. What Curiosity in the Structure, what Accuracy in the Mixture and Composition of the parts, ought not we to expect in the Fabrick of this Globe, made to be the lasting Habitation of so many various Species of Animals, in each of which there want not many Instances that manifest the boundless Power and Goodness of their Divine Author; and can we then think it a hard Supposition, that the Internal Parts of this Bubble of Earth should be replete with such Saline and Vitriolick Particles as may contribute

tribute to Petrefaction, and diſpoſe the tranſuding Water to ſhoot and coagulate into Stone, ſo as continually to fortifie, and, if need were, to conſolidate any breach or flaw in the Concave Surface of the Shell.

And this perhaps may not without Reaſon be ſuppos'd to be the final Cauſe of the admixture of the Magnetical Matter in the Maſs of the Terreſtrial parts of our Globe, *viz.* To make good and maintain the Concave Arch of this Shell: For by what the Excellent Mr. *Newton* has ſhewn in his *Principia Philoſophiæ*, it will follow, that according to the general Principle of Gravity, viſible throughout the whole Univerſe, all thoſe Particles that by length of time, or otherwiſe, ſhall moulder away, or become looſe on the Concave Surface of the External Sphere, would fall in, and with great force deſcend on the Internal, unleſs thoſe Particles were of another ſort of Matter capable by their ſtronger tendency to each other, to ſuſpend the force of Gravity; but we know no other Subſtances capable of ſupporting each other by their mutual Attraction but the Magnetical, and theſe we ſee miraculouſly to perform that Office, even where the Power of Gravity has its full effect, much more within the Globe where it is weaker. Why then may we not ſuppoſe theſe ſaid Arches to be lin'd throughout with a Magnetical Matter, or rather to be one great Concave Magnet, whoſe two Poles are the Poles we have before obſerv'd to be fixt in the Surface of our Globe.

Another Argument, favouring this Hypotheſis, is drawn from a Propoſition of the ſame Mr. *Newton*, where he determines the force wherewith the *Moon* moves the *Sea* in produing the *Tides*: His Words are, *Densitas Lunæ est ad densitatem Terræ ut* 680 *ad* 387 *seu* 9 *ad* 5 *quamproximé. Est igitur corpus Lunæ densius ac magis terrestre quam Terra nostra*, p. 466. Now if the Moon be more solid than the Earth, as 9 to 5, why may we not reasonably suppose the Moon, being a small Body, and a secondary Planet, to be solid Earth, Water, Stone, and this Globe to consist of the same Materials, only four Ninths thereof to be Cavity, within and between the Internal Spheres; which I would render not improbable.

To those that shall enquire of what use these included Globes can be, it must be allow'd, that they can be of very little service to the Inhabitants of this outward World, nor can the Sun be serviceable to them, either with his Light or Heat. But since it is now taken for granted, that the Earth is one of the Planets, and they all are with Reason suppos'd Habitable, though we are not able to define by what sort of Animals; and since we see all the parts of the Creation abound with Animate Beings, as the Air with Birds and Flies, the Water with the numerous varieties of Fish, and the very Earth with Reptiles of so many sorts; all whose ways of Living would be to us incredible did not daily Experience teach us. Why then should we think it strange that the prodigious Mass of Matter, whereof this Globe does consist, should be capable of some other improvement than barely to serve to support its Surface? Why may not we rather suppose that the exceeding small quantity of solid Matter, in respect of the fluid Æther, is so dispos'd by the Almighty Wisdom, as to yield as great a Surface for the use of living Creatures, as can consist

ſiſt with the conveniency and ſecurity of the whole? We our ſelves, in Cities where we are preſſed for Room, commonly build many Stories one over the other, and thereby accommodate a much greater multitude of Inhabitants.

But ſtill it will be ſaid, That without Light there can be no no living, and therefore all this *apparatus* of our inward Globes muſt be uſeleſs: To this I Anſwer, That there are many ways of producing Light which we are wholly ignorant of; the Medium it ſelf may be always luminous after the manner of our *Ignes fatui.* The Concave Arches may in ſeveral places ſhine with ſuch a Subſtance as inveſts the Surface of the Sun; nor can we, without a boldneſs unbecoming a Philoſopher, adventure to aſſert the impoſſibility of peculiar Luminaries below, of which we have no ſort of *Idea.* I am ſure the Poets *Virgil* and *Claudian* have gone before me in this Thought, inlightning their *Elyſian Fields* with Sun and Stars proper to thoſe infernal, or rather internal Regions. *Virg. Æneid. 6.*

Largior hic compos Æther & lumine veſtit
Purpureo; Solemque ſuum ſua Sidera norunt.

And *Claudian* lib 2. *De Raptu Proſerpinæ.*

Amiſſum ne crede diem, ſunt altera nobis
Sidera, ſunt orbes alii, luménque videbis
Purius, Elyſiumque magis mirabere Solem.

And though this be not to be eſteem'd as an Argument, yet I may take the liberty I ſee others do, to quote the Poets when it makes for my purpoſe.

Laſtly,

Laſtly, To explain yet farther what I mean, I have adventur'd to adjoin the following Scheme, (*Tab.* 1. *Fig.* 3) wherein the Earth is repreſented by the outward Circle, and the three inward Circles are made nearly proportionable to the Magnitudes of the Planets *Venus*, *Mars* and *Mercury*, all which may be included within the Globe of Earth, and all the Arches more than ſufficiently ſtrong to bear their weight. The Concave of each Arch, which is ſhaded differently from the reſt, I ſuppoſe to be made up of Magnetical Matter; and the whole to turn about the ſame common Axis *p*, *p*, only with this difference, that the Outer Sphere ſtill moves ſomewhat faſter than the Inner. Thus the Diameter of the Earth being about eight thouſand *Engliſh* Miles, I allow five hundred Miles for the thickneſs of its Shell, and another ſpace of five hundred Miles for a Medium between, capable of an immenſe Atmoſphere for the uſe of the Globe of *Venus*: *Venus* again I give a Shell of the ſame thickneſs, and leave as great a ſpace between her Concave and *Mars*; ſo likewiſe from *Mars* to *Mercury*, which latter Ball we will ſuppoſe ſolid, and about two thouſand Miles Diameter. Thus I have ſhew'd a poſſibility of a much more ample Creation, than has hitherto been imagin'd; and if this ſeem ſtrange to thoſe that are unacquainted with the Magnetical Syſtem, it is hop'd that all ſuch will endeavour, firſt, to inform themſelves of the Matter of Fact, and then try if they can find out a more ſimple Hypotheſis, at leaſt a leſs abſurd, even in their own Opinions. And whereas I have adventur'd to make theſe Subterraneous Orbs capable of being Inhabited, 'twas done deſignedly for the ſake of thoſe who will be apt

to

to ask *cui bono*, and with whom Arguments drawn from *Final Causes* prevail much. If this ſhort Eſſay ſhall find a kind Acceptance, I ſhall be encourag'd to enquire farther, and to Poliſh this rough Draft of a Notion till hitherto not ſo much as ſtarted in the World, and of which we could have no Intimation from any other of the *Phæno-mena* of Nature.

Since this was written, a Diſcovery I have made in the Cœleſtial Motions, ſeems to render a farther Account of the Uſe of the Cavity of the Earth, *viz.* To diminiſh the Specifick Gravity thereof, in reſpect of the Moon; for I think I can demonſtrate that the Oppoſition of the Æther to the Motions of the Planets in long time becomes ſenſible; and conſequently the greater Body muſt receive a leſs Oppoſition than the ſmaller, unleſs the Specifick Gravity of the ſmaller do proportionably exceed that of the greater, in which caſe only they can move together; ſo that the Cavity I aſſign in the Earth, may well ſerve to adjuſt its weight to that of the Moon, for otherwiſe the Earth would leave the Moon behind it, and ſhe become another Primary Planet.

An

An Hiſtorical Account of the Trade Winds *and* Monſoons, *obſervable in the Seas between and near the* Tropicks, *with an attempt to aſſign the Phyſical Cauſe of the ſaid Winds, by Mr.* Ed. Halley.

AN exact Relation of the conſtant and periodical Winds, obſervable in ſeveral Tracts of the Ocean, is a part of Natural Hiſtory not leſs deſireable and uſeful, than it is difficult to obtain, and its *Phænomena* hard to explicate: I am not ignorant that ſeveral Writers have undertaken this Subject, and although *Varenius* (*Lib.* 1. *Chap.* 21. *Geo. Gen.*) ſeems to have endeavour'd after the beſt information from *Voyagers*, yet cannot his Accounts be admitted for accurate, by thoſe that ſhall attentively conſider and compare them together, and ſome of them are moſt evident Miſtakes; which, as near as I can, I ſhall attempt to rectify, having had the opportunity of converſing with Navigators, acquainted with all parts of *India*, and having liv'd a conſiderable time between the *Tropicks*, and there made my own Remarks.

The Subſtance of what I have collected is briefly as follows.

The Univerſal *Ocean* may moſt properly be divided into three Parts, *viz.* 1. The *Atlantick* and *Æthiopick-Sea.* 2. The *Indian Ocean.*

3. The

3. The Great *South Sea*, or the *Pacifick Ocean*; and though theſe Seas do all communicate by the South, yet as to our preſent purpoſe of the *Trade Winds*, they are ſufficiently ſeparated by the interpoſition of great Tracts of *Land*; the firſt lying between *Africa* and *America*, the ſecond between *Africa* and the *Indian Iſlands*, and *Hollandia Nova*; and the laſt between the *Phillipine Iſles*, *China*, *Japan* and *Hollandia Nova* on the *Weſt*, and the Coaſt of *America* on the *Eaſt*. Now following this natural diviſion of the Seas, ſo will we divide our Hiſtory into three parts in the ſame order.

I. In the *Atlantick* and *Æthiopick* Seas between the *Tropicks*, there is a general *Eaſterly Wind* all the Year long, without any conſiderable Variation, excepting that it is ſubject to be deflected therefrom, ſome few Points of the Compaſs towards the *North* or *South*, according to the Poſition of the place. The Obſervations which have been made of theſe Deflections, are the following.

1. That near the Coaſt of *Africa*, as ſoon as you have paſs'd the *Canary Iſles*, you are ſure to meet a freſh Gale of *North Eaſt* Wind, about the Latitude of 28 Degrees *North*, which ſeldom comes to the *Eaſtwards* of the *Eaſt North-Eaſt*, or paſſes the *North North-Eaſt*. This Wind accompanies thoſe bound to the Southward, to the Latitude of ten North, and about a hundred Leagues from the *Guinea* Coaſt, where, till the fourth Degree of North Latitude, they fall into the Calms and Tornadoes; of which more hereafter.

2. That

2. That thoſe bound to the *Caribbee Iſles*, find, as they approach the *American* ſide, that the aforeſaid *North-Eaſt* Wind becomes ſtill more and more Eaſterly, ſo as ſometimes to be *Eaſt*, ſometimes *Eaſt* by *South*, but yet moſt commonly to the *Northward* of the *Eaſt* a Point or two, ſeldom more. 'Tis likewiſe obſerv'd, that the ſtrength of theſe Winds does gradually decreaſe, as you ſail to the *Weſtwards*.

3. That the limits of the Trade and variable Winds, in this Ocean, are farther extended on the *American* ſide than the *African*; for whereas you meet not with this certain Wind till after you have paſs'd the Latitude of twenty eight Degrees on this ſide; on the *American* ſide it commonly holds to thirty, thirty one, or thirty two Degrees of Latitude; and this is verified likewiſe to the Southwards of the Æquinoctial, for near the *Cape* of *Good-Hope* the limits of the Trade Winds, are three or four Degrees nearer the Line, than on the Coaſt of *Brazile*.

4. That from the Latitude of four Degrees *North*, to the aforeſaid Limits on the *South* of the Æquator, the Winds are generally and perpetually between the *South* and *Eaſt*, and moſt commonly between the *South-Eaſt* and *Eaſt*, obſerving always this Rule, That on the *African* ſide they are more *Southerly*, on the *Brazilian* more *Eaſterly*, ſo as to become almoſt due *Eaſt*, the little deflection they have being ſtill to the *Southwards*. In this part of the Ocean it has been my fortune to paſs a full Year, in an Employment that oblig'd me to regard more than ordinary the Weather, and I found the Winds conſtantly about the *South-Eaſt*, the moſt uſual Point *S E b E*; when it

was

was Easterly, it generally blew hard, and was gloomy, dark, and sometimes rainy Weather; if it came to the Southwards it was generally Serene, and a small Gale next to a Calm, but this not very common. But I never saw it to the Westwards of the South, or Northwards of the East.

5. That the Season of the Year has some small effect on these Trade Winds, for that when the Sun is considerable to the Northwards of the Æquator, the South-East Winds, especially in the Straight of this Ocean (if I may so call it) between *Brazile* and the Coast of *Guinea*, do vary a Point or two to the Southwards, and the North-East become more Easterly; and on the contrary, when the Sun is towards the Tropick of *Capricorn* the South-Easterly Winds become more Easterly, and the North-Easterly Winds on this side the Line veere more to the Northwards.

6. That as there is no general Rule that admits not of some Exception, so there is in this Ocean a Tract of Sea wherein the Southerly and South-West Winds are perpetual, *viz.* all along the Coast of *Guinea*, for above five hundred Leagues together, from *Sierra Leona* to the Isle of St. *Thomas*; for the South-East Trade Wind having pass'd the Line, and approaching the Coast of *Guinea* within eighty or 100 Leagues, inclines towards the Shore, and becomes S. S. E. and by Degrees, as you come nearer, it veeres about to South, S. S. W. and in with the Land South-West, and sometimes West South-West; which Variation is better express'd in the Mapp hereto annexed, (*Vide Plate* 2.) than it can well be in Words. These are the Winds which are observ'd on this Coast when it

blows

blows true, but there are frequent Calms, violent ſudden Guſts call'd *Tornado's*, from all Points of the Compaſs, and ſometimes unwholſome foggy Eaſterly Winds, call'd *Hermitaa* by the Natives, which too often infeſt the Navigation of theſe parts.

7. That to the Northwards of the Line, between four and ten Degrees of Latitude, and between the Meridians of *Cape Virde*, and of the Eaſtermoſt Iſlands that bear that Name, there is a Tract of Sea wherein it were improper to ſay there is any Trade Wind, or yet a Variable; for it ſeems condemn'd to perpetual Calms, attended with terrible Thunder and Lightning, and Rains ſo frequent, that our Navigators from thence call this part of the Sea the *Rains*; the little Winds that are, be only ſome ſudden uncertain Guſts, of very little Continuance and leſs Extent; ſo that ſometimes each Hour you ſhall have a different Gale, which dies away into a Calm before another ſucceed, and in a Fleet of Ships in ſight of one another, each ſhall have the Wind from a ſeveral Point of the Compaſs; with theſe weak *Breezes* Ships are oblig'd to make the beſt of their way to the Southward through the aforeſaid ſix Degrees, wherein 'tis reported ſome have been detain'd whole Months for want of Wind.

From the three laſt Obſervables is ſhewn the Reaſon of two notable Occurents in the *Eaſt-India* and *Guinea* Navigations: The one is, why, notwithſtanding the narroweſt part of the Sea between *Guinea* and *Brazile* be aboot five hundred Leagues over, yet Ships bound to the Southward, ſometimes, eſpecially in the Months of *July* and *Auguſt*, find a great difficulty to paſs it. This happens becauſe of the South-

East Winds, at that time of the Year commonly extending some Degrees beyond the ordinary limit of four Degrees North Latitude, and withal they come so much Southerly, as to be sometimes South, sometimes a Point or two to the West; there remains then only to ply to Windward, and if on the one side they stand away W. S. W. they gain the Wind still more and more Easterly; but there is danger of not weathering the *Brazilian* Shoar, or at least the Shoals upon that Coast. But if upon the other Tack they go away E. S. E. they fall into the Neighbourhood of the Coast of *Guinea*, from which there is no departing without running Easterly, as far as the Isle of St. *Thomas*, which is the constant practice of all the *Guinea* Ships, and which may seem very strange, without the consideration of the sixth Remark, which shews the Reason of it: For being in with the Coast, the Wind blows generally at S. W. and W. S. W. with which Winds they cannot go to the Northward for the Land; and on the other Tack they can lie no nearer the Wind than S. S. E. or South; with these Courses they run off the Shoar, but in so doing they always find the Winds more and more contrary; so that when near the Shoar they could lie South, at a greater distance they can make their way no better than S. E. and afterwards E. S. E. with which Courses they fetch commonly the Isle of St. *Thomas* and Cape *Lopez*, where finding the Winds to the Eastward of the South, they keep them favourable, by running away to the Westward in the South Latitude, of three or four Degrees, where the S. E. Winds are perpetual.

For the sake of these general Winds, all those that use the *West-Indian* Trade, even those

bound

bound to *Virginia*, count it their beſt Courſe to get as ſoon as they can to the Southwards, that ſo they may be certain of a fair and freſh Gale to run before it to the Weſtwards; and for the ſame Reaſon thoſe homewards bound from *America*, endeavour to gain the Latitude of thirty Degrees, as ſoon as poſſible, where they firſt find the Winds begin to be variable; tho' the moſt ordinary Winds in the Northern part of the *Atlantick* Ocean come from between the South and Weſt.

As to thoſe furious Storms call'd *Hurricanes*, which are, as it were, peculiar to the *Caribbee* Iſles; and which ſo dreadfully afflict them in the Month of *Auguſt*, or not much before or after, they do not ſo properly belong to this place, both by Reaſon of their ſmall continuance and extent, as likewiſe becauſe they are not Anniverſary, ſome Years having more than one, and ſometimes for ſeveral Years together there being none at all. But their Violence is ſo unconceivable, and their other *Phænomena* ſo ſurpriſing, that they merit well to be conſider'd apart.

What is here ſaid, is to be underſtood of the Sea Winds at ſome diſtance from the Land; for upon and near the Shoars, the Land and Sea Breezes are almoſt every where ſenſible; and the great Variety which happens in their Periods, Force and Direction, from the ſituation of the Mountains, Vallies and Woods, and from the various Texture of the Soil, more or leſs capable of retaining and reflecting Heat, and of exhaling or condenſing Vapours, is ſuch, that it were an endleſs task, to endeavour to account for them.

II. In the *Indian* Ocean, the Winds are partly general, as in the *Æthiopick* Ocean, partly Periodical; that is, half the Year they blow one way, and the other half near upon the opposite Points; and these Points and Times of shifting are different in different parts of this Ocean; the limits of each Tract of Sea, subject to the same Change or *Monsoon*, are certainly very hard to determine, but the diligence I have used to be rightly inform'd, and the care I have taken therein, has, in a great measure, surmounted that Difficulty; and I am perswaded that the following Particulars may be relied upon.

1. That between the Latitudes of ten Degrees and thirty Degrees South, between *Madagascar* and *Hollandia Nova*, the general Trade Wind about the S. E. by E. is found to blow all the Year long, to all Intents and Purposes after the same manner as in the same Latitudes in the *Æthiopick* Ocean, as it is describ'd in the fourth *Remark* aforegoing.

2. That the aforesaid S. E. Winds extend to within two Degrees of the *Æquator*, during the Months of *June*, *July*, *August*, &c. to *November*, at which time between the *South Latitudes* of three and ten Degrees, being near the Meridian of the North end of *Madagascar*, and between two and twelve South Latitude, being near *Sumatra* and *Java*, the contrary Winds from the N. W. or between the North and West, set in and blow for half the Year, *viz.* from the beginning of *December* till *May*; and this *Monsoon* is observ'd as far as the *Molucca* Isles, of which more anon.

3. That

3. That to the Northward of three Degrees South Latitude, over the whole *Arabian* or *Indian-Sea* and Gulph of *Bengall*, from *Sumatra* to the Coast of *Africa*, there is another *Monsoon*, blowing from *October* to *April* upon the North East Points; but in the other half Year, from *April* to *October*, upon the opposite Points of S. W. and W. S. W. and that with rather more force than the other, accompanied with dark rainy Weather, whereas the N. E. blows clear; 'tis likewise to be noted, that the Winds are not so constant, either in strength or point in the Gulph of *Bengall*, as they are in the *Indian-Sea*, where a certain and steady Gale scarce ever fails. 'Tis also remarkable, that the S. W. Winds in these Seas are generally more Southerly on the *African* side, more Westerly on the *Indian*.

4. That as an *Appendix* to the last describ'd *Monsoon*, there is a Tract of Sea to the Southwards of the Æquator, subject to the same Changes of the Winds, *viz.* near the *African*-Coast, between it and the Island *Madagascar* or St. *Lawrence*, and from thence Northwards as far as the Line; wherein from *April* to *October* there is found a constant fresh S. S. W. Wind, which, as you go more Northerly, becomes still more and more Westerly, so as to fall in with the W. S. W. Winds, mention'd before, in those Months of the Year to be certain to the Northward of the Æquator: What Winds blow in these Seas, for the other half Year, from *October* to *April*, I have not yet been able to obtain to my full satisfaction, for that our Navigators always return from *India* without *Madagascar*, and so are little acquainted in this Matter; the Account that has been given me is

 only

only this, that the Winds are much Eaſterly hereabouts, and as often to the North of the true Eaſt as to the Southwards thereof.

5. That to the Eaſtward of *Sumatra* and *Malacca*, to the Northwards of the Line, and along the Coaſt of *Camboia* and *China*, the *Monſoons* blow North and South, that is to ſay, the N. E. Winds are much Northerly, and the S. W. much Southerly: This Conſtitution reaches to the Eaſtwards of the *Philippine* Iſles, and as far Northerly as *Japan*. The Northern *Monſoon* ſetting in, in theſe Seas, in *October* or *November*, and the Southern in *May*, blowing all the Summer Months: Here it is to be noted, That the Points of the Compaſs, from whence the Wind comes in theſe Parts of the World, are not ſo fixt as in thoſe lately deſcrib'd; for the Southerly will frequently paſs a Point or two to the Eaſtwards of the South, and the Northerly as much to the Weſtwards of the North, which ſeems occaſion'd by the great quantity of Land, which is interſpers'd in theſe Seas.

6. That in the ſame *Meridians*, but to the Southwards of the Æquator, being that Tract lying between *Sumatra* and *Java* to the Weſt, and *New Guinea* to the Eaſt, the ſame Northerly *Monſoons* are obſerv'd, but with this difference, that the inclination of the Northerly is towards the N. Weſt. and of the Southerly towards the S. E. but the *plagæ venti* are not more conſtant here than in ~~the~~ former, *viz*. variable five or ſix Points; beſides the times of the Change of theſe Winds, are not the ſame as in the *Chineſe* Seas, but about a Month or ſix Weeks later.

7. That

7. That theſe contrary Winds do not ſhift all at once, but in ſome places the time of the Change is attended with Calms, in others with variable Winds; and it is particularly remarkable, that the end of the Weſterly *Monſoon* on the Coaſt of *Coromandel*, and the two laſt Months of the Southerly *Monſoon* in the Seas of *China*, are very ſubject to be tempeſtuous: The violence of theſe Storms is ſuch, that they ſeem to be of the Nature of the *Weſt-India Hurricanes*, and render the Navigation of theſe parts very unſafe about that time of the Year. Theſe Tempeſts are by our Seamen uſually term'd, *The breaking up of the Monſoons*.

By reaſon of the ſhifting of theſe Winds, all thoſe that ſail in theſe Seas, are oblig'd to obſerve the Seaſons proper for their Voyages, and ſo doing they fail not of a fair Wind and ſpeedy Paſſage; but if ſo be they chance to out-ſtay their time, till the contrary *Monſoon* ſets in, as it frequently happens, they are forc'd to give over the hopes of accompliſhing their intended Voyages, and either return to the Port from whence they came, or elſe put in to ſome other Habour, there to ſpend the time till the Winds ſhall come favourable.

III. The third Ocean call'd *Mare Pacificum*, whoſe Extent is equal to that of the other two (it being from the Weſt Coaſt of *America* to the *Philippine* Iſlands, not leſs than 150 Degrees of Longitude) is that which is leaſt known to our own or the Neighbour Nations; that Navigation that there is on it, is by the *Spaniards*, who go Yearly from the Coaſt of *New Spain* to the *Manilha's*, but that but by one beaten track; ſo that I cannot be ſo particular here as in the other two. What the *Spanish* Authors say of the Winds they find in their Courses, and what is confirm'd by the old Accounts of *Drake* and *Candish*, and since by *Schooten*, who sail'd the whole breadth of this Sea in the Southern Latitude of fifteen or sixteen Degrees, is, that there is a great conformity between the Winds of this Sea, and those of the *Atlantick* and *Æthiopick*; that is to say, that to the Northwards of the Æquator, the predominant Wind is between the East and North-East, and to the Southwards thereof there is a constant steady Gale between the East and South-East, and that on both sides the Line with so much constancy, that they scarce ever need to attend the Sails, and Strength, that it is rare to fail of crossing this vast Ocean in ten Weeks time, which is about 130 Miles *per diem*; besides, 'tis said that Storms and Tempests are never known in these parts: So that here is the very best of Sailing; no want of a fresh fair Wind, and yet no danger of having too much: Wherefore some have thought it might be as short a Voyage to *Japan* and *China*, to go by the Streights of *Magellan*, as by the *Cape* of *Good Hope*.

The Limits of these general Winds are also much the same as in the *Atlantick* Sea, *viz.* about the thirtieth Degree of Latitude on both sides; for the *Spaniards* homewards bound from the *Manilha's*, always take the advantage of the Southerly *Monsoon*, blowing there in the Summer Months, and run up to the Northwards of that Latitude, as high as *Japan*, before they meet with variable Winds, to shape their Course to the Eastwards. And *Schooten* and others that have gone about by the *Magellan* Streights, have found the Limits of S. E. Winds,

Winds, much about the ſame Latitude to the Southwards; beſides a farther *Analogy* between the Winds of this Ocean, and the *Æthiopick*, appears in that, upon the Coaſt of *Peru*, they are always much Southerly, like as they are found near the Shoars of *Angola*.

Thus far Matter of Fact, wherein if the information I have receiv'd be not in all parts Accurate, it has not been for want of inquiry from thoſe I conceiv'd beſt able to inſtruct me; and I ſhall take it for a very great Kindneſs if any Maſter of a Ship, or other Perſon, well inform'd of the Nature of the Winds, in any of the aforemention'd parts of the World, ſhall pleaſe to communicate their Obſervations thereupon; ſo that what I have here Collected may be either confirm'd or amended, or by the addition of ſome material Circumſtances enlarg'd. It is not the work of one, nor of few, but of a multitude of Obſervers, to bring together the Experience requiſite to compoſe a perfect and compleat Hiſtory of theſe Winds; however I am not much doubtful that I have err'd in, or omitted any of the principal Obſervables, whatever leſſer Particulars may have eſcaped my Knowledge.

To help the Conception of the Reader in a manner of ſo much difficulty, I believ'd it neceſſary to adjoin a Scheme, *(Plate 2.)* ſhewing at one view all the various Tracts and Courſes of theſe Winds; whereby 'tis poſſible the thing may be better underſtood, than by any verbal Deſcription whatſoever.

The Limits of theſe ſeveral Tracts are deſign'd every where by prickt Lines, as well in the *Atlantick* and *Æthiopick*, where they are the boundaries of the Trade and variable Winds, as in the *Indian* Ocean, where they also shew the Extent of the several *Monsoons.* I could think of no better way to design the Course of the Winds on the Map, than by drawing rows of stroaks in the same Line that a Ship would move going always before it; the sharp end of each little stroak pointing out that part of the Horizon, from whence the Wind continually comes; and where there are *Monsoons*, the rows of the stroaks run alternately backwards and forwards, by which means they are thicker there than elsewhere. As to the great South Sea, considering its vast Extent, and the little Variety there is in its Winds, and the great *Analogy* between them, and those of the *Atlantick* and *Æthiopick* Oceans; besides, that the greatest part thereof is wholly unknown to us; I thought it unnecessary to lengthen the Map therewith.

In the foregoing History are contained several Problems, that merit well the Consideration of our acutest Naturalists, both by reason of the constancy of the Effect, and of the immense Extent thereof; near half the Surface of the Globe being concerned. The chief of these Problems are, 1. Why these Winds are perpetually from the East in the *Atlantick* and *Æthiopick*, as likewise in the *Pacifick* Ocean, between the Latitudes of 30 North and South? 2. Why the said Winds extend no farther with constancy than to the Latitude of 30 Degrees? 3. Why there should be a constant South-westerly Wind upon and near the Coast of *Guinea*? 4. Why in the North part of the *Indian* Ocean, the Winds, which for one half Year do agree with those of the other two Oceans, should change in the other half Year, and blow from the opposite Points;

Points; whilſt the Southern part of that Ocean follows the General Rule, and has perpetual Winds about S. E? 5. Why in theſe General Trade-Winds it ſhould be always true, that to the Northward of the *Æquator* it is inclin'd to the Northwards of the Eaſt; and in South Latitudes, to the Southward thereof? 6. Why in theſe Seas of *China* there ſhould be ſo great an Inclination from the Eaſt to the North, more than elſewhere? with many more, which it would be much eaſier to propoſe than anſwer.

But leſt I ſhould ſeem to propoſe to others, Difficulties which I have not thought worth my own Time and Pains, take here the reſult of an earneſt Endeavour after the true reaſon of the aforeſaid *Phænomena*; wherein if I am not able to account for all Particulars, yet 'tis hoped the Thoughts I have ſpent thereon, will not be judged wholly loſt, by the Curious in Natural Enquiries.

Wind is moſt properly defined to be the Stream or Current of the Air, and where ſuch a Current is perpetual and fixt in its Courſe, 'tis neceſſary that it proceed from a permanent unintermitting Cauſe. Wherefore ſome have been inclin'd to propoſe the diurnal *Rotation* of the Earth upon its *Axis*, by which, as the *Globe* turns Eaſtwards, the looſe and *fluid* Particles of the Air, being ſo exceeding light as they be, are left behind, ſo that in reſpect of the Earths *Surface* they move Weſtwards, and become a conſtant Eaſterly Wind. This Opinion ſeems confirm'd, for that theſe Winds are found only near the *Æquinoctial*, in thoſe Parallels of Latitude where the diurnal Motion is ſwifteſt; and I ſhould readily aſſent to it, if the conſtant Calms in the *Atlantick* Sea, near the *Æquator*, the Weſterly Winds near the Coaſt of *Guinea*; and the *Periodical* Weſterly *Monſoons* under the *Æquator* in the *Indian* Seas, did not declare the inſuffiency of that *Hypotheſis*. Beſides the Air being kept to the Earth by the Principle of *Gravity*, would acquire the ſame degree of *Velocity* that the Earths *Surface* moves with, as well in reſpect of the diurnal *Rotation*, as of the Annual about the Sun, which is about thirty times ſwifter.

It remains therefore to ſubſtitute ſome other Cauſe, capable of producing a like conſtant Effect, not liable to the ſame Objections, but agreeable to the known Properties of the Elements of Air and Water, and the Laws of the Motion of fluid Bodies. Such an one is, I conceive, the Action of the Sun Beams upon the Air and Water, as he paſſes every Day over the Oceans, conſider'd together with the Nature of the Soil, and Situation of the adjoining Continents: I ſay therefore, firſt, that according to the Laws of *Staticks*, the Air which is leſs rarified or expanded by heat, and conſequently more ponderous, muſt have a Motion towards thoſe parts thereof, which are more rarified, and leſs ponderous, to bring it to an *Æquilibrium*; and ſecondly, That the Preſence of the Sun continually ſhifting to the Weſtwards, that part towards which the Air tends, by reaſon of the Rarifaction 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.

Thus a general Eaſterly Wind is formed, which being impreſſed upon all the Air of a vaſt Ocean, the Parts impel one the other, and ſo keep moving till the next return of the Sun, whereby

whereby ſo much of the Motion as was loſt, is again reſtored, and thus the Weſterly Wind is made perpetual.

From the ſame Principle it follows, that this Eaſterly Wind ſhould on the North ſide of the *Æquator*, be to the Northwards of the Eaſt, and in South Latitudes to the Southwards thereof; for near the *Line*, the Air is much more rarified, than at a greater diſtance from it; becauſe of the Sun twice in a Year Vertical, and at no time diſtant above 23 Degr. and a half; at which diſtance the Heat, being as the Sine of the Angle of Incidence, is but little ſhort of that of the perpendicular Ray. VVhereas under the Tropicks, though the Sun ſtay long Vertical, yet he is as long 47 Degr. off; which is a kind of Winter, wherein the Air ſo cools, as that the Summer-heat cannot warm it to the ſame degree with that under the Æquator. Wherefore the Air to the Northwards and Southwards, being leſs rarified than that in the middle, it follows, that from both ſides it ought to tend towards the Æquator: This Motion compounded with the former Eaſterly Wind, anſwers all the *Phænomena* of the general Trade-winds; which, if the whole Surface of the Globe were Sea, would undoubtedly blow all round the World, as they are found to do in the *Atlantick* and *Æthiopick* Oceans.

But ſeeing that ſo great Continents do interpoſe, and break the continuity of the Oceans, regard muſt be had to the Nature of the Soil, and the Poſition of the high Mountains, which I ſuppoſe the two principal Cauſes of the ſeveral Variations of the Winds, from the former general Rule: For if a Country lying near the Sun, prove to be flat, ſandy, low Land, ſuch

as

as the Deſarts of *Lybia* are uſually reported to be, the Heat occaſion'd by the Reflection of the Suns Beams, and the retention thereof in the Sand, is incredible to thoſe that have not felt it; whereby the Air being exceedingly rarified, it is neceſſary that the cooler and more denſe Air ſhoud run thitherwards to reſtore the *Æquilibrium*: This I take to be the cauſe, why near the Coaſt of *Guinea* the Wind always ſets in upon the Land, blowing Weſterly inſtead of Eaſterly, there being ſufficient Reaſon to believe, that the Inland Parts of *Africa* are prodigiouſly hot, ſince the Northern Borders thereof were ſo intemperate, as to give the Ancients cauſe to conclude, that all beyond the *Tropick* was made uninhabitable by exceſs of Heat: From the ſame Cauſe it happens, that there are ſo conſtant Calms in that part of the Ocean, called the *Rains*, (deſcribed in the 7th Remark on the *Atlantick* Sea) for this Tract being placed in the middle, between the Weſterly Winds blowing on the Coaſt of *Guinea*, and the Eaſterly Trade-winds, blowing to the Weſtwards thereof, the tendency of the Air here, is indifferent to either, and ſo ſtands in *Æquilibrio* between both; and the weight of the incumbent Atmoſphere being diminiſhed by the continual contrary Winds blowing from hence, is the reaſon that the Air here holds not the copious Vapour it receives, but lets it fall into frequent Rains.

But as the cool and denſe Air, by reaſon of its greater Gravity, preſſes upon the hot and rarified, 'tis demonſtrative that this latter muſt aſcend in a continued Stream as faſt it rarifies; and that being aſcended, it muſt diſperſe it ſelf to preſerve the *Æquilibrium*: that is, by a contrary Current, the upper Air muſt move from thoſe Parts where the greateſt Heat is: So by a kind of Circulation, the

the North-East Trade-Wind below, will be attended with a South-Westerly above, and the South-Easterly with a North-West Wind above; that this is more than a bare Conjecture, the almost instantaneous Change of the Wind to the opposite Point, which is frequently found in passing the limits of the Trade-winds, seems to assure us; but that which above all confirms this *Hypothesis* is the *Phænomenon* of the *Monsoons*, by this means most easily solved, and without it hardly explicable.

Supposing therefore such a Circulation, as above, 'tis to be considered that to the Northward of the *Indian* Ocean there is every where Land within the usual limit of the Latitude of 30, *viz.* *Arabia*, *Persia*, *India*, *&c.* which for the same reason as the *Mediterranean* Parts of *Africa*, are subject to unsufferable Heats when the Sun is to the North, passing nearly Vertical; but yet are temperate enough when the Sun is removed towards the other *Tropick*; because of a ridge of Mountains at some distance within the Land, said to be frequently in Winter cover'd with Snow, over which the Air, as it passes, must needs be much chill'd. Hence it comes to pass, that the Air coming according to the general Rule, out of the N. E. in the *Indian* Seas, is sometimes hotter, sometimes colder, than that which by this Circulation is return'd out of the S. W. and by consequence, sometimes the under Current or Wind, is from the N. E. sometimes from the S. W.

That this has no other Cause, is clear from the times wherein these Winds set in, *viz.* in *April*, when the Sun begins to warm those Countries to the North, the S. W. *Monsoon* begins, and blows during the Heats till *October*; when the

Sun

Sun being retir'd, and all things growing cooler Northward, and the Heat increaſing to the South, the North-Eaſt Winds enter and blow all the Winter till *April* again. And it is undoubtedly from the ſame Principle that to the Southwards of the Æquator, in part of the *Indian* Ocean, the North-Weſt Winds ſucceed to the South-Eaſt, when the Sun draws near the *Tropick* of *Capricorn*; but I muſt confeſs, that in this latter occurs a difficulty, not well to be accounted for, which is, why this Change of the *Monſoons* ſhould be any more in this Ocean, than in the ſame Latitudes in the *Æthopick*, where there is nothing more certain than a S. E. Wind all the Year.

'Tis likewiſe very hard to conceive why the limits of the Trade-wind ſhould be fixt, about the thirtieth Degree of Latitude all round the Globe; and that they ſhould ſo ſeldom tranſgreſs or fall ſhort of thoſe bounds; as alſo that in the *Indian* Sea, only the Northern Part ſhould be ſubject to the changeable *Monſoons*, and in the Southern there be a conſtant S. E.

Theſe are Particulars that merit to be conſider'd more at large, and furniſh a ſufficient Subject for a juſt Volume, which will be a very commendable Task for ſuch, who being us'd to Philoſophick Contemplation, ſhall have leiſure to apply their ſerious Thoughts about it.

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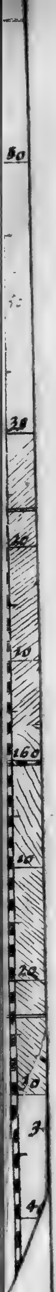
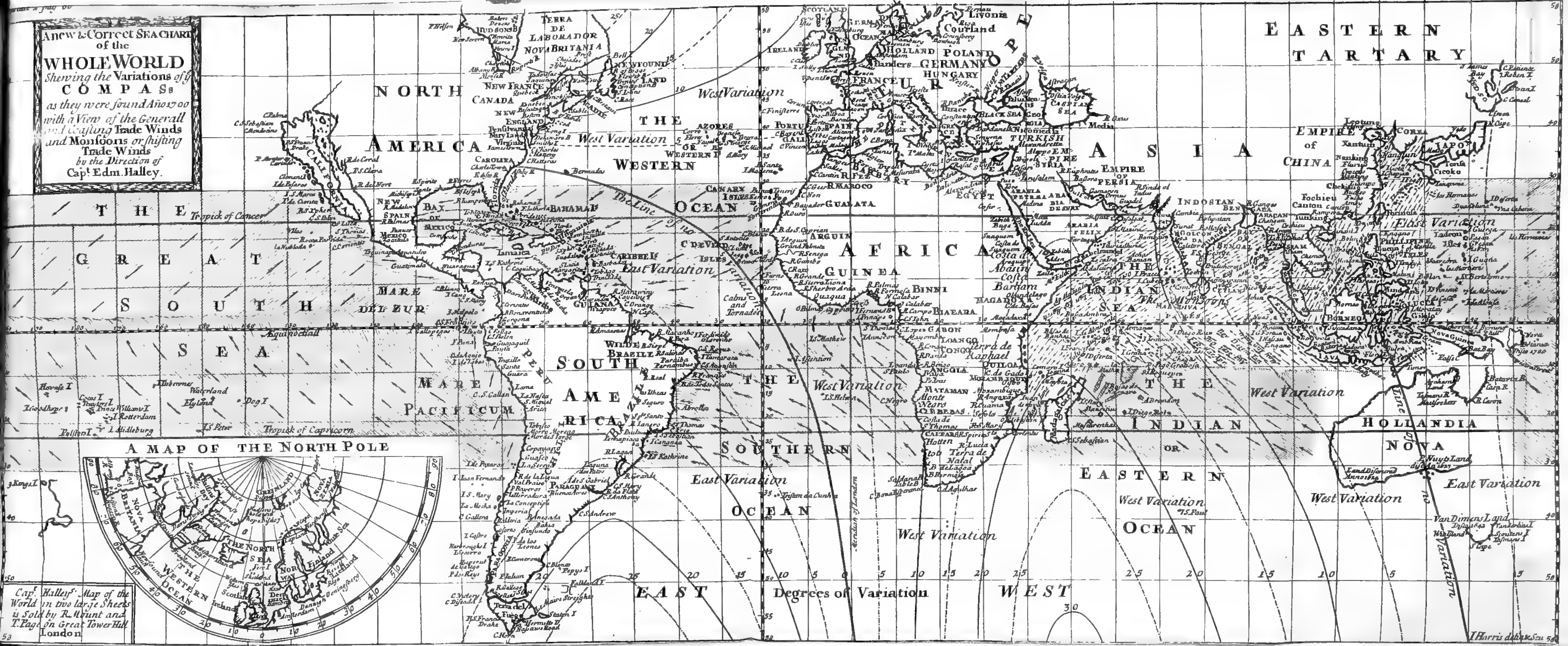



A new & Correct SEA CHART of the WHOLE WORLD Shewing the Variations of ye COMPASS as they were found Año 1700 with a View of the Generall and Coasting Trade Winds and Monsoons or shifting Trade Winds by the Direction of Capt. Edm. Halley
NORTH AMERICA
THE WESTERN OCEAN
EUROPE
ASIA
AFRICA
EASTERN TARTARY
EMPIRE of CHINA
EMPIRE OF PERSIA
TURKISH EMPIRE
THE GREAT SOUTH SEA
MARE DEL ZUR
MARE PACIFICUM
SOUTH AMERICA
THE SOUTHERN OCEAN
THE INDIAN SEA
THE INDIAN OR EASTERN OCEAN
HOLLANDIA NOVA
Tropick of Cancer
Equinoctiall
Tropick of Capricorn
West Variation
East Variation
The Line of no Variation
A MAP OF THE NORTH POLE
Degrees of Variation
EAST
WEST
Capt. Halley's Map of the World in two large Sheets is Sold by R. Mount and T. Page on Great Tower Hill London

A Diſcourſe of the Rule of the Decreaſe of the height of the Mercury *in the Barometer, according as Places are elevated above the Surface of the Earth; with an Attempt to diſcover the true Reaſon of the Riſing and Falling of the* Mercury, *upon Change of Weather. By* Edm. Halley.

THE Elaſtick Property of the Air has been long ſince made out, by Experiments before the *Royal Society*, and elſewhere; and the Reſiſtance of its Spring is found to be nearly equal to the Weight or Force that compreſſes it; as alſo, that the Spaces the ſame Air occupies, under differing Preſſures, are reciprocally as thoſe Preſſures: It has been ſhewn likewiſe by undoubted Experiment, that the ſpecifick Gravity of the Air, near the Earth's Surface to that of Water, was once as 1 to 840; again as 1 to 852; and a third time, in a very large Veſſel holding 10 Gallons, as 1 to 860; all which, conſidering the Difficulty of the Experiment, agree well enough, the Mercury ſtanding at all thoſe times about 29 Inches $\frac{3}{4}$: But by Reaſon 'twas Summer-weather, and conſequently the Air rarified, when all theſe were tried, we may without ſenſible Error ſay in round numbers, that the Barometer ſtanding at 30 Inches, and in a mean State of Heat and Cold, the ſpecifick Gravity of the Air to Water, is as 1 to 800. By the like Trials the weight of Mercury to Water, is as $13\frac{1}{2}$ to 1, or very near it; ſo that the weight of Mercury to Air, is as 10800 to 1; and a Cylinder of Air of 10800 Inches or 900 Feet, is equal to an Inch of Mercury; and were the Air of an equal denſity like Water, the whole Atmoſphere would be no more than 5, 1 Miles high, and in the Aſcent of every 900 Feet the Barometer would ſink an Inch. But the Expanſion of the Air increaſing in the ſame proportion as the incumbent weight of the Atmoſphere decreaſes; that is, as the Mercury in the Barometer ſinks; the upper Parts of the Air are much more rarified than the lower, and each Space anſwering to an Inch of Quickſilver, grows greater and greater; ſo that the Atmoſphere muſt be extended to a much greater height. Now, upon theſe Principles, to determine the height of the Mercury at any aſſigned height in the Air; and *è contra*, having the height of the *Mercury* given, to find the height of the Place where the Barometer ſtands, are Problems not more difficult than curious; and which I thus reſolve.

The Expanſions of the Air being reciprocally as the heights of the Mercury, it is evident, that by the help of the Curve of the *Hyperbola* and its *Aſymptotes*, the ſaid Expanſions may be expounded to any given height of the *Mercury*: For by the 65th *Prop. lib. 2. Conic. Mydorgii, the Rectangles, A B C E, A K G E, A L D E, &c.* (in *Plate* 1. *Fig.* 4.) are always equal, and conſequent-

ly

ly the ſides, *C B*, *G K*, *L D*, &c. are reciprocally as the ſides *A B*, *A K*, *A L*, &c. If then the Lines *A B*, *A K*, *A L*, be ſuppoſed equal to the heights of the *Mercury*, or the preſſures of the Atmoſphere, the Lines *C B*, *G K*, *L D*, anſwering thereto, will be as the Expanſions of the Air under thoſe Preſſures, or the Bulks that the ſame quantity of Air will occupy; which Expanſions being taken infinitely many, and infinitely little, (according to the Method of Indiviſibles) their Summ will give the Spaces of Air between the ſeveral heights of the *Barometer*; that is to ſay, the Summ of all the Lines between *C B* and *K G*, or the *Area C B K G*, will be proportioned to the Diſtance or Space intercepted between the Levels of two Places in the Air, where the *Mercury* would ſtand at the heights repreſented by the Lines *A B*, *A K*; ſo then the Spaces of Air anſwering to equal Parts of *Mercury* in the *Barometer*, are as the *Area's C B K G*, *G K L D*, *D L F M*, &c. Theſe *Area's* again are, by the Demonſtration of *Gregory* of St. *Vincent*, proportionate to the *Logarithms* of the Numbers expreſſing the *Rationes* of *A K* to *A B*, of *A L* to *A K*, of *A M* to *A L*, &c. So then by the common Table of *Logarithms*, the height of any Place in the *Atmoſphere*, having any aſſign'd height of the *Mercury*, may moſt eaſily be found: For the Line *C B* in the *Hyperbola*, whereof the *Area's* deſign the *Tabular Logarithms*, being 0,0144765; 'twill be, as 0, 0144765, to the difference of the *Logarithms* of 30, or any other leſſer Number, for 900 Feet, or the Space anſwering to an Inch of *Mercury*, if the Air were equally preſt with 30 Inches of *Mercury*, and every where alike, to the height of the *Barometer* in the Air, where it will ſtand at that leſſer number of Inches: And by the Converſe of this Proportion may the height of the *Mercury* be found, having the Altitude of the Place given. From theſe Rules I deriv'd the following Tables.

A Table ſhewing the Altitude, to given heights of the Mercury.

Inch.		Feet.
30		0
29		915
28		1862
27		2844
26		3863
25		4922
20		10947
15		18715
10		29662
5		48378
1		91831
0. 5		110547
0. 25		129262
0. 1	29 mil. or	154000
0. 01	41 m. or	216169
0. 001	53 m.	278338

A Table ſhewing the heights of the Mercury, *at given Altitudes.*

Feet.		Inch.	
0		30	00
1000		28	91
2000		27	86
3000		26	85
4000		35	87
5000	feet	24	93
1	mile	24	67
2		20	29
3		16	68
4		13	72
5		11	28
10		4	24
15		1	60
20		0	95
25		0	23
30		0	08
40		0	012

Upon

UPON these Suppositions it appears, that at the height of 41 Miles the Air is so rarified, as to take up 3000 times the Space it occupies here, and at 53 Miles high it would be expanded above 30000 times; but it's probable that the utmost Power of its Spring cannot exert it self, to so great an Extension, and that no part of the *Atmosphere* reaches above 45 Miles from the Surface of the Earth.

This seems confirm'd from the Observations of the *Crepusculum*, which is observ'd commonly to begin and end when the Sun is about 18 Degrees below the Horizon; for suppoing the Air to reflect light from its most rarified Parts, and that as long as the Sun illuminates any of its *Atoms*, they are visible to an Eye not intercepted by the Curvity of the Earth, it will follow from *Fig.* 5. *Plate* 1. that the proportion of the height of the whole Air, to the Semi-diameter of the Earth, is much about, as 1 to 90, or as the excess of the *Secant* of about 8½ Degrees to the *Radius*. For if *E* be the Eye of the Observer, *S* a Place where the Sun sets at the end of Twilight in *E*, and the Arch *E C S*, or *T C A*, be found 18 Degrees, the excess of the *Secant* of half thereof *E C H*, would be the height of the Air, *viz.* *G H*: But the Beam of the Sun *A S H*, and the Visual Ray *E H*, do each of them suffer a Refraction of about 32 or 33 Minutes, whereby being bent inwards from *H* towards *G*, the height of the Air need not be so great as if they went streight; and having from the Angle *E C S* taken the double Refraction of the *Horizontal Ray*, the half of the Remainder will be 8½ Degrees *circiter*, whose *Secant* being 10, 111, it follows, that as 10000 to 111, so the Semi-diamter of the Earth supposed 4000 Miles, to 44,4 Miles; which will be the height of the whole Air, if the Places *E*, *S*, whose visible Portions of the *Atmosphere* *E R Z H*, and *S H K B*, just touch one the other, be 18 Degrees asunder.

At this height the Air is expanded into above 3000 times the space it occupies here, and we have seen the Experience of condensing it into the 60th part of the same Space; so that it should seem, that the Air is a Substance capable of being compressed into the 180000th part of the Space it would naturally take up, when free from pressure. Now what Texture or Composition of Parts shall be capable of this great Expansion and Contraction, seems a very hard Question; and which, I suppose, is scarce sufficiently accounted for, by comparing it to Wool, Cotten, and the like springy Bodies.

Hitherto I have only consider'd the *Air* and *Atmosphere*, as one unalter'd Body, as having constantly at the Earth's Surface the 800th part of the weight of Water, and being capable of Rarifaction and Condensation *in infinitum*; neither of which *Hypotheses* are rigidly true: For here in *England* it is notoriously known, that the weight of the whole *Atmosphere* is various, being counterpoised sometimes by 28½ Inches of *Mercury*, and at other times by no less than 30½; so that the under parts being pressed by about a 15th part, less weight, the *specifick* Gravity of the Air upon that score will sometimes be a 15th part lighter than another; besides Heat and Cold, does very considerably dilate and contract the Air, and consequently alter its Gravity; to which add the mixture of *Effluvia*, or steams arising from almost all Bodies,

dies, which aſſimulating into the Form of Air, are kept ſuſpended therein, as Salts diſſolv'd in Liquors, or Metals in corroding *Menſtrua*; which Bodies being all of them very much heavier than Air, their Particles by their Admixture muſt needs encreaſe the weight of that Air they lie incorporated withal, after the ſame manner as melted Salts do augment the ſpecifick Gravity of Water. The other Conſideration is, that the Rarifaction and Condenſation of the Air is not preciſely according to the proportion here laid down; for the Experiment very nearly agrees thereto, as may be ſeen in the 58th Chapter of Mr. *Hook's Micrography*; yet are the Condenſations not poſſible beyond certain degrees: For being compreſſed into an 800th part of the Space it takes up here, its conſiſtence would be equally denſe with that of Water; which yields not to any force whatſoever, as hath been found by ſeveral Experiments tried here, and at *Florence*, by the *Academia del Cimento.* Nor can the Rarifaction proceed *in infinitum*; for ſuppoſing the Spring whereby it dilates it ſelf, occaſion'd by what Texture of Parts you pleaſe, yet muſt there be a determinate Magnitude of the natural State of each Particle, as we ſee it is in Wool, and the like, whoſe Bodies being compreſſable into a very ſmall Space, have yet a determinate bulk which they cannot exceed, when free'd from all manner of Preſſure.

Theſe Objections being true, do diſturb the Geometrical Accuracy of theſe Concluſions, drawn from the ſpecifick Gravity of the Air obſerv'd at any time; but the Method here ſhewn will compute by a like Calculation, the heights of the Quick-ſilver, and the Rarifactions of the Air from any aſſign'd height of the *Barometer* at the Earth's Surface, and any ſpecifick Gravity given. As to the Condenſation and Rarifaction by Heat and Cold, and the various mixture of Aqueous and other Vapours, theſe two Objections ſeem generally to compenſate each other; for when the Air is rarified by Heat, they are raiſed moſt copiouſly; ſo that though the Air properly ſo call'd, be expanded, and conſequently lighter, yet the *Interſtices* thereof being crouded full of Vapours of much heavier Matters, bulk for bulk, the weight of the *Compoſitum* may continue much the ſame; at leaſt a moſt curious Experiment made by the Ingenious Mr. *John Caſwell*, of *Oxford*, upon the top of *Snowdon* Hill, in *Carnarvanſhire*, ſeems to prove, that the firſt Inches of *Mercury* have their Portions of Air near enough to what I now determine: For the height of the Hill being 1240 Yards, or very near it, he found the *Mercury* to have ſubſided to 25,6 Inches, or 4 Inches below the mean Altitude thereof at the Level of the Sea, (which is a greater difference than has been found in any of our former Experiments,) and the Space anſwering to 4 Inches, by my Calculation, ſhould be 1288 Yards; and it agrees as well with the Obſervations in the Appendix to Mr. *Paſcall*'s Book, *del Equilibre des Liqueurs*, made on the high Hill in *Auvergne*, call'd *le puy de Domme*. So that the Rarifaction and Vapours ſeem not to have alter'd conſiderably, the Gravity of the under Parts of the *Air*; and much above the height where theſe Experiments were made, do few Vapours aſcend, and the Cold is ſuch that the Snow lies continually, ſo that for the more elevated Parts of the Sphere of *Air*, there is much leſs Reaſon to doubt. But

But now we have had occasion to mention the difference there is between the height of the *Mercury* at one time, from the height thereof at another, it may not be unacceptable to offer at some Reasons for the said difference; which, at least to my self, seem to have some appearance of Truth. *First*, Then it's undoubtedly demonstrable, that the height of the Cylinder of *Mercury* is equal to the weight of the whole incumbent Air, and consequently that that whole is sometimes a fifteenth more than at other times; which cannot otherwise be, but by the access of new Matter when 'tis heavy, and its diminution when 'tis light; that *Hypothesis* therefore that shews how the Air shall be encreased or diminished, in any particular place, will give a Reason for the greater and lesser height of the *Mercury* in the *Baroscope*: But to direct us in the choice of the several Causes, which may be assign'd for the Increase and Decrease of the Air, 'twill not be unnecessary to enumerate some of the principal Observations made upon the *Barometer*, most whereof are sufficiently known already to all those that are curious in these Matters.

The *First* is, That in calm Weather, when the Air is inclin'd to Rain, the *Mercury* is commonly low.

2. That in serene good settled Weather, the *Mercury* is generally high.

3. That upon very great Winds, though they be not accompanied with Rain, the *Mercury* sinks lowest of all, with relation to the Point of the Compass the Wind blows upon.

4. That

4. That *cæteris paribus* the greateſt heights of the *Mercury* are found upon Eaſterly and North-Eaſterly Winds.

5. That in calm froſty Weather the *Mercury* generally ſtands high.

6. That after very great Storms of Wind, when the *Quickſilver* has been low, it generally riſes again very faſt.

7. That the more Northerly places have greater Alterations of the *Baroſcope*, than the more Southerly.

8. That within the *Tropicks* and near them, thoſe Accounts I have had from others, and my own Obſervation at St. *Helena*, make very little or no Variation of the height of the *Mercury* in all Weathers. Now that Theory that can well account for all theſe appearances, will, in all probability, approach nearer the true cauſe of the *Barometers* Variations, than any thing hitherto afforded; and ſuch an one I am bound to believe, is that which I here lay down with ſubmiſſion to better Judgments.

I conceive that the principal Cauſe of the riſe and fall of the *Mercury*, is from the variable Winds, which are found in the *Temperate Zones*, and whoſe great unconſtancy here in *England* is moſt notorious. I ſhall not at preſent inquire into the Cauſe of its uncertainty, but the Matter of Fact being moſt undoubted, the Legitimate Conſequences thereof muſt be allow'd me, let it proceed from what it will.

A ſecond Cauſe is the uncertain Exhalation and Præcipitation of the Vapours lodging in the Air, whereby it comes to be at one time much more crowded than at another, and conſequently heavier; but this latter in a great meaſure depends upon the former. Now from theſe Principles I ſhall endeavour to explicate the ſeveral *Phænomena* of the *Barometer*, taking them in the ſame order I laid them down.

1. *Why in calm Weather the* Air *being inclin'd to Rain, the* Mercury *is commonly low?* I Anſwer, That the *Mercury*'s being low, inclines it to Rain; for the Air being light, the Vapours are no longer ſupported thereby, being become ſpecifically heavier than the Medium wherein they floated; ſo that they deſcend towards the Earth, and in their fall meeting with other aqueous Particles, they incorporate together, and form little drops of Rain; but the *Mercury*'s being at one time lower than another, is the effect of two contrary Winds blowing from the place whence the *Barometer* ſtands; whereby the Air of that place is carried both ways from it, and conſequently the incumbent Cylinder of Air is diminiſhed, and accordingly the *Mercury* ſinks; as for Inſtance, if in the *German Ocean* it ſhould blow a Gale of Weſterly Wind, and at the ſame time an Eaſterly Wind in the *Iriſh Sea*; or if in *France* it ſhould blow a Southerly Wind, and in *Scotland* a Northern; it muſt be granted me, that That part of the *Atmoſphere* impendent over *England*, would thereby be exhauſted and attenuated, and the *Mercury* would ſubſide, and the Vapours which before floated in thoſe parts of the *Air* of equal Gravity with themſelves, would ſink to the Earth.

2. *Why*

2. *Why in serene good settled weather the* Mercury *is generally high?* To this I Answer, That the greater height of the *Barometer*, is occasion'd by two contrary Winds blowing towards the place of Observation, whereby the Air of other places is brought thither and accumulated; so that the incumbent Cylinder of Air being encreas'd both in height and weight, the *Mercury* press'd thereby must needs rise and stand high, as long as the Winds continue so to blow; and then the Air being specifically heavier, the Vapours are better kept suspended, so that they have no inclination to Præcipitate and fall down in Drops, which is the reason of the serene good Weather, which attends the greater heights of the *Mercury*.

3. *Why upon very great Winds or Storms, tho' accompanied with no Rain, the* Mercury *sinks lowest of all, with relation to the Point of the Compass upon which the Wind blows?* This is caus'd by the very rapid Motion of the Air in these Storms; for the Tract or Region of the Earths Surface, wherein these Winds rage, not extending all round the Globe, that stagnant Air which is left behind, as likewise that on the sides, cannot come in so fast as to supply the Evacuation made by so swift a Current; so that the Air must necessarily be attenuated, when and where the said Winds continue to blow, and that more or less, according to their Violence; add to which, that the *Horizontal* Motion of the Air being so quick as it is, may in all probability take off some part of the perpendicular pressure thereof; and the great Agitation of its Particles, is the Reason why the Vapours are dissipated, and do not condense into Drops,

so

ſo as to form Rain, otherwiſe the natural Conſequence of the Airs Rarifaction.

4. *Why* cæteris paribus *the* Mercury *ſtands higheſt upon an Eaſterly or North-Eaſterly Wind?* This happens becauſe that in the great *Atlantick Ocean*, on this ſide the thirty fifth Degree of North Latitude, the Weſterly and South-Weſterly Trade-Winds blow almoſt always; ſo that whenever here the Wind comes up at Eaſt and North-Eaſt, 'tis ſure to be checked by a contrary Gale, as ſoon as it reaches the Ocean; wherefore, according to what is made out in our ſecond Remark, the Air muſt needs be heaped over this Iſland; and conſequently the *Mercury* muſt ſtand high, as often as theſe Winds blow. This holds true in this Country, but is not a general Rule for others, where the Winds are under different Circumſtances; and I have ſometimes ſeen the *Mercury* here as low as twenty nine Inches, upon an Eaſterly Wind, but then it blows exceeding hard, and ſo comes to be accounted for by what was obſerv'd upon the third Remark.

5. *Why in calm Weather the* Mercury *genenerally ſtands high?* The cauſe hereof is, as I conceive, that it ſeldom freezes but when the Winds come out of the Northern and North-Eaſtern Quarters, or at leaſt unleſs thoſe Winds blow at no great diſtance off; for the Northern Parts of *Germany*, *Denmark*, *Sweden*, *Norway*, and all that Tract from whence North-Eaſtern Winds come, are ſubject to almoſt continual Froſt all the Winter; and thereby the lower Air is very much condens'd, and in that State is brought hitherwards by theſe Winds,

and

and being accumulated by the oppoſition of the Weſterly Wind blowing in the Ocean, the *Mercury* muſt needs be preſt to a more than ordinary height, and as a concurring Cauſe, the ſhrinking of the lower parts of the Air into leſſer room by cold, muſt needs cauſe a deſcent of the upper parts of the Atmoſphere, to reduce the Cavity made by this contraction to an *Æquilibrium.*

6. *Why after very great Storms of Wind, when the* Mercury *has been very low, it generally riſes again very faſt?* This I have frequently obſerved, and once found it riſen an Inch and a half in leſs than ſix Hours, after a long continu'd Storm of South-Weſt Wind. This ſeems to be occaſion'd by the ſudden Acceſſion of new Air to ſupply the great Evacuation which ſuch continu'd Storms make thereof, in thoſe places whence they happen (as in the third Remark) and by the Recoile of the Air, after the force ceaſes that impell'd it; and the Reaſon why the *Mercury* riſes ſo faſt, is becauſe the Air being very much rarify'd beyond its mean denſity, the Neighbouring Air runs in the more ſwiftly to bring it to an *Æquilibration*, as we ſee Water runs the faſter for having a great declivity.

7. *Why in more Northerly places the Variations of the* Baroſcope *are greater than in the Southerly?* The truth of the Matter of Fact is prov'd from Obſervations made at *Clermont* and *Paris*, compar'd with others, made at *Stockholm*, as may be ſeen in the Appendix to Mr. *Paſcal*'s Book before-cited. The Reaſon I conjecture to be, that the more Northerly Parts have uſually greater Storms of Wind than the more Southerly, whereby the *Mercury* ſhould

ſhould ſink lower in that Extream; and then the Northerly Winds bringing the condens'd and ponderous Air from the Neighbourhood of the Pole, and that again being check'd by a Southerly Wind, at no great diſtance, and ſo heaped, muſt of neceſſity make the *Mercury* in ſuch caſe ſtand higher in the other Extream.

.8 And Laſtly, *Why near the* Æquinoctial, *as at* Barbadoes *and St.* Helena, *there is very little or no Variation of the height of the Barometer?* This Remark, above all others, confirms the Hypotheſis of the variable Winds, being the cauſe of theſe Variations of the height of the *Mercury*; for in the Places above-named, there is always an eaſie Gale of Wind blowing nearly upon the ſame Point, *viz.* E. N. E at *Barbadoes*, and E. S. E. at St. *Helena*; ſo that there being no contrary Currents of the Air, to exhauſt or accumulate it, the Atmoſphere continues much in the ſame State: However, upon Hurricanes, the moſt violent of Storms, the *Mercury* has been obſerv'd very low, but this is but for once in two or three Years, and it ſoon recovers its ſettled ſtate of about 29½ Inches. I doubt not but the ſame thing is in the Eaſt Coaſt of *Africa*, and in *India*, where the Monſoons or Trade-Winds are for half the Year one way, and half the Year another; only it's probable, that there may ſomething worth noting happen, about the times of the change or ſhifting of the Winds, which might be obtain'd, if any Body had the Curioſity to keep the *Barometer* at our Factories in *India.*

I doubt not but this Doctrine will find ſome Oppoſers, and that one principal Objection will be, that I ſuppoſe the Air ſometimes to move from thoſe Parts where it is already evacuated below

below the *Æquilibrium*, and ſometimes again towards thoſe parts, where it is condens'd and crouded above the mean State, which may be thought contradictory to the Laws of Staticks and the Rules of the *Æquilibrium* of Fluids. But thoſe that ſhall conſider how, when once an impetus is given to a Fluid Body, it is capable of mounting above its Level, and checking others that have a contrary tendency to deſcent by their own Gravity, will no longer regard this as a material Obſtacle, but will rather conclude, that the great *Analogy* there is between the riſing and falling of the Water upon the Flux and Reflux of the Sea, and this of the accumulating and extenuating the Air, is a great Argument for the Truth of this Hypotheſis: For as the Sea over againſt the Coaſt of *Eſſex*, riſes and ſwells by the meeting of the two contrary Tides of Flood, (whereof the one comes from the S. W. along the Channel of *England*, and the other from the North); and on the contrary ſinks below its Level upon the retreat of the Water both ways in the Tide of Ebb; ſo it is very probable that the Air may Ebb and Flow, after the ſame manner; but by reaſon of the diverſity of Cauſes, whereby the Air may be ſet in moving, the times of theſe Fluxes and Refluxes thereof, are purely Caſual, and not reducible to any Rule, as are the Motions of the Sea, depending wholly upon the regular Courſe of the Moon.

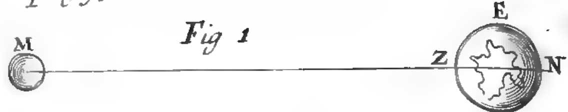


Fig 1

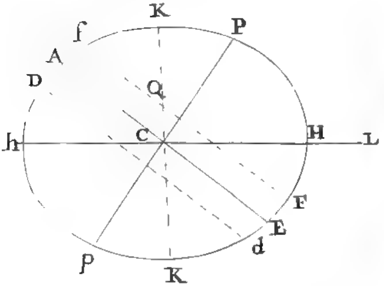


Fig. 2

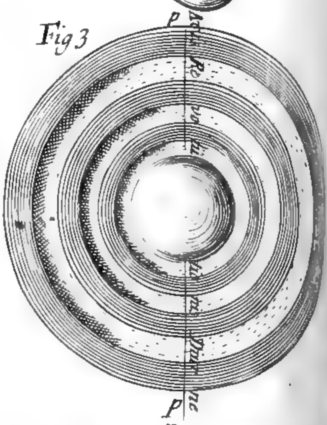


Fig 3

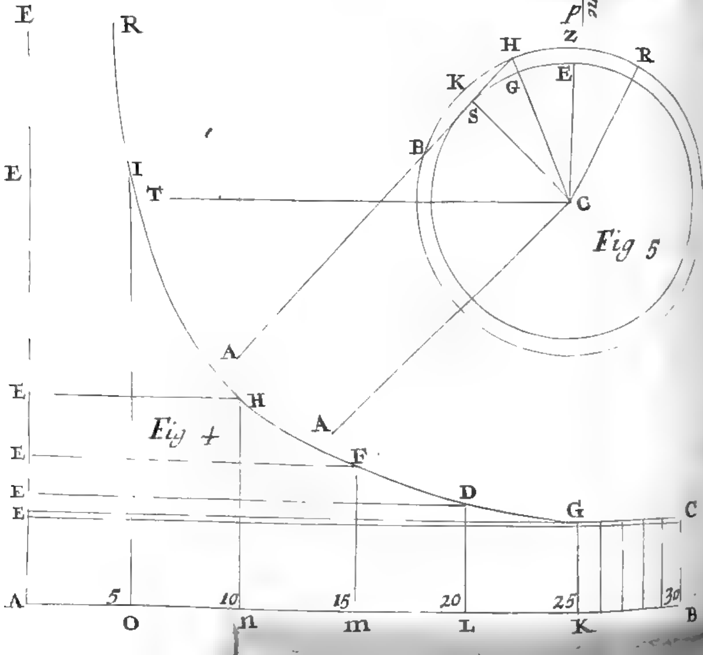


Fig 5

Fig 4

Fig 1

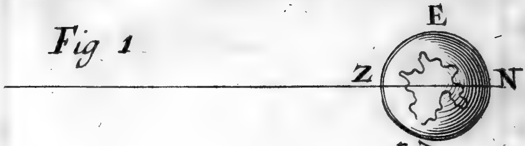
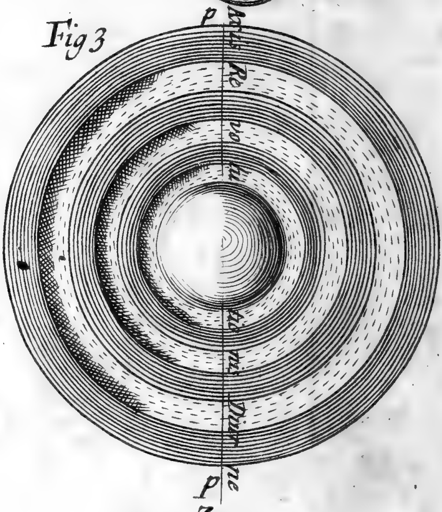
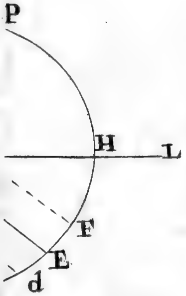
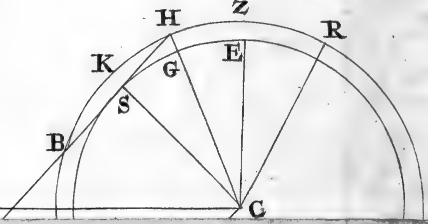


Fig 3







A Letter of Mr. Isaac Newton, *Professor of the Mathematicks in the University of* Cambridge; *containing his New Theory about* Light *and* Colours: *Sent by the Author to the Publisher from* Cambridge, *Feb.* 6. $167\frac{1}{2}$; *in order to be communicated to the* Royal Society.

SIR,

TO perform my late promise to you, I shall without further Ceremony acquaint you, That in the beginning of the Year 1666 (at which time I apply'd my self to the grinding of Optick-glasses of other Figures than *Spherical*,) I procur'd me a Triangular Glass-Prism, to try therewith the celebrated *Phænomena* of *Colours.* And in order thereto, having darken'd my Chamber, and made a small hole in my Window-shuts, to let in a convenient quantity of the Sun's Light, I plac'd my Prism at his entrance, that it might be thereby refracted to the opposite Wall. It was at first a very pleasing Divertisement, to view the vivid and intense Colours produced thereby; but after a while applying my self to consider them more circumspectly, I became surpriz'd to see them in an *oblong* Form; which, according to the received Laws of Refraction, I expected should have been *Circular*.

They were terminated at the ſides with ſtreight Lines, but at the ends, the decay of Light was ſo gradual, that it was difficult to determine juſtly, what was their Figure; yet they ſeem'd *Semicircular.*

Comparing the length of this colour'd *Spectrum* with its breadth, I found it about five times greater; a diſproportion ſo extravagant, that it excited me to a more than ordinary Curioſity of examining, from whence it might proceed. I could ſcarce think, that the various thickneſs of the Glaſs, or the termination with ſhadow or darkneſs, could have any Influence on Light to produce ſuch an effect; yet I thought it not amiſs, firſt to examine thoſe Circumſtances, and ſo try'd what would happen by tranſmitting Light through parts of the Glaſs of divers thickneſſes, or through holes in the Window of divers bigneſſes, or by ſetting the Priſm without, ſo that the Light might paſs through it, and be refracted before it was terminated by the hole: But I found none of thoſe Circumſtances material. The faſhion of the Colours was, in all theſe Caſes, the ſame.

Then I ſuſpected, whether by any unevenneſs in the Glaſs, or other contingent Irregularity, theſe Colours might be thus dilated. And to try this, I took another Priſm like the former, and ſo plac'd it, that the Light paſſing through them both, might be refracted contrary ways, and ſo by the latter return'd into that Courſe, from which the former had diverted it. For, by this means, I thought the *regular* effects of the firſt Priſm would be deſtroy'd by the ſecond Priſm, but the *irregular* ones more augmented by the multiplicity of Refractions. The Event was, that the Light, which by the firſt Priſm

was

was diffuſed into an *oblong* Form, was, by the ſecond, reduc'd into an *orbicular* one, with as much regularity, as when it did not at all paſs through them. So that whatever was the cauſe of that length, 'twas not any contingent Irregularity:

I then proceeded to examine more critically, what might be effected by the difference of the incidence of Rays coming from divers parts of the Sun; and to that end, meaſur'd the ſeveral Lines and Angles belonging to the Image. Its diſtance from the Hole or Priſm was twenty two Foot; its utmoſt length $13\frac{1}{4}$ Inches; its breadth $2\frac{5}{8}$; the Diameter of the Hole $\frac{1}{4}$ of an Inch; the Angle, with the Rays, tending towards the middle of the Image, made with thoſe Lines, in which they would have proceeded without Refraction, was $44° 56'$. And the Vertical Angle of the Priſm, $63° 12'$. Alſo the Refractions on both ſides the Priſm, that is, of the Incident, and Emergent Rays, were as near, as I could make them, equal, and conſequently about $54° 4'$. And the Rays fell perpendicularly upon the Wall. Now ſubducting the Diameter of the Hole from the length and breadth of the Image, there remains 13 Inches the length, and $2\frac{3}{8}$ the breadth, comprehended by thoſe Rays, which paſſed thro' the Center of the ſaid Hole, and conſequently the Angle of the Hole, which that breadth ſubtended, was about $31'$, anſwerable to the Sun's Diameter; but the Angle, which its length ſubtended, was more than five ſuch Diameters, namely $2° 49'$.

Having made theſe Obſervations, I firſt computed from them the refractive Power of that Glaſs, and found it meaſur'd by the *ratio* of the Sines, twenty to thirty one. And then, by that *ratio*, I computed the Refractions of two Rays flowing from opposite parts of the Sun's *discus*, so as to differ 31′ in their obliquity of Incidence, and found that the emergent Rays should have comprehended an Angle of about 31′, as they did, before they were incident.

But because this Computation was founded on the Hypothesis of the proportionality of the Sines of Incidence and Refraction, which, tho' by my own Experience I could not imagine to be so erroneous as to make that Angle but 31′, which in reality was 2° 49′; yet my Curiosity caus'd me again to take my Prism. And having plac'd it at my Window, as before, I observ'd, that by turning it a little about its *Axis* to and fro, so as to vary its obliquity to the light, more than an Angle of four or five Degrees, the Colours were not thereby sensibly translated from their place on the Wall, and consequently by that Variation of Incidence, the quantity of Refraction was not sensibly varied. By this Experiment therefore, as well as by the former Computation, it was evident, that the difference of the Incidence of Rays, flowing from divers parts of the Sun could not make them, after decussation, diverge at a sensiblygreater Angle, than that at which they before converged; which being, at most, but about thirty one or thirty two Minutes, there still remain'd some other cause to be found out, from whence it could be two Deg. 49 Min.

Then I began to suspect, whether the Rays, after their Trajection through the Prism, did not move in curve Lines, and according to their more or less Curvity, tend to divers parts of the Wall. And it increas'd my suspicion, when I remember'd that I had often seen a Tennis-Ball, struck with an oblique Racket, describe such a curve Line. For a Circular as well as a Pro-

gressive

greſſive Motion being communicated to it by that ſtroak, its parts on that ſide, where the Motions conſpire, muſt preſs and beat the contiguous Air more violently than on the other, and there excite a Reluctancy and Reaction of the Air proportionably greater. And for the ſame Reaſon, if the Rays of Light ſhould poſſibly be globular Bodies, and by their oblique Paſſage out of one Medium into another, acquire a circulating Motion, they ought to feel the greater reſiſtance from the ambient Æther, on that ſide, where this Motion conſpires, and thence be continually bowed to the other. But notwithſtanding this plauſible ground of ſuſpicion, when I came to examine it, I could obſerve no ſuch Curvity in them. And beſides (which was enough for my purpoſe) I obſerv'd, that the difference 'twixt the length of the Image, and Diameter of the Hole, through which the Light was tranſmitted, was proportionable to their diſtance.

The gradual removal of theſe ſuſpicions, at length led me to the *Experimentum Crucis*, which was this; I took two Boards, and plac'd one of them cloſe behind the Priſm at the Window, ſo that the light might paſs through a ſmall hole, made in it for the purpoſe, and fall on the other Board, which I plac'd at about twelve Feet diſtance, having firſt made a ſmall hole in it alſo, for ſome of that incident Light to paſs through. Then I plac'd another Priſm behind this ſecond Board, ſo that the Light, trajected through both the Boards, might paſs thro that alſo, and be again refracted before it arrived at the Wall. This done, I took the firſt Priſm in my Hand, and turn'd it to and fro ſlowly about its *Axis*, ſo much as to make the ſeveral parts of the Image, caſt on the ſecond Board, successively pass through the hole in it, that I might observe to what places on the Wall the second Prism would refract them. And I saw by the Variation of those places, that the Light, tending to that end of the Image, towards which the Refraction of the first Prism was made, did, in the second Prism, suffer a Refraction considerably greater than the Light tending to the other end. And so the true cause of the length of that Image was detected to be no other, than that *Light* consists of *Rays differently refrangible*, which, without any respect to a difference in their incidence, were, according to their degrees of Refrangibility, transmitted towards divers parts of the Wall.

When I understood this, I left off my aforesaid Glass Works; for I saw, that the perfection of Telescopes was hitherto limited, not so much for want of Glasses truly figur'd, according to the prescriptions of Optick Authors (which all Men have hitherto imagin'd), as because that Light it self is a *Heterogeneous mixture of differently refrangible Rays.* So that, were a Glass so exactly figur'd, so as to collect any one sort of Rays into one Point, it could not collect those also into the same Point, which having the same Incidence upon the same Medium, are apt to suffer a different Refraction. Nay, I wonder'd, that seeing the difference of Refrangibility was so great, as I found it, Telescopes should arrive to that perfection they are now at. For, measuring the Refractions in one of my Prisms, I found, that, supposing the common Sine of Incidence upon one of its plains, was forty four Parts, the Sine of Refraction of the utmost Rays on the red end of the Colours, made out of the Glass into the Air, would be sixty eight parts, and the Sine of

Refraction

Refraction of the utmost Rays on the other end, sixty nine parts; so that the difference is about a twenty fourth or twenty fifth part of the whole Refraction. And consequently the Object glass of any Telescope cannot collect all the Rays, which come from one point of an Object, so as to make them convene at its *Focus* in less room than in a Circular space, whose Diameter is the fiftieth part of the Diameter of its Aperture; which is an irregularity, some hundred of times greater, than a circularly figur'd *Lens*, of so small a section as the Object-glasses of long Telescopes are, would cause by the unfitness of its Figure, were Light *uniform*.

This made me take *Reflections* into Consideration, and finding them regular, so that the Angle of Reflection of all sorts of Rays was equal to their Angle of Incidence; I understood, that by their mediation, Optick Instruments might be brought to any degree of Perfection imaginable, provided a *Reflecting* Substance could be found, which would polish as finely as Glass, and *reflect* as much Light as Glass *transmits*, and the art of communicating to it a *Parabolick* Figure be also attain'd. But there seem'd very great Difficultities, and I have almost thought them insuperable, when I further consider'd, that every Irregularity in a reflecting Superficies makes the Rays stray five or six times more out of their due course, than the like Irregularities in a refracting one: So that a much greater Curiosity would be here requisite, than in Figuring Glasses for Refraction.

Amidst these Thoughts I was forc'd from *Cambridge* by the Intervening Plague, and it was more than two Years before I proceeded further. But then having thought on a tender way of polishing, proper for Metal, whereby, as I imagin'd, the Figure also would be corrected to the last; I began to try what might be effected in this kind, and by degrees so far perfected an Instrument (in the essential parts of it like that I sent to *London*,) by which I could discern *Jupiter's* four Concomitants, and shew'd them divers times to two others of my Acquaintance. I could also discern the Moon-like Phase of *Venus*, but not very distinctly, nor without some niceness in disposing the Instrument.

From that time I was interrupted, till this last Autumn, when I made the other. And as that was sensibly better than the first (especially for Day-Objects,) so I doubt not but they will be still brought to a much greater perfection by their Endeavours, who, as you inform me, are taking care about it at *London*.

I have sometimes thought to make a *Microscope*, which in like manner should have, instead of an Object-glass, a reflecting piece of Metal. And this I hope they will also take into Consideration: For those Instruments seem as capable of improvement as *Telescopes*, and perhaps more, because but one reflective piece of Metal is requisite in them, as you may perceive in *Plate* 3. *Fig.* 1. where *A B* representeth the Object Me[illegible]l, C D the Eye-glass, F their common Focus, and O the other Focus of the Metal, in which the Object is placed.

But to return from this digression, I told you, that Light is not similar, or homogeneal, but consists of *difform* Rays, some of which are more refrangible than others: So that of those, which are alike incident on the same Medium, some shall be more refracted than others, and that not by any virtue of the Glass, or other

external

external Cause, but from a predisposition, which every particular Ray hath to suffer a particular degree of Refraction.

I shall now proceed to acquaint you with another more notable deformity in its Rays, wherein the *Origin of Colours* is unfolded: Concerning which I shall lay down the *Doctrine* first, and then, for its Examination, give you an Instance or two of the *Experiments*, as a Specimen of the rest.

The Doctrine you will find comprehended and illustrated in the following Propositions.

1. As the Rays of Light differ in degrees of Refrangibility, so they also differ in their disposition to exhibit this or that particular Colour. Colours are not *Qualifications of Light*, derived from Refractions, or Reflections of natural Bodies, (as 'tis generally believed) but *Original* and *connate Properties*, which in divers Rays are divers. Some Rays are disposed to exhibit a red Colour and no other; some a yellow and no other, some a green and no other, and so of the rest. Nor are there only Rays proper and particular to the more eminent Colours, but even to all their intermediate Gradations.

2. To the same degree of Refrangibility ever belongs the same Colour, and to the same Colour ever belongs the same degree of Refrangibility. The *least Refrangible* Rays are all disposed to exhibit a *Red* Colour, and contrarily those Rays, which are disposed to exhibit a *Red* Colour, are all the least Refrangible: So the *most Refrangible* Rays are all disposed to exhibit a deep *Violet Colour*, and contrarily those which are apt to exhibit such a *Violet Colour*, are all the most Refrangible. And so to all the intermediate Colours in a continued Series belong intermediate degrees of Refrangibility. And

this Analogy 'twixt Colours, and Refrangibility, is very precise and strict; the Rays always either exactly agreeing in both, or proportionally disagreeing in both.

3. The Species of Colour, and Degree of Refrangibility proper to any particular sort of Rays, is not mutable by Refraction, nor by Reflection from Natural Bodies, nor by any other Cause, that I could yet observe. When any one sort of Rays hath been well parted from those of other kinds, it hath afterwards obstinately retain'd its Colour, notwithstanding my utmost Endeavours to change it. I have refracted it with Prisms, and reflected it with Bodies, which in Day-light were of other Colours; I have intercepted it with the colour'd Film of Air interceding two compressed Plates of Glass; transmitted it through colour'd Mediums, and through Mediums irradiated with other sorts of Rays, and diversly terminated it, and yet could never produce any new Colour out of it. It would by contracting and dilating become more brisk, or faint, and by the loss of many Rays in some Cases very obscure and dark; but I could never see it chang'd *in specie.*

4. Yet seeming Transmutations of Colours may be made, where there is any mixture of divers sorts of Rays. For in such mixtures, the component Colours appear not, but by their mutual allaying each other, constitute a midling Colour. And therefore, if by Refraction, or any other of the aforesaid Causes, the difform Rays, latent in such a mixture, be separated, there shall emerge Colours different from the colour of the Composition. Which Colours are not new generated, but only made apparent by being parted; for if they be again intirely mix'd

mix'd and blended together, they will again compose that Colour, which they did before separation. And for the same reason, Transmutations made by the convening of divers Colours are not real; for when the difform Rays are again severed, they will exhibit the very same Colours, which they did before they entered the Composition; as you see, *Blue* and *Yellow* Powders, when finely mixed, appear to the naked Eye *Green*, and yet the Colours of the component Corpuscles are not thereby really transmuted, but only blended. For, when viewed with a good Microscope, they still appear *Blue* and *Yellow* interspersedly.

5. There are therefore two sorts of Colours. The one Original and Simple, the other compounded of these. The Original or Primary Colours are, *Red*, *Yellow*, *Green*, *Blue*, and a *Violet-purple*, together with Orange, Indico, and an indefinite variety of intermediate Gradations.

6. The same Colours in *Specie* with these primary Ones, may be also produced by Composition: For, a mixture of *Yellow* and *Blue* makes *Green*; of *Red* and *Yellow*, makes *Orange*; of *Orange* and *Yellowish Green*, makes *Yellow*. And in general, if any two Colours be mix'd, which in the Series of those, generated by the Prism, are not too far distant one from another, they by their mutual Alloy compound that Colour, which in the said Series appeareth in the mid-way between them. But those, which are situated at too great a distance, do not so. *Orange* and *Indico* produce not the intermediate *Green*, nor *Scarlet* and *Green* the intermediate *Yellow*.

7. But the most surprizing and wonderful Composition was that of *Whiteness*. There is no one sort of Rays which alone can exhibit this.

'Tis

'Tis ever compounded, and to its Composition are requisite all the aforesaid primary Colours, mix'd in a due proportion. I have often with admiration beheld, that all the Colours of the Prism being made to converge, and thereby to be again mixed as they were in the light before it was incident upon the Prism, reproduced light, intirely and perfectly white, and not at all sensibly differing from a *direct* light of the Sun, unless when the Glasses, I used, were not sufficiently clear; for then they would a little incline it to *their* Colour.

8. Hence therefore it comes to pass, that *Whiteness* is the usual Colour of *Light*; for Light is a confused aggregate of Rays, indued with all sorts of Colours, as they are promiscuously darted from the various parts of luminous Bodies. And of such a confused aggregate, as I said, is generated Whiteness, if there be a due proportion of the Ingredients; but if any one predominate, the Light must incline to that Colour; as it happens in the blue Flame of Brimstone, the yellow Flame of a Candle, and the variours Colours of the fixed Stars.

9. These things consider'd, the *manner*, how Colours are produced by the Prism, is evident. For, of the Rays, constituting the incident Light, since those which differ in Colour proportionally differ in Refrangibility, *they* by their unequal Refractions must be severed and dispersed into an oblong Form, in an orderly succession, from the least refracted Scarlet to the most refracted Violet. And for the same reason it is, that Objects, when look'd upon through a Prism, appear coloured. For the difform Rays, by their unequal Refractions, are made to diverge towards several parts of the *Retina*, and there express

preſs the Images of things coloured, as in the former caſe they did the Sun's Image upon a Wall. And by this inequality of Refractions, they become not only coloured, but alſo very confuſed and indiſtinct.

10. Why the Colours of the *Rainbow* appear in falling drops of Rain, is alſo from hence evident. For thoſe drops, which refract the Rays, diſpoſed to appear Purple, in greateſt quantity to the Spectators Eye, refract the Rays of other ſorts ſo much leſs, as to make them paſs beſide it; and ſuch are the drops on the inſide of the *Primary* Bow, and on the outſide of the *Secondary* or Exteriour one. So thoſe drops, which refract in greateſt plenty the Rays, apt to appear red, toward the Spectator's Eye, refract thoſe of other ſorts ſo much more, as to make them paſs beſide it; and ſuch are the drops on the Exteriour part of the *Primary*, and Interiour part of the *Secondary* Bow.

11. The odd Phænomena of an infuſion of *Lignum Nephriticum*, *Leaf-gold*, *Fragments of colour'd Glaſs*, and ſome other tranſparently coloured Bodies, appearing in one Poſition of one Colour, and of another in another, are on theſe grounds no longer Riddles. For thoſe are Subſtances apt to reflect one ſort of Light, and tranſmit another; as may be ſeen in a dark Room, by illuminating them with ſimilar or uncompounded Light. For then they appear of that Colour only, with which they are illuminated; but yet in one Poſition more vivid and luminous than in another, accordingly as they are diſpoſed more or leſs to reflect or tranſmit the incident Colour.

12. From hence alſo is manifeſt the reaſon of an unexpected Experiment, which Mr. *Hook*, ſomewhere in his *Micrography*, relates to have made

made with two wedge-like transparent Vessels fill'd, the one with a red, the other with a blue Liquor; namely, that though they were severally transparent enough, yet both together became opake: For, if one transmitted only red, and the other only blue, no Rays could pass through both.

13. I might add more Instances of this Nature; but I shall conclude with this general one, that the Colours of all natural Bodies have no other Origin than this, that they are variously qualified to reflect one sort of Light in greater plenty than another. And this I have experimented in a dark Room, by illuminating those Bodies with uncompounded Light of divers Colours. For by that means any body may be made to appear of any Colour. They have there no appropriate Colour, but ever appear of the Colour of the Light cast upon them; but yet with this difference, that they are most brisk and vivid in the Light of their own day-light-colour. *Minium* appeareth there of any Colour indifferently, with which 'tis illustrated, but yet most luminous in red; and so *Bise* appeareth indifferently of any Colour with which 'tis illustrated, but yet most luminous in blue. And therefore *Minium* reflecteth Rays of any Colour, but most copiously those endu'd with red, and consequently when illustrated with day-light, that is, with all sorts of Rays promiscuously blended, those qualified with red, shall abound most in the reflected Light, and by their prevalence cause it to appear of that Colour. And for the same reason *Bise*, reflecting blue most copiously, shall appear blue by the excess of those Rays in its reflected Light; and the like of other Bodies. And that this is the intire

intire and adequate cauſe of their Colours, is manifeſt, becauſe they have no power to change or alter the Colours of any ſort of Rays incident apart, but put on all Colours indifferently, with which they are enlightned.

Theſe things being ſo, it can be no longer diſputed, whether there be Colours in the dark, nor whether they be the Qualities of the Objects we ſee, no nor perhaps, whether Light be a Body. For, ſince Colours are the *Qualities* of Light, having its Rays for their intire and immediate Subject, how can we think thoſe Rays *Qualities* alſo, unleſs one Quality may be the Subject of and ſuſtain another; which in effect is to call it *Subſtance*? We ſhould not know Bodies for Subſtances, were it not for their ſenſible Qualities; and the principal of thoſe being now found due to ſomething elſe, we have as good reaſon to believe that to be a Subſtance alſo.

Beſides, whoever thought any Quality to be a *heterogeneous* Aggregate, ſuch as Light is diſcovered to be? But to determine more abſolutely, what Light is, after what manner refracted, and by what Modes or Actions it produceth in our Minds the Phantaſms of Colours, is not ſo eaſie. And I ſhall not mingle Conjectures with Certainties.

Reviewing what I have written, I ſee the Diſcourſe it ſelf will lead to divers Experiments ſufficient for its Examination; and therefore I ſhall not trouble you farther, than to deſcribe one of thoſe, which I have already inſinuated.

In a darkned Room, make a hole in the ſhut of a Window, whoſe Diameter may conveniently be about a third part of an Inch, to admit a convenient quantity of the Sun's Light: And there place a clear and colourleſs Priſm, to refract

fract the entring Light towards the farther part of the Room; which, as I ſaid, will thereby be diffuſed into an oblong coloured Image. Then place a *Lens* of about three Foot Radius (ſuppoſe a broad Object-glaſs of a three Foot Teleſcope,) at the diſtance of about four or five Foot from thence, through which all thoſe Colours may at once be tranſmitted, and made by its Refraction to convene at a farther diſtance of about ten or twelve Feet. If at that diſtance you intercept this Light with a Sheet of white Paper, you will ſee the Colours converted into whiteneſs again by being mingled. But it is requiſite, that the *Priſm* and *Lens* be placed ſteady, and that the Paper, on which the Colours are caſt, be moved to and fro; for, by ſuch motion, you will not only find at what diſtance the whiteneſs is moſt perfect, but alſo ſee how the Colours gradually convene, and vaniſh into whiteneſs; and afterwards, having croſſed one another in that place where they compound whiteneſs, are again diſſipated and ſevered, and in an inverted order retain the ſame Colours, which they had before they entred the Compoſition. You may alſo ſee, that, if any of the Colours at the *Lens* be intercepted, the whiteneſs will be changed into the other Colours. And therefore, that the Compoſition of whiteneſs be perfect, care muſt be taken that none of the Colours fall beſides the *Lens*.

In the annexed Deſign, *Tab.* 3. *Fig.* 2. of this Experiment, *A B C* expreſſeth the Priſm ſet endwiſe to ſight, cloſe by the hole *F* of the Window *E G*. Its vertical Angle *A B C* may conveniently be about 60 Degrees: *M N* deſigneth the *Lens*. Its breadth 2½ or 3 Inches. *S F* one of the ſtreight Lines, in which difform Rays may be be conceived to flow ſucceſſively from the Sun. *F P*, and *F R* two of thoſe Rays unequally refracted, which the *Lens* makes to converge towards Q, and after decuſſation to diverge again. And H I the Paper, at divers diſtances, on which the Colours are projected, which in Q conſtitute *Whiteneſs*, but are *Red* and *Yellow* in *R*, *r*, and *ϱ*, and *Blue* and *Purple* in *P*, *p*, and *π*.

If you proceed further to try the impoſſibility of changing any uncompounded Colour (which I have aſſerted in the third and thirteenth Propoſitions,) 'tis requiſite that the Room may be very dark, leſt any ſcattering light, mixing with the Colour, diſturb and allay it, and render it compound, contrary to the deſign of the Experiment. 'Tis alſo requiſite, that there be a perfecter ſeparation of the Colours, than, after the manner above deſcribed, can be made by the Refraction of one ſingle Priſm; and how to make ſuch farther ſeparations, will ſcarce be difficult to them, that conſider the diſcovered Laws of Refractions. But if trial ſhall be made with Colours not throughly ſeparated, there muſt be allowed changes proportionable to the mixture. Thus if compound Yellow Light fall upon blue *Biſe*, the Biſe will not appear perfectly yellow, but rather green, becauſe there are in the yellow mixture many Rays indued with green, and green being leſs remote from the uſual blue Colour of Biſe than yellow, is the more copiouſly reflected by it.

In like manner, if any one of the Priſmatick Colours, ſuppoſe red, be intercepted, on deſign to try the aſſerted impoſſibility of reproducing that Colour out of the others which are pretermitted; 'tis neceſſary, either that the Colours be very well parted before the red be intercepted; or that, together with the red, the neighbouring Colours, into which any red is secretly dispersed, (that is, the yellow, and perhaps green too) be intercepted; or else, that allowance be made for the emerging of so much red out of the yellow green, as may possibly have been diffused, and scatteringly blended in those Colours. And if these things be observed, the new Production of red, or any intercepted Colour, will be found impossible.

This, I conceive, is enough for an Introduction to Experiments of this kind; which if any of the *Royal Society* shall be so curious as to prosecute, I should be very glad to be informed with what success: That, if any thing seem to be defective, or to thwart this Relation, I may have an opportunity of giving farther Direction about it, or of acknowledging my Errors, if I have committed any.

Since the Publication of this Theory, some Misunderstandings happening between a French *Philosopher at* Paris *and* Mr. Newton, *he has endeavour'd to explain himself a little further in these Things, according to the following Method.*

DEFINITIONS.

1. I call that Light Homogeneal, Similar, or Uniform, whose Rays are equally refrangible.

2. And that Heterogeneal, whose Rays are unequally refrangible.

Note, There are but three Affections of Light in which I have observ'd its Rays to differ; *viz.* Refrangibility, Reflexibility, and Colour; and those Rays which agree in Refrangibility, agree also

in

in the other two, and therefore may well be defined Homogeneal; especially since Men usually call those things Homogeneal, which are so in all Qualities that come under their Knowledge, tho' in other Qualities, that their Knowledge extends not to, there may possibly be some Heterogeneity.

3. Those Colours I call Simple or Homogeneal, which are exhibited by Homogeneal Light.

4. And those Compound or Heterogeneal, which are exhibited by Heterogeneal Light.

5. Different Colours, I call, not only the more eminent Species, Red, Yellow, Green, Blue, Purple, but all other the minutest Gradations; much after the same manner, that not only the more eminent Degrees in Musick, but all the least Gradations, are esteem'd different Sounds.

PROPOSITIONS.

1. The Sun's Light consists of Rays differing by indefinite Degrees of Refrangibility.

2. Rays which differ in Refrangibility, when parted from one another, do proportionally differ in the Colours which they exhibit. These Two Propositions are Matter of Fact.

3. There are as many Simple or Homogeneal Colours, as Degrees of Refrangibility. For to every Degree of Refrangibility belongs a different Colour, by *Prop.* 2. and that Colour is Simple, by *Def.* 1, and 3.

4. Whiteness, in all respects like that of the Sun's immediate Light, and of all the usual Objects of our Senses, cannot be compounded of two Simple Colours alone. For such a Composition

muſt be made by Rays that have only two Degrees of Refrangibility, by *Def.* 1 and 3. and therefore it cannot be like that of the Sun's Light. by *Prop.* 1. nor, for the ſame Reaſon, like that of ordinary white Objects.

5. Whiteneſs, in all reſpects, like that of the Sun's immediate Light, cannot be compounded of Simple Colours without an indefinite Variety of them. For to ſuch a Compoſition, there are requiſite Rays endu'd with all the indefinite Degrees of Refrangibility, by *Prop.* 1. And thoſe infer as many Simple Colours, by *Def.* 1 and 3. and *Prop.* 2 and 3.

To make theſe a little plainer, I have added alſo the Propoſitions that follow.

6. The Rays of Light do not act on one another, in paſſing through the ſame Medium.

7. The Rays of Light ſuffer not any change of their Qualities from Refraction.

8. Nor afterwards from the adjacent quiet *Medium*: Theſe two Propoſitions are manifeſt *de Facto* in Homogeneal Light, whoſe Colour and Refrangibility is not at all changeable, either by Refraction, or by the Contermination of a quiet *Medium*. And as for Heterogeneal Light, it is but an Aggregate of ſeveral ſorts of Homogeneal Light, no one ſort of which ſuffers any more alteration than if it were alone; becauſe the Rays act not on one another, by *Prop.* 6. and therefore the Aggregate can ſuffer none. Theſe two Propoſitions alſo might be further proved apart, by Experiments too long to be here deſcribed.

9. There can no Homogeneal Colours be reduced out of Light by Refraction, which were not commixt in it before: Becauſe by *Prop.* 7. and 8. Refraction changeth not the Qualities of the Rays, but only ſeparates thoſe which have

divers

divers Qualities, by means of their different Refrangibility.

10. The Sun's Light is an Aggregate of an indefinite variety of Homogeneal Colours, by *Prop.* 1, 3, and 9. And hence it is, that I call Homogeneal Colours alſo Primitive or Original. And thus much concerning Colours.

For a further Illuſtration of this Doctrine, *Mr.* Newton, *in his Book of Opticks lately publiſhed, has by undeniable Experiments explained moſt of the Principal Phænomena of Light and Colours: To which we refer the Reader.*

A Demonſtration concerning the Motion of Light, communicated from Paris.

PHiloſophers have been labouring for many Years to decide by ſome Experiment, whether the Action of Light be conveyed in an inſtant to diſtant Places, or whether it requireth time. M. *Romer*, of the *Royal Academy* of Sciences, hath deviſed a way taken from the Obſervations of the firſt Satellit of *Jupiter*, by which he demonſtrates, that for the diſtance of about 3000 Leagues, ſuch as is very near the bigneſs of the Diameter of the Earth, Light needs not one Second of Time.

Let (in *Fig.* 3. *Plate* 3.) *A* be the *Sun*, *B Jupiter*, *C* the firſt Satellit of *Jupiter*, which enters into the ſhadow of *Jupiter*, to come out at *D*, and let *E F G H K L* be the *Earth*, placed at divers diſtances from *Jupiter*.

Now ſuppoſe the *Earth*, being in *L*, towards the ſecond Quadrature of *Jupiter*, hath ſeen the firſt Satellit, at the time of its emerſion, or iſſuing out of the ſhadow at *D*, and that about 42½ Hours after (*viz.* after one Revolution of this *Satellit*) the *Earth* being in *K*, do ſee it return'd in *D*: It is manifeſt, that if the Light require time to traverſe the Interval *L K*, the *Satellit* will be ſeen return'd later in *D*, than it would have been if the *Earth* had remained in *L*. So that the Revolution of the *Satellit* being thus obſerv'd by the Emerſions, will be retarded

ded by ſo much time, as the Light ſhall have taken in paſſing from *L* to *K*; and that on the contrary, in the other Quadrature *F G*, where the *Earth* by approaching goes to meet the Light, the Revolutions of the Emerſions will appear to be ſhortned, by ſo much as thoſe of the Emerſions had appear'd to be lengthned. And becauſe $42\frac{1}{2}$ Hours, which this *Satellit* very near takes to make one Revolution, the diſtance between the *Earth* and *Jupiter*, in both the Quadratures, varies at leaſt 210 Diameters of the *Earth*: It follows, that if for the Account of every Diameter of the *Earth* there were required a Second of Time, the Light wou'd take $3\frac{1}{2}$ Minutes for each of the Intervals *G F*, *K L*; which would cauſe near half a quarter of an Hour between two Revolutions of the firſt *Satellit*, one obſerv'd in *F G*, and the other in *K L*, whereas there is not obſerved any ſenſible difference.

Yet doth it not follow hence, that Light demands no time. For after M. *Romer* had examin'd the thing more nearly, he found that what was not ſenſible in two Revolutions, became very conſiderable in many being taken together; and that, for Example, forty Revolutions obſerved on the ſide *F*, might be ſenſibly ſhorter, than forty others obſerv'd in any place of the *Zodiack* where *Jupiter* may be met with; and that in proportion of Twenty two for the whole Interval of *H E*, which is the double of the Interval that is from hence to the Sun.

The neceſſity of this new Equation of the Retardment of Light, is eſtabliſh'd by all the Obſervations that have been made in the *Royal Academy*, and in the *Obſervatory*, for the ſpace of eight Years; and it hath been lately confirmed by the Emersion of the first *Satellit* observ'd at *Paris*, the 9*th* of *November* last, at 5 a-clock 35′ 45″ at Night, 10 Minutes later than it was to be expected, by deducting it from those that had been observ'd in the Month of *August*, when the *Earth* was much nearer to *Jupiter*; which M. *Romer* had predicted to the said Academy from the beginning of *September*.

But to remove all doubt, that this Inequality is caused by the Retardment of the Light, he demonstrates, that it cannot come from any Excentricity, or other Cause of those that are commonly alledged to explicate the Irregularities of the *Moon*, and the other Planets; though he be well aware, that the first *Satellit* of *Jupiter* was Excentrick; and that, besides his Revolutions were advanced or retarded, according as *Jupiter* did approach to or recede from the Sun; as also, that the Revolutions of the *Primum Mobile* were unequal: Yet, saith he, these three last Causes of Inequality do not hinder the first from being manifest.

An

An introductory Eſſay *to the Doctrine of* Sounds, *containing ſome Propoſals for the improvement of* Acouſticks; *As it was preſented to the* Dublin Society, *Nov.* 12. 1683, *by the Right Reverend Father in God* Narciſſus *Lord Biſhop of* Ferns *and* Leighlin.

BEing to treat of the Doctrine of *Sounds*, I hold it convenient to premiſe ſomething in the general, concerning this Theory; which may ſerve at once to ingage your Attention, and excuſe my Pains, when I ſhall have recommended them, as beſtow'd on a Subject not altogether uſeleſs and unfruitful.

And for this purpoſe I ſhall omit to ſpeak any thing of the *Excellency* of the Matter in Hand; though it might be celebrated by Arguments drawn from ſeveral Topicks, and particularly from this, that new Diſcoveries and Improvements may be made, both as to the *Generation*, *Propagation* and *Reception* of Sounds into the Senſe; which, in a peculiar manner agrees to this, above the Object of any other Senſe whatſoever. I ſhall, I ſay, omit theſe things, and apply my ſelf wholly to the *Uſefulneſs* of the Theory, that we are now falling upon, which I think cannot better be diſcovered, than by making a comparison 'twixt the

Senſes

Senſes of *Seeing* and *Hearing*, as to their Improvements. I mean, by ſhewing, that this latter of *Hearing* is capable of all thoſe improvements which the Senſe of *Seeing* has receiv'd from Art, beſides many more advantages that the *Ear* may enjoy, by the help of our Doctrine, above the *Eye*; all which moreover will be of as great benefit to Mankind, as any thing that *Opticks* have yet diſcover'd, if not of greater; which, with ſome other pre-eminencies that it has upon another Score, will happily render *Acouſticks* the nobler Science of the two.

In order to the making good what I but now premiſed of the Compariſon of theſe two Faculties of *Seeing* and *Hearing*, as to their Improvements, I obſerve;

That *Viſion* is threefold, *Direct*, *Refracted*, and *Reflex'd*; anſwerable whereunto we have *Opticks*, *Dioptricks*, and *Catoptricks*.

In like manner *Hearing* may be divided into *Direct*, *Refracted* and *Reflex'd*; whereto anſwer three parts of our Doctrine of *Acouſticks*, which are yet nameleſs, unleſs we call them *Acouſticks*, *Diacouſticks*, and *Catacouſticks*, or (in another Senſe, but to as good Purpoſe) *Phonicks*, *Diaphonicks*, and *Cataphonicks*.

1. Direct Viſion has been improv'd two ways, *ex parte* Objecti, and *ex parte* Organi *vel* Medii.

1. *Ex parti Objecti*, Direct Viſion has receiv'd advantages by the Arts of *Producing*, *Conſerving* and *Imitating Light* and *Colours*, which are the Objects of Viſion.

1. For the Art of *Producing Light*, we have the Frication of all hard Bodies that beget Fire; eſpecially of the Flint and Steel; and

inſtead

instead of the Flint, most hard Stones (as well as the Cane) may be us'd to the same effect, as upon trial I have found. Add hereto the lately invented *Phosphorus*, which is a new and admirable way of producing a *Lucid Substance* by Art, out of a Body in itself not *Lucid*; and therefore may not unfitly be term'd an *Artificial production* of *Light*.

And then of the Art of *Conserving Light*, the *Lapis Bononiensis* is a notable Instance; and so happily were the *Sepulchral Lamps* of the Ancients.

2. As to *Colours*, 'tis the greatest part of the Art of *Dying* to be able to make and fix (that is preserve) them; and the *Painters* and *Limners* will own it to be no small part of their Skill to be able well to *Mix* (that is, in effect, to *Generate*) *Colours*.

3. For *Imitation of Light* and *Colours*, 'tis well known how far *Perspective* with the Art of *Limning* and *Shadowing* have gone therein, which all tend some way to the Advance or Improvement of *Direct Vision*.

Add to all these, That *a due Application of Light to the Object* renders it Visible, if it were not so before; as appears from a dark Room illuminated; or else makes it better and more truly discernable by the Sense of *Seeing*, if before it might have been discern'd.

Hence the same *Colour*, in a diverse Light, will appear different, and no *Picture* can well be discern'd or judg'd of but by its true Light. Besides, the *Limner* will assure you, that he can hardly make true Work, or hit the Air of a Face exactly, unless he draw by a *North-Light*, by reason of the steadinss of that, and the uncertainty of all other Lights whatsoever.

Which

Which things ſhew, that the *Art of duly applying Light to the Object* does very much help and improve Viſion. So alſo does the due placing of the *Object*, as to *Height* and *Diſtance*. But to enumerate all things that help *Direct Viſion*, would be infinite.

2. *Ex parte Organi vel Medii*, Direct Viſion has been improv'd by making uſe of a *Tube*, without Glaſſes, or a Man's clos'd Hand, to look thro'; which admitting into the *Eye* only the principal Rays, that come directly from the Object, do very much ſtrengthen and clear the Sight, by excluding all the Collateral Rays, that crouding into the Eye, together with the direct ones, would confound and diſturb it, partly by mixing and interfering with the direct Rays, and partly (or rather chiefly) by too much enlightning the fund of the Eye, wherein Viſion is truly (tho' then imperfectly) made.

On this is founded the Art of making *Spectacles* without Glaſſes; (as well as *Tubes*) which is done by putting into the Glaſs-holes (inſtead of Glaſſes) two ſhort *Tubes* of between three and four Inches long (for their length is to be vary'd according to the Age or Eye of the Beholder, and ſo alſo is the Diameter of the extream ends) which *Tubes* being made of *Spaniſh Leather* (or Paſt-board, or ſome ſuch like Matter) and black'd on the inſide, are ſo to be placed, as that the viſual Rays, receiv'd thro' them, may meet in one point (or rather iſſue out from one Point) of the Object ſtanding at ſuch a due diſtance, as the Perſon may clearly and diſtinctly ſee it, or according to his length of Sight (as ABC, in the 4th *Fig. Tab.* 3.)

And

And these *Spectacles* may be suppos'd better for preserving the Sight, than the ordinary ones with Glasses, because they represent the Object more naturally, and withal more clearly and distinctly to the Eye, than the other, whose refracted Rays being collected together with the right ones in the Glasses, do somewhat confound good Vision, as before: Especially if the visive Power be strong enough to be sufficiently determin'd by the right Rays alone.

For I speak now of preserving a good Eye by these Spectacles, which holds in proportion true also of a bad one. Because those Rays (both right and refracted) being collected and brought so near the Eye (whether good or bad) as the Spectacles are usually plac'd, do too much affect it, both by their own brightness, and also by the brightness of the Colours of the Object (when they are bright) which is brought very near also; whereby the Eye is dazl'd and confounded, unless there be a strong attention and *conatus* of the Spirits, whereto the bright Rays do certainly engage them, which of necessity weakens Vision, especially if these Glass-spectacles be much us'd.

Wherefore the now describ'd new Tube-spectacles, contributing so much to the help and preservation of Sight, may well be counted an improvement of *Direct Vision*, because they convey the Rays to the Eye without any kind of Refraction whatsoever. Seeing the same Object also through various holes, plac'd at certain distances, does somewhat alter Vision; but of this perhaps more hereafter.

Now as *Direct Vision* has thus been improved, so likewise *Direct Hearing* partly has already receiv'd, and partly may (by the Doctrine whereof

whereof we are treating, (if well cultivated) farther receive as great and notable Improvements, both *ex parte* Objecti, and *ex parte* Organi *vel* Medii.

1. As to the *Object* of Hearing, which is Sound, improvement has been and may be made, both as to the *Begetting*, and as to the *Conveying* and *Propagating* (which is a kind of *Conserving*) of Sounds.

1. As to the *Begetting* of Sounds. The Art of imitating any Sound, whether by *Speaking* (that is pronouncing) any kind of Language, (which really is an Art, and the *Art of Speaking*, perhaps one of the greatest) or by *Whistling*, or by *Singing* (which are allow'd Arts) or by *Hollowing* or *Luring* (which the Huntsman or Faulkner would have to be an Art also) or by imitating with the Mouth (or otherwise) the Voice of any Animal, as of *Quails*, *Cats*, and the like; or by *representing* any Sound begotten by the Collision of Solid Bodies, or after any other manner; these are all *Improvements* of *Direct Hearing*, and may be improv'd.

Moreover the Skill to make all sorts of *Musical Instruments*, both Ancient and Modern, whether *Wind* Instruments or *String'd*, or of any other sort, whereof there are very many (as *Drums*, *Bells*, the *Systrum* of the *Egyptians*, and the like) that beget (and not only propagate) Sounds; the Skill of making these, I say, is an Art, that has as much improv'd *Direct Hearing*, as an Harmonious Sound exceeds a single and rude one, that is, an immusical *Tone*; which Art is yet capable of farther improvement. And I do hope, that by the Rules, which may happily be laid down concerning the *Nature*, *Propagation* and *Proportion*, or *A-*

dapting

dapting of Sounds, a way may be found out, both to improve *Musical Instruments* already in uſe, and to invent new ones, that ſhall be more ſweet and luſcious, than any yet known. Beſides that, by the ſame means *Instruments* may be made, that ſhall imitate any Sound in Nature, that is not Articulate, be it of Bird, Beaſt, or what thing elſe ſoever.

2. The *Conveying* and *Propagating* (which is a kind of *Conſerving*) of Sounds, is much help'd by *duly placing the Sonorous Body*, and alſo by the *Medium.*

For if the Medium be *Thin* and *Quieſcent*, and the Sounding Body *plac'd conveniently*, the Sound will be eaſily and regularly propagated, and mightily conſerv'd. I ſay,

1. If the *Medium be Thin and Quieſcent*, becauſe it otherwiſe cauſes a *Refracted Sound*, of which afterwards. Hence in a *ſtill Evening*, or the *dead of the Night* (when the Wind ceaſes) a Sound is better ſent out, and to a greater diſtance than otherwiſe, tho' much of this may be aſcrib'd to its *Refraction* alſo.

2. I ſay, that the *Sonorous Body muſt be plac'd conveniently*, near a *Smooth Wall*, near *Water*, or *a Plain*, whoſe Surface is even.

1. Near a *Smooth Wall*, either Plain or Arch'd (Cycloidically or Elliptically, rather than otherwiſe, tho' a Circular or any Arch will do, but not ſo well.)

Hence in a Church, the nearer the Preacher ſtands to the Wall (and certainly 'tis much the beſt way to place Pulpits near the Wall) the better is he heard, eſpecially by thoſe who ſtand near the Wall alſo, though at a greater diſtance from the Pulpit; thoſe at the remoteſt end of the Church, by laying their Ears ſome-

what

what close to the Wall, may hear him easier than those in the middle.

Hence also do arise *Whispering Places.* For the Voice being apply'd to one end of an Arch, easily rowls to the other. And indeed were the *Motion* and *Propagation* of Sounds but rightly understood, 'twould be no hard matter to contrive *Whispering Places* of infinite variety and use. And perhaps there could be no better or more pleasant hearing a *Consort of Musick* than at such a place as this, where the Sounds rowling along together, before they come to the Ear, must needs consolidate and imbody into one; which becomes a true composition of Sounds, and is the very Life and Soul of Consort.

2. If the Sonorous Body be plac'd near *Water*, the Sound will easily be convey'd, yet mollified; as Experience teacheth us from a Ring of *Bells* near a River, and a great *Gun* shot off at Sea, which yet differ much in the strength, and softness and continuance, or propagation of their Sounds, from the same at Land, where the Sound is more harsh and more perishing, or much sooner decays.

3. In a *Plain* a Voice may be heard at a far greater distance than in uneven Ground.

The *Reason* of all which last nam'd *Phænomena* is the same; because the Sonorous Air meeting with little or no resistance upon a *Plane* (much less upon an Arch'd) smooth Superficies, easily rowls along it, without being let or hinder'd in its Motion, and consequently without having its parts disfigured, and put into another kind of Revolution, than what they had at the first begetting of the Sound. Which is the true cause of its *Preservation* or *Progression*, and fails much when the Air passes over an uneven

even Surface, according to the degrees of its inequality, and somewhat also, when it passes over the plain Superficies of a Body that is hard and resisting.

Wherefore the smooth Top of the Water (by reason of its yielding to the Arch'd Air, and gently arising again with a kind of Resurge, like to *Elasticity*, tho' it be not so, by which Resurge it quickens and hastens the motion of the Air rowling over it, and by its yielding preserves it in its Arch'd Cycloidical or Elliptical Figure) the smooth Top of the Water, I say, for these Reasons, and by these Means, conveys a Sound more entire, and to a greater distance than the plain Surface of a piece of Ground, a Wall, or any other Solid Body whatever, can do.

As for the *Speaking Trumpet*, by which a Voice may be convey'd to a considerable distance, I refer its consideration to that of *Refracted Sounds*, or *Refracted Audition*.

Thus much of the Improvements of Hearing, that respect its *Object*, which is *Sound*.

2. The *Organ* and *Medium* are to be consider'd. And, 1. The *Organ*, which is the *Ear*, is helpt much by placing it near a Wall (especially at one end of an Arch, the Sound being begotten at the other) or near the Surface of Water, or of the Earth, along which the Sounds are most easily and naturally convey'd, as was before declar'd. And 'tis incredible how far a Sound made upon the Earth (by the trampling of a Troop of of Horses, for Example) may be heard in a still Night, if a Man lays his Ear close to the Ground in a large Plain.

Otacousticks here come in for helping the *Ear*; which may be so contriv'd (by a right understanding the *Progression of Sounds*, which is the principal thing to be known for the due regulating all such kinds of Instruments) as that the Sound might enter the Ear without any Refraction, but as now they are generally made I refer them to *Refracted Audition.*

2. As to the *Medium*, I know not how that, by any contrivance of Art, can advantage *Direct Hearing*, otherwise than I have declar'd already in the propagation or conveyance of Sounds, though to the Refracting or Reflecting of them it may very much conduce; of which presently.

And so I have done with the first part of my present undertaking, which is the *Comparison of Direct Vision and Audition*, as to their Improvements from Art. The rest follow. Wherefore,

II. Concerning *Refracted Vision* and its Comparison, I observe, That *Refracted Vision* is always made *Ex parte Medii*, as *Reflected* is *ex parte Objecti.* And therefore, though *Direct Vision* may be help'd *ex parte Objecti, Medii vel Organi*, yet *Refracted* can be improv'd only *ex parte Medii*, and *Reflected ex parte Corporis oppositi* alone. Unless it be in a mixt or compound Vision, that is *Refracto-Reflext*, when the reflext Rays pass to the Eye through a refracting Medium, such as the *Medium Internum*, contain'd in the Body of the Eye, always is. So that in truth, all Vision is *Refracted* by an internal Refraction made in *ipso Oculo.*

And

And all that I have ſpoken of *Viſion* holds true of *Hearing* alſo, both *Refracted* and *Reflext*, and therefore need not be repeated.

Refracted Viſion ariſes from the different *Denſity*, *Figure*, and *Magnitude* of the Medium, which is ſomewhat alter'd alſo by the diverſe incidence of the viſible Rays. And ſo it is in *Refracted Hearing*, all theſe Cauſes concur to its Production, and ſome others to be hereafter conſider'd.

Now as any Object (a Man for example) ſeen through a thicken'd Air, by *Refraction* appears greater than really he is: So likewiſe a *Sound*, heard through the ſame thicken'd part of the *Atmoſphere*, will be conſiderably vary'd from what it would ſeem to be, if heard through a thinner Medium.

And this I call a *Refracted Sound*: But what this Refraction of Sound is, and how caus'd, may hereafter be diſcuſs'd, when the Nature, and Motion, or Progreſſion of Sounds are well ſtated.

For the Improvement of *Refracted Viſion* artificial Inſtruments have been made, by grinding or blowing Glaſſes, into a certain Figure, and placing them at due diſtances, whereby the Object may be (as 'twere) enabled to ſend forth its Rays more vigorouſly, and the Viſive Faculty impower'd the better to receive them. And thus alſo Inſtruments may be contriv'd for the aſſiſting both the *Sonorous Body*, to ſend forth its Sound more ſtrongly, and the *Acouſtick Faculty*, to receive and diſcern it more eaſily and clearly. *For*,

1. As a fine *Glaſs Bubble*, fill'd with clear Water, and placed before a burning Candle or Lamp, does help it to dart forth its Rays to a

prodigious Length and Brightness: So an *Instrument* may be invented, that apply'd to the Mouth (or any Sonorous Body) shall send forth the Voice distinctly to as prodigious a Distance and Loudness.

For if the *Stentoro-phonecon* (which is but a rude and unartificial Instrument) does such great feats, what might be done with one compos'd according to the Rules of Art? whose make should comply with the Laws of *Sonorous Motion* (which that does not). and therefore not so much *Refract*, as to alter and confound the *Tone* of the *Voice* and Words (as that somewhat does.)

Now of what use such an Instrument might be for speaking clearly and articulately at a distance (and that without altering the Tone of the Voice) whether it be at Sea or at Land (but especially at Sea in tempestuous Weather and in the Night) is obvious to any Man to conceive.

2. As Instruments have been invented to help the Eye, So likewise are there some, and more such there may be, for the Ear.

For,

1. As *Spectacles* and other *Glasses* are made to help the *Purblind* and weak *Eyes*, to see at any competent distance: So there are *Otacousticks* (and better may be made) to help weak *Ears* to hear at a reasonable distance also. Which would be as great a help to the infirmity of Old Age, as the other invention of Spectacles is, and perhaps greater; forasmuch as the Hearing what's spoken is of more daily use and concern to such Men, then to be able to *read Books* or to *view Pictures.*

2. As

2. As *Perſpective-Glaſſes* and Teleſcopes help the Eye to ſee Objects at a very great diſtance, which otherwiſe would not be diſcernable; in like manner may a ſort of *Otacouſticks* be ſo contriv'd, as that they ſhall receive in *Sounds* made at a very great diſtance alſo, but with ſo much advantage, that the Ear ſhall be able to hear them, which otherwiſe would have been *inaudible.*

And theſe *Otacouſticks* in ſome reſpects would be of greater uſe than *Perſpectives.* For whereas at Land *Perſpectives* are many times render'd almoſt uſeleſs, by the interpoſition of Woods and Mountains, which hinder the Sight from reaching very far: Our *Otacouſticks* would, notwithſtanding theſe Obſtacles, take in a Sound made ſome Leagues off. Which might be of notable uſe in the time of War, for diſcovering the Enemy at a good diſtnnce, when he marches or lyes incamp'd behind a Mountain or Wood, or any ſuch place of ſhelter.

Yea, even at Sea alſo, where *Perſpectives* are of moſt uſe, by reaſon of the plaineſs of the Surface of the Water; yet ſometimes there *Otacouſticks* may be of more benefit, when in dark hazy Weather the Air is too thick, or in Stormy Tempeſtuous Weather the Waves ariſe too high for the *Perſpective* to be made uſe of.

But, whether at Sea or Land, *Perſpectives* become altogether inſignificant in the Night-time (unleſs it be for viewing the Stars) which is the chief time for uſing *Otacouſticks*; as it is generally, for Soldiers to take their March, when they would ſurpriſe their Enemies.

And therefore this ſort of *Otacouſticks* have then their chief uſe, when *Perſpectives* are of no uſe

use at all; besides that they may be imploy'd in the Day-time, as well as *Perspectives*, whence they may (not unfitly) be term'd *the most useful Instrument* of the two.

3. As *Microscopes* or *Magnifying-Glasses* help the Eye to see near *Objects*, that by reason of their smallness were *Invisible* before; which Objects they Magnify to a strange greatness: So *Microphones* or *Micracousticks*, that is Magnifying Ear Instruments, may be contriv'd after that manner, that they shall render the most minute Sound in nature distinctly audible, by Magnifying it to an unconceivable loudness.

By the help hereof we may hear the different Cries and Tones, as well as by *Microscopes* see the divers Shapes and Figures of the smallest Animals.

4. As by *Polyscopes* or *Multiplying-Glasses*, one thing is represented to the Eye as many, whether in the same or different Shapes (for so Multiplying-Glasses may be contriv'd:) So by a *Polyphone* or *Polyacoustick* well order'd, one *Sound* may be heard as many, either of the same or a different Note. Insomuch, that who uses this Instrument, he shall, at the Sound of a single Viol, seem to hear a whole Consort and all true Harmony. By which means this Instrument has much the advantage of the *Polyscope*.

And thus much may suffice for comparing the Improvements made upon *Refracted Seeing and Hearing*; I call it *Refracted Hearing*, because made through a *Medium*, viz. thick Air, or an Instrument, through which the Sound passing is broken or refracted.

III. *Reflected*

III. *Reflected Vision* has been improv'd by the Invention of *Looking-glasses* and *Polish'd Metals*, whether *Plane*, *Concave*, or *Convex*; and these two last, either *Spherical*, *Oval*, *Cylindrical*, *Conical*, *Hyperbolical*, or of several other shapes; all which cause a different Reflection, and vary the *Phænomena*.

Thus also *Reflext Audition*, made by *Ecchoes*, may be improv'd, by contriving several sorts of *Artificial Ecchoes*; as 'tis no hard matter to do in almost any place.

For (speaking in the general) *Any Sound, falling directly or obliquely upon any dense Body, of a smooth (whether Plane or Arch'd) Superficies, is beat back again and reflected, or does eccho more or less.*

I say (1.) *falling directly or obliquely*; because, if the Sound be sent out and propagated parallel to the Surface of the *Dense Body*, or be made so *far off* and so *weak*, that it cannot reach it, there will be no Reflection of Sound, no *Eccho*.

I say (2.) *upon a Body of a smooth Superficies*; because if the Surface of the *Corpus Obstans* be uneven, the Air by reverberation will be put out of its regular Motion, and the Sound thereby broken and extinguish'd: So that tho' in this case also the Air be beaten back again, yet Sound is not reflected, nor is there any Eccho.

I say (3.) *it does eccho more or less*, to shew, that when all things are, as is before describ'd, there is still an Ecchoing, though it be not always heard; either because the *direct Sound* is too weak to be beaten quite back again to him that made it; or that it does return home to him, but so weak, that without the help of a good *Otacoustick* it cannot be discern'd; or that he stands in a wrong place, to receive the reflected Sound, which passes over his head, under his Feet, or to one side of him; which therefore may be heard by a Man standing in that place, where the reflected Sound will come, provided no interpos'd Body does intercept it; but not by him, that first made it.

I shall further make out the comparison 'twixt *Reflex'd Vision* and *Audition*, by these following *Propositions*.

1. As a *Plain Speculum* reflects the *Object* in its due *Dimensions* and *Colours*; allowing for their difference of appearance, according to their distance: So a *Plane Corpus Obstans* reflects the *Sound* back in its due *Tone* and *Loudness*; if allowance be likewise made for the proportionable decrease of the Sound, according to its distance.

2. As a *Convex Speculum* reflects the *Object less*, but somewhat *brighter* or clearer: So a *Convex Corpus Obstans* repels the Sound (insensibly) *smaller*; but somewhat *quicker* (though *weaker*) than otherwise it would be.

3. As a *Concave Speculum* reflects the Object *bigger*, more obscure and *Inverted*: So a *Concave Corpus Obstans* ecchoes back the Sound (insensibly) *bigger*, *slower* (though *stronger*) and also *inverted*; but never according to the order of Words. Nor do I think it possible for the Art of Man to contrive a *Single Eccho*, that shall invert the Sound, and repeat backwards; because then the Words last spoken, that is, which do last occur to the *Corpus Obstans*, must first be repell'd; which cannot be: For where, in the mean time, should the first Words hang, and be conceal'd, or lie dormant? Or how, after such a pause, be reviv'd and animated again into

into Motion? Yet in complicated or *Compound Ecchoes*, where many receive from one another, I know not whether ſomething that way may not be done.

From the determinate *Concavity* or *Arched-neſs* of theſe reflecting Bodies, it comes to paſs, that ſome of them, from a certain diſtance or poſture, will eccho back but one determinate Note, and from no other place will they reverberate any; becauſe of the undue Poſition of the ſounding Body. Such an one (as I remember) is the Vault in *Merton* College in *Oxford*.

4. As a *Speculum* takes in and reflects more of its Object, when plac'd at a great diſtance from it, than when nearer; becauſe it reflects according to the apparent Magnitude of the Body at ſuch a diſtance, which is leſs: So alſo the *Ecchoing Body*, being remov'd farther off, reflects more of the Sound, than when nearer. And this is the reaſon, why ſome Ecchoes repeat but one Syllable, ſome one Word, and ſome many.

5. As *Specula's* may be ſo plac'd, that reflecting one upon or into the other, either directly or obliquely, one Object ſhall appear many; as in Sir *Samuel Moreland*'s Glaſs-room: After the ſame manner *Ecchoing Bodies* may be ſo contriv'd and plac'd, as that reflecting the Sound from one to the other, either directly and mutually, or obliquely and by Succeſſion, out of one Sound ſhall many Ecchoes be begotten; which in the firſt caſe will be all together, and ſomewhat involv'd or ſwallow'd up of each other, and thereby confus'd (as a Face in Looking-glaſſes obverted) in the other they will be diſtinct, ſeparate, and ſucceeding one another; as moſt *multiple Ecchoes* do.

Moreover

Moreover a *Multiple-Eccho* may be made, by so placing the *Eccho*ing *Bodies*, at unequal distances, that they reflect all one way, and not one on the other; by which means a manifold successive Sound will be heard (not without astonishment) one Clap of the hands like many, one Ha, like a laughter, one single Word like many of the same Tone and Accent, and so one Viol like many of the same kind imitating each other.

Furthermore, as *Specula's* may be so order'd, that by Reflection they shall make one single thing appear many different things; as one single Man to seem many Men, differing as to Shape and Complexion (or a company of Men) which I think Sir *Samuel Moreland's* Contrivance does not: So may *Eccho*ing *Bodies* also be order'd, that from any one Sound given, they shall produce many Ecchoes, different both as to their *Tone* and *Intension*. (The ground whereof has elsewhere been laid down in a Treatise concerning the *Sympathy of Lute-strings*.)

By this means a *Musical Room* may be so contriv'd, that not only one Instrument, play'd on in it shall seem many of the same *sort* and *size*; but even a Consort of (somewhat) different ones; only by placing certain *Eccho*ing *Bodies* so, as that any Note (play'd) shall be return'd by them in *3ds*, *5ths*, and *8ths*, which is possible to be done otherwise than was mention'd before in *Refracted Audition*.

I have now done with my *Comparison* of the two Noblest *Senses*, and *Sciences*, as to their *Improvements*; wherein I have been thus large, that I might give you a little prospect into the *Excellency* and *Usefulness* of *Acousticks*; and that thereby I might excite all that hear me, to bend

their

their Thoughts towards the making of Experiments for the compleating this (yet very imperfect, tho' noble) Science; a *Specimen* whereof I will give you in three *Problems*, and then preſent you with the *Semiplane* of an *Acouſtick or Phonical Sphere*, as an Attempt to explicate the great *Principle* in this Science, which is *The Progreſſion of Sounds.*

The Problems are theſe :

1. *Sonum intendere quouſque velis* ; or, *Datum ſonum ad datum gradum intendere.*

2. *Sonum extendere quouſque velis* ; or, *Datum ſonum ad datum diſtantiam extendere ſeu propagare.*

3. *Sonum tranſire ab extremo ad extremum & non per Medium.*

1. The firſt is, *To make the leaſt Sound* (by the help of Inſtruments) *as loud as the greateſt* ; a whiſper to become as loud as the ſhot of a Cannon.

By the help of this *Problem*, the moſt minute Sounds in Nature may be clearly and diſtinctly heard.

2. The ſecond is, *To propagate any* (the leaſt) *Sound to the greateſt diſtance.*

By the help hereof any Sound may be convey'd to any, and therefore heard at any diſtance, (I muſt add, within a certain, tho' very large Sphere.)

Moreover, by this means, a *Weather-cock* may be ſo contriv'd, as that with an ordinary blaſt of Wind it ſhall cry (or whiſtle) loud enough to be heard many Leagues : Which happily may be found of ſome uſe, not only for *Pi-*

lots

lots in mighty tempestuous Weather, when *light Houses* are render'd almost useless; but also for the measuring the strength of Winds, if allowance be made for their different moisture. For I conceive, that the more dry any Wind is, the louder it will whistle *cæteris paribus*; I say, *cæteris paribus*, because, besides the strength and dryness of Winds or Breaths, there are a great many other things (hereafter to be considered) that concur to the increase or magnifying of Sounds, begotten by them in an Instrument exposed to their Violence, or blown into.

3. The third *Problem*, is, *That a Sound may be convey'd from one extreme to the other* (or from one distant place to another) *so as not to be heard in the middle.*

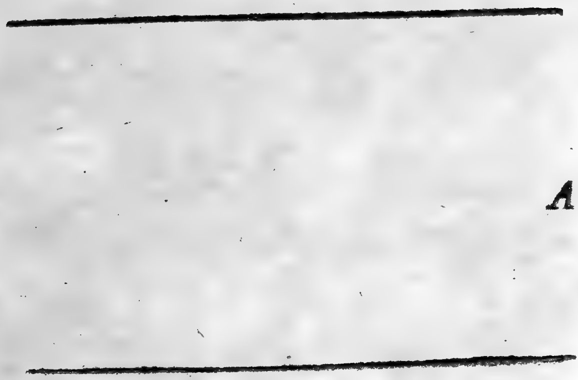
By the help of this *Problem* a Man may talk to his Friend at a very considerable distance, so that those in the middle space shall hear nothing of what passed betwixt them.

FIG. V. TAB. III.

Semiplanum Sphæræ Phonicæ seu Acousticæ.

You are to conceive that (rude) *Semiplane*, as parallel to the *Horizon*: For if it be perpendicular thereunto, I suppose the upper extremity will be no longer *Circular*, but *Hyperbolical*, and the lower part of it suited to a greater Circle of the Earth. So that the whole *Phonical* Sphere (if I may so call it) will be a solid *Hyperbola*, standing upon a *Concave Spherical* Base. I speak this concerning *Sounds* made (as usually they are) nigh the Earth,

Earth, and whoſe Sonorous *Medium* has a free paſſage every way. For if they are generated high in the Air, or directed one way, the caſe will be different; which is partly deſign'd in the inequality of that Draught.



A Diſcourſe concerning the Modern Theory *of* Generation, *by Dr.* George Garden *of* Aberdeen, *being part of a Letter to Dr.* William Muſgrave, *L. L. D. Reg. Soc. S. and by him communicated the Royal Society.*

THE Subject I pitch upon, is that of the Formation of Animals. You know how wide and unſatisfying Men's Conjectures were upon this Head, until this Age, in which firſt the deſervedly Famous Dr. *Harvey* diſcovered the proper place of the Formation of the Chick in the *Cicatricula* of the Egg, and the Formation of the Parts ſo far as was diſcernable by the naked Eye; and after him *Malpighius*, by the help of exact Glaſſes, obſerv'd the firſt Rudiments of it there, both before and after Incubation: And *R. de Graef*, and others, having upon many Obſervations concluded, that the *Teſtes Fœminei* were the Ovaries of Females, and conſequently that all Animals were *ex ovo*; they began from hence to infer, that the Rudiments of each Animal were originally in the reſpective Females, and that the Male contributed only to give a new Ferment to the Maſs of the Blood and Spirits, by which means a ſpirituous Liquor (which the Blood in its ordinary Ferment could not produce) did inſinuate it ſelf into the

the ſame Ducts and Pores of the Rudiments of thoſe Animals, which were in greateſt forwardneſs in the Ovary, and ſo extend and enlarge all their Parts, and at laſt bring them to perfection, as Mr. *Perrault* does ingeniouſly diſcourſe in the third Part of his *Eſſais de Phyſique*; till now at laſt *Leowenhoek* has diſcover'd an infinite number of *Animalcula in ſemine marium* of all kinds, which has made him condemn the former Opinions about the Propagation of all Animals *ex Ovo.*

Now upon comparing the Obſervations and Diſcoveries which have been made with one another, theſe three things ſeem to me very probable. 1. That Animals are *ex Animalculo.* 2. That theſe Animalcles are originally *in ſemine Marium & non in Fœminis.* 3. That they can never come forward, nor be formed into Animals of the reſpective kind, without the *Ova in Fœminis.*

The firſt of theſe ſeems probable from theſe three Obſervations. 1. That ſome ſuch thing has been ſo often obſerv'd by *Malpighius*, in the *Cicatricula* of an Egg before Incubation, as the Rudiments of an Animal in the ſhape of a Tadpole, as may be ſeen in his firſt, and in his repeated Obſervations *de formatione Pulli in Ovo.* 2. The ſudden appearance and diſplaying of all the Parts after Incubation, makes it probable, that they are not then actually formed out of a fluid, but that the *Stamina* of them have been formerly there exiſtent, and are now expanded. The firſt Part of the Chick which is diſcovered with the naked Eye, is, you know, the *Punctum ſaliens*, and that not till three days and nights of Incubation be paſt; and then, on the fifth day, the Rudiments of the Head and Body do appear. This made Dr. *Harvey* conclude, that the Blood had a being before any other Part of the Body; and that from it, all the Organs of the *Fœtus* were both form'd and nouriſhed: But by *Malpighius*'s Obſervations we find that the Parts are then only ſo far extended, as to be made viſible to the naked Eye, and that they were actually exiſtent before, and diſcernable by Glaſſes. After an Incubation of thirty hours, are to be ſeen the Head, the Eyes, and the *Carina* with the *Vertebræ*, diſtinct, and the Heart. After forty hours its Pulſe is viſible, and all the other Parts more diſtinct, which cannot be diſcerned by the naked Eye before the beginning of the fifth day; from whence it ſeems probable, that even the ſo early diſcovery of thoſe Parts of the *Fœtus* by the Microſcope, is not the diſcerning of Parts newly formed, but only more dilated and extended by receiving of Nutriment from the *Colliquamentum*; ſo that they ſeem all to have been actually exiſtent before the Incubation of the Hen. And what *Swammerdam* has diſcovered in the tranſformation of Inſects, gives no ſmall light to this; whilſt he makes appear in the Explanation of the 13th Table of the General Hiſtory of Inſects, that in thoſe large *Eruca's* which feed upon Cabbage, if they be taken about the time they retire to be transformed into *Aurelia's*, and plung'd often in warm Water to make a Rupture of the outer Skin, you will diſcern through the tranſparency of their ſecond Membrane, all the Parts of the Butterfly, the Trunk, Wings, Feelers, &c. folded up. But that after the *Eruca* is chang'd into an *Aurelia*, none of theſe Parts can be diſcern'd, they are ſo

drencht

drencht with moisture, tho' they be there actually form'd. Another Consideration is from the Analogy, which we may suppose between Plants and Animals. All Vegetables we do see proceed *ex Plantula*, the Seeds of Vegetables being nothing else but little Plants of the same kind folded up in Coats and Membranes; and from hence we may probably conjecture, that so curiously an organized Creature as an Animal, is not the sudden Product of a Fluid or *Colliquamentum*, but does much rather proceed from an Animalcle of the same kind, and has all its little Members folded up according to their several Joints and Plicatures, which are afterwards enlarged and distended, as we see in Plants. Now tho' this Consideration alone may seem not to bear much weight; yet being join'd to the two former, they do mutually strengthen each other. And indeed all the Laws of Mon tion, which are as yet discovered, can give bu a very lame account of the forming of a Plant or Animal. We see how wretchedly *Des Cartes* came off when he began to apply them to this Subject; they are formed by Laws yet unknown to Mankind; and it seems most probable, that the *Stamina* of all the Plants and Animals that have been, or ever shall be in the World, have been form'd, *ab Origine Mundi*, by the Almighty Creator within the first of each respective kind. And he who considers the Nature of Vision, that it does not give us the true magnitude, but the proportion of things; and that what seems to our naked Eye but a Point, may truly be made up of as many Parts as seem to us to be in the whole visible World, will not think this an absurd or impossible thing.

But the second thing which later Discoveries have made probable, is, that these Animalcles are originally *in Semine Marium & non in Fœminis.* And this I collect from these Considerations: 1. That there are innumerable *Animalcula* discover'd *in Semine Masculo omnium Animalium.* Mr. *Leewenhoeck* has made this so evident by so many Observations, that I do not in the least question the truth of the thing. The reason of their Multitude, and some of the Difficulties which arise thereupon, he has cleared to very good Purpose, so that I shall not repeat them. 2. The observing the Rudiments of the *Fœtus* in Eggs, which have been fecundated by the Male, and the seeing no such thing in those which are not fecundated, as appears from *Malpighius* his Observations, make it very probable that these Rudiments proceed originally from the Male, and not from the Female. 3. The resemblance between the Rudiments of the *Fœtus in Ovo*, both before and after Incubation, and the *Animalcle*, makes it very probable, that they are one and the same. The same Shape and Figure which Mr. *Leewenhoeck* gives us of the *Animalcle*, *Malpighius* likewise gives of the Rudiments of the *Fœtus*, both before and after Incubation; yea, and even the *Fœtus's* of Animals do appear so at first to the naded Eye, so that Dr. *Harvey* does acknowledge that all Animals, even the most perfect, are begotten of a Worm, *De Gen. Anim. Ex.* 18. 4. This gives a rational account of many *Fœtus's* at one Birth, especially that of the Countess of *Holland*, and how at least a whole Cluster of Eggs in a Hen are fecundated by one Coition of the Male. 5. This gives a new light, as it were, to the first Prophecy concerning the

Messiah,

Messiah, that the Seed of the Woman shall bruise the Head of the Serpent, all the rest of Mankind being thus most properly and truly the Seed of the Man. 6. The Analogy I have already mentioned, which we may rationally suppose between the manner of the propagation of Plants and Animals, does likewise make this probable. Every Herb and Tree bears its Seed after its kind; which Seed is nothing else but a little Plant of the same kind, which being thrown into the Earth, as into its *Uterus*, spreads forth its Roots, and receives its Nourishment, but has its form within its self, and we may rationally conjecture somce such Analogy in the Propagation of Animals.

The third Particular which later Discoveries make probable, is, that Animals cannot be formed of these *Animalcula* without the *Ova in fœminis*, which are necessary for supplying of them with proper Nutriment: And this these Considerations seem to evince. 1. It is probable that an *Animalcle* cannot come forward, if it do not fall into a proper *Nidus*. This we see is the *Cicatricula* in Eggs; and tho' a Million of them should fall into an Egg, none of them would come forward, but what were in the Center of the *Cicatricula*; and perhaps the *Nidus* necessary for their formation is so proportion'd to their bulk, that it can hardly contain more than one *Animalcle*; and this may be the reason why there are so few Monsters. This we see is absolutely necessary in *Oviparis*; and the only difference which seems to be between them and the *Vivipara*, in this matter, is in this, that in the latter the *Ova* are properly nothing more but the *Cicatricula*, with its *Colliquamentum*, so that the *Fœtus* must spread forth its Roots into the *Uterus* to receive its nouriſhment; but the Eggs in *Oviparis* may be properly term'd an *Uterus*, in relation to the *Fœtus*; for they contain not only the *Cicatricula*, with its *Amnion* and the *Colliquamentum*, which is the immediate nouriſhment of the *Fœtus*, but alſo the materials which are to be converted into that *Colliquamentum*; ſo that the *Fœtus* ſpreads forth its Roots no farther than into the White and Yolk of the Egg, from whence it derives all its nouriſhment. Now that an Animalcle cannot come forward without ſome ſuch proper *Nidus*, Mr. *Leewenhoek* will not readily deny; for if there were nothing needful, but their being thrown into the *Uterus*, I do not ſee why many hundreds of them ſhould not come forward at once; for as to what Mr. *Leewenhoeck* ſays, that one of them would be-dwarf and choak the reſt; this might fall out in proceſs of time: But at firſt I do not ſee why many of them ſhould not grow together, whilſt ſcatter'd in ſo large a Field (and yet no ſuch thing is obſerved) if there were not an abſolute neceſſity of a *Cicatricula* for their growth and thriving. Now, 2. That this *Cicatricula* is not originally in *Utero*, ſeems evident from the frequent Conceptions which have been found *extra Uterum*: Such as the Child which continued Twenty ſix Years in the Woman of *Tholouſe*'s Belly, mention'd *Numb.* 139. of the *Philoſ. Tranſ.* And the little *Fœtus* found in the *Abdomen de St. Mere*, together with the Teſticle torn and full of clotted Blood, recorded *Numb.* 150. both taken out of the Journals *des Savans*: Such alſo ſeem to be the *Fœtus* in the *Abdomen* of the Woman of *Copenhagen*, mention'd in the *Nouvelles des Lettres*, for *Sept.* 85. *pag.* 996. all the

the Members of which were easily to be felt through the Skin of the Belly, and which she had carried in her Belly for four Years; and the seven Years Gravidation, related by Dr. *Cole*, *Numb.* 172. of the *Transact.* That these two were undoubtedly *extra Uterum*, is uncertain, because the last was not open'd after her death, and the former may be yet still alive. Now granting once the necessity of ~~a~~ proper *Nidus*, for the formation of an Animalcle into the Animal of its respective kind; these Observations make it probable, that the *Testes* are the *Ovaria* appropriated for this use; for tho' the Animalcles coming thither in such Cases may seem to be extraordinary, and that usually the Impregnation is in *Utero*; yet it may be collected from hence, that the *Cicatriculæ* or *Ova* to be impregnated, are in *Testibus fœmineis*; for if it were not so, the accidental coming of Animalcles thither could not make them come forward more than in any other part of the Body, since they cannot be formed and nourished without a proper *Nidus*. But 3. It is acknowledg'd by all, that the *Fœtus in Utero*, for some considerable time after Conception, has no connexion with the Womb, that it sits wholly loose to it, and is perfectly a little round Egg with the *Fœtus* in the midst, which sends forth its Umbilical Vessels by degrees, and at last lays hold on the *Uterus*. Now from hence it seems evident, that the *Cicatricula*, which is the Fountain of the Animalcles nourishment, does not sprout from the *Uterus*, but has its *Origin* elsewhere, and falls in thither as into a fit Soil, from whence it may draw Nutriment for the growth of the *Fœtus*, else it cannot be easily imagin'd, how it should not have an immediate

Connexion with the *Uterus* from the time of Conception. If you join all theſe three Conſiderations together, *viz.* that an *Animalcle* cannot come forward without a proper *Nidus* or *Cicatricula*; that there have been frequent *Fœtus's extra Uterum*; and that they have no *Adhæſion* to the *Uterus*, for a conſiderable time after Conception, they ſeem to make it evident, that Animals cannot be form'd *ex Animalculis* without the *Ova in Fœminis.* To all theſe I ſhall ſubjoin the Propoſal of an *Experimentum Crucis*, which may ſeem to determine, whether the *Teſtes Fœmineæ* be truly the *Ovaria*, *viz.* Open the *Abdomen* of the Females of ſome kinds, and cut out theſe Teſticles, and this will determine, whether they be abſolutely neceſſary for the formation of Animals.

There are ſome Difficulties propoſed againſt this Conjecture, which I think may be eaſily reſolved. Some object the diſtance between the *Tubæ* or *Cornua Uteri*, and the Teſticles; but to this is oppoſed by *Swammerdam*, and others, the like diſtance between the *Infundibulum*, in Hens and Frogs, and the Ovary; and yet it cannot be denied that the Eggs are tranſmitted thro' this into the *Uterus*: And beſides *R. de Graef*, and others, have by repeated Obſervations found that the *Cornua Uteri* do at certain times after Conception, embrace the *Teſtes* on both ſides the *Uterus.* They object in the ſecond place the great diſproportion between the pretended Eggs in the *Ovary*, and the Aperture of the *Tubæ* or *Cornua Uteri*, the former being a great deal bigger than the latter: But both *R. de Graef* and *Malpighius* have clear'd that Matter, by making appear, that theſe Bladders in the Ovary are not the *Ova*, but ſerve to form the *Glandules*

within

within which the *Ova* are formed, which break through a small *Papilla* opening in the *Glandule*, which bears a proportion to the Aperture of the Tube. They object 3, The difficulty to conceive how these Eggs should be impregnated *per semen Maris*, both because there is no Connexion between the *Tubæ* and the *Ovary* for its transmission, and for that Dr. *Harvey* could never discover any thing of it *in Utero*. As to the last, Mr. *Leewenhoeck* has cleared that difficulty, by the discovery of innumerable *Animalcula Seminis Maris in Cornubus Uteri*, and those living a considerable time after Coition. *Numb.* 174. of the *Transact*. And as to the former, we may either suppose that there is such an Inflation of the *Tubæ* or *Cornua Uteri tempore Coitionis*, as makes them embrace the *Ovaria*, and such an approach of the *Uterus* and its *Cornua*, as that I may easily transmit the Seed into the *Ovary*; or else, that the *Ova* are impregnated by the Animalcles after they descend into the *Uterus*, and not in the *Ovary*; the former seems probable for this Reason, that at least a whole Cluster of Eggs in a Hen will be fecundated by one Tread of the Cock: Now this Fecundation seems to be in the Vitellary, and not in the *Uterus*, as the Eggs pass along from day to day; for it can hardly be supposed that the Animalcles should subsist so long, being scattered loosely in the *Uterus*, as to wait there for many days for the Fecundation of the Eggs as they pass along. The latter Conjecture has this to strengthen it, that the Animalcles are found to live a considerable time in the *Uterus*; and that if they should impregnate the *Ova* in the Ovary it self, the *Fœtus* would increase so fast, that the *Ova* could not pass through the *Tubæ Uteri*, but would either burst the Ovary, or fall down into the Abdomen from the Orifices of the *Tubæ*; and that from hence proceed those extraordinary Conceptions in *Abdomine extra Uterum*. But, 4. Mr. *Leewehoeck*, *Numb.* 147. of the *Transact.* to weaken the third Consideration about the Conceptions, being like unto an *Ovum* in the Womb, proposes a Parallel between these Animalcules and Insects; and insinuates, that as the latter cast their Skins, and appear of another Shape, so the other which at first seem like Tadpoles, may cast their outer Skin, and then be round; and that this may be the occasion of the round Figure of the Conception in the Womb. To this it may be replied, that according to Mr. *Leewenhoeck*'s own Sentiment, the Animalcles cannot come forward, if they do not find the *Punctum* or proper place for their Nourishment, to which it seems they must have some *Adhæsion*. Now the Conception in *Viviparis* is not fastned unto the Womb for many days, nor does adhere to any point of it; so that it seems this roundish Body is not the Animalcle thus chang'd after having cast an outer Skin, but is rather the *Cicatricula* or little Egg, into which the Animalcle has entred as its *Punctum* or place or nourishment; else I do not see why they should not be adhering to the Womb from the first Conception, or why (as I have said) many hundreds of them are not conceiv'd and formed together, *&c.*

A ſhort Diſcourſe concerning Concoction: Read at a Meeting of the Royal Society, May... 1699, *by* Clopton Havers, *M. D. Fellow of the Royal Society.*

THE manner in which the Digeſtion of the Aliment is performed, is a thing not very eaſie to be underſtood and explained. However, it has not eſcap'd the Conjectures of ſome Philoſophical Men, who having curiouſly obſerv'd the *Phænomena* of Nature, and enquired into their Cauſes, have, amongſt other things, endeavour'd to account for this. But their Sentiments about it have been various, and the Hypotheſis, by which they have ſtudied to explain it, very different. Some have thought the Concoction of the Food to be a kind of Elixation; and that the groſſer and more ſolid Parts being, as it were, boil'd in the Liquid by the Heat of the Stomach, and the Parts adjacent to it, as the Liver, Spleen, and Omentum, are by a long and continued Elixation, firſt render'd more tender, and then colliquated, and diſſolved into minuter Particles, ſo as to mix more equally with the Fluid, and with that to make one Pulpament, or chylous Maſs. And *Hippocrates*, tho' he does not plainly call it an Elixation, yet ſeems to attribute the Concoction of the Food to the Heat of the Stomach, as the Cauſe of it, *Sect.* 4. *Libro de ſalubri victus ratione.*

ratione. So where he takes notice of the voiding of ſuch Fæces, as appear to be like the Food that has been eaten; he adds, *Conſtat enim, ſane ventriculum, ciborum copiam, ut concoquat, calefacere non poſſe.* And there are other Paſſages in the ſame Book, from which we may conclude, that he ſuppos'd the Heat of the Stomach to be the great Cauſe of the Digeſtion of the Food.

There are others that make the Stomach itſelf to be the great Inſtrument of Digeſtion, but in a different manner: And they ſuppoſe it to be perform'd by an Attrition, as if the Stomach, by thoſe repeated Motions, which are the neceſſary Effects of Reſpiration, when it is diſtended by the Aliment, did both rub or grind off ſome minuter Particles from the groſſer Parts; and by continually agitating the Maſs of Food, make thoſe Parts, which are not contiguous to the Stomach, ſtrike one againſt another, and break one another in pieces, until they are all attenuated. It is evident enough, that the ſides of the Stomach do in Expiration preſs upon the *Contenta*, ſo as to oblige, at leaſt ſome Parts of them, every time the Muſcles of the Abdomen are contracted, to move and ſhift their places. So in Inſpiration, when the Diaphragm and Liver preſs upon the upper part of the Stomach, the Aliment muſt be moved again. So that by theſe reciprocal Motions, that part of the Food which is contiguous to the Stomach, and moves in a Line parallel to it, muſt rub againſt it; and all the other Parts being moved by ſuch a Compreſſion, as gives them a different Tendency, it is certain they muſt be continually ſtriking one againſt another. And for Bread, and ſuch things as are made of Flower, that will be softned and dissolv'd with any common Liquid, that Agitation of the Stomach which moves them in Respiration, might seem sufficient to break and dissolve them, when they are sufficiently moisten'd with a Fluid. Yet this cannot be thought enough to break and digest Flesh-meat, Fruits, or any other thing that will not be softned and dissolv'd in Water, or some such Liquid. But although this Motion of the Aliment, caused by Respiration, does not actually digest it, yet it has a great and necessary Use in Concoction, and makes all the grosser Parts, as they are attenuated, mix equally with the Fluid.

Some think that the Bilious Juice; others, that the Spirits are chiefly concern'd in this Affair. *Galen*, in his Book *de Neutralibus Facultatibus*, makes it to be the Effect, not of one, but of several Causes; as a pituitous Juice in the Stomach, the Bile, *&c.* which appears from what he has said, and the Translator thus render'd: '*Verum* '*quanto ii (cibi) qui mansi sunt, iis, qui inhæse-* '*runt, magis sunt alterati; tanto etiam his magis* '*ii, qui devorati sunt. Siquidem incomparabilis* '*erit horum alterationis excessus, si & quæ in ven-* '*tre est Pituita & Bilis, & Spiritus, & Calor, &* '*tota Ventris substantia, æstimentur.*

Some there are that will have the Food to be dissolv'd by a Menstruum, which is supply'd from the Glands of the Stomach, or some other way: But those that do so far agree in the General, as to think Concoction is perform'd by a Dissolvent, do differ in their Notions of the Nature of the Menstruum: For there are some that suppose it to be an Acid, which does erode the grosser parts of the Food, and dissolves them in the same manner as Vinegar, Spirit of Vitriol,

triol, or any ſuch-like Acid, will diſſolve even ſo ſolid a Body as Iron. And it cannot be deny'd, but that Oil of Vitriol will diſſolve Fleſh-meat, and reduce it to a Pulp; but it is not to be ſuppos'd, that the Fibres of the Stomach can admit any ſuch ſtrong and corroding Acid, without ſomething to correct it, but it muſt be injur'd in its Tone, and labour under great and extraordinary Pains. Neither does ſuch a Menſtruum, tho' it will digeſt ſome things, ſeem capable of diſſolving ſo great a Variety of Things as we eat, eſpecially when a great many of them are of a contrary Nature. Some will have the Menſtruum to be a *nitro-aerius* Spirit, that is, quick, and very penetrating, and included in its proper Vehicle; which, being in its own Nature apt to penetrate the Maſs of the Aliment, does diffuſe it ſelf through the Whole, and breaking the Vinculum of the more ſolid Parts, does diſſolve their Compages. By others, it is thought to be ſome ſaline Juice in the Stomach, by which the Parts of the Aliment are divided and diſſolved, and thoſe which are fit for Nouriſhment, are volatiliz'd.

Laſtly, There are ſome others who reject the Opinions I have already mention'd, and ſuppoſe the Digeſtion of the Food to be perform'd by the Benefit of a Ferment; which, when it is mixed with the Aliment, excites in the Maſs an inteſtine motion; and the different and contrary motions and tendency of the Parts, making ſome kind of Colliſion, gradually break off Particles from the groſſer, and more ſolid Parts, till they are ſo attenuated as to be apt to mix more equallly with the Fluid, and with them to make one ſoft or chylous Subſtance. But yet there is not amongſt them an univerſal Con-

ſent,

sent, either about the Nature of this Ferment, or the manner how it is supply'd. For first, some think it to be the Remains of the Food that was last digested; which having lain some time in the Stomach, after the rest is carried down into the Intestines, contracts an Acid, or some other Quality, and is so alter'd, as to partake of the Nature of a Leaven. And this Leaven being a part of the Food, which has been already digested, is so soft and liquid as to be capable of mixing with the Aliment, which is next taken into the Stomach; and being agitated with it by the repeated Pressures of the Diaphragm, Liver, and Abdominal Muscles upon the Stomach in Respiration, does diffuse it self through the whole Mass; and being mixed with it, like Leaven, or Yest added to new Wort, *&c.* puts it into a State of Fermentation; and by this Fermentation, or the Expansion of the Ferment, and the more tenuious Parts, which are first put into motion by it, those which are more solid, and with which they are intermixed, are rent, and divided, and so attenuated, as to become a soft and pulpous matter. And altho' the greatest part of the Food, that is thus broken and concocted, is by the Contraction of the Fibres of the Stomach press'd into the Duodenum; yet they do not contract themselves so as to force out all the Aliment, but leave between the *Rugæ* or Folds, on the inside of the Stomach, a sufficient Quantity to be a Leaven to the next Meal; and so from time to time.

Some have a Notion, That this Ferment, or Principle of Fermentation, is in the Aliment it self; which being a Congeries of Matter, consisting of various Parts of a different Nature,

is

is no sooner enclosed in the Stomach, and digested in the Heat of that, and the adjacent Parts, but the more spirituous and subtil Particles are put into motion both from that Warmth, and the difference of their Natures, and enter upon a Fermentation. And so by their intestine Commotion, and the Violence they offer to those Parts which oppose the tendency of any of them, they break and dissolve what is more solid.

Again: Some suppose, that this Ferment is supply'd from the Glands of the Stomach.

And Lastly, Others, and perhaps with much better Reason, contend for the Saliva, and make that to be the Ferment, which serves principally for the Digestion of the Food; which in Mastication being mix'd with our Aliment, is with that carried down into the Stomach, where the Parts of it being put into motion by a kindly and agreeable Heat, they do ferment with, and exagitate first those Parts of the Food which are most apt to ferment with it, and then both conspire to break and dissolve the grosser and more stubborn Parts. And *Galen*, in the Book I have before-mention'd, plainly allows that the *Saliva* is concern'd in the business of Concoction, tho' he supposes the Alteration, which is produc'd by this Juice, to be made in the Mouth, as appears from these Words: *Quæ (alteratio) in ore agitur mutat quidem id (nutrimentum) in alteram speciem manifestè, non tamen ad perfectionem transmutat*— *Qui mansi sunt cibi primum quidem hac Pituita (oris) imbuunter, & cum ea miscentur*—— *Itaque majorem mutationem consecuti sunt, quam ii, qui in vacuis dentium intervallis fuere impacti.*

Now

Now I have given this ſhort Account of the various Opinions of ſome Ingenious Men, concerning the manner how Concoction is perform'd; I come now to propoſe my own Hypotheſis, by which I ſhall endeavour to explain it.

In order to the more eaſie and effectual Digeſtion of the Food, Nature has appointed ſome Parts for the breaking our Aliment, and reducing whatever is groſs into ſmaller Parts, before it is put upon Digeſtion: Others to ſupply the Ferment, by which it is to be diſſolv'd and concocted, and which, before it comes to be included in the Stomach, does moiſten, and make it more ſoft, that it may more eaſily be penetrated, and broken by thoſe Parts which ſerve to divide every Morſel into ſmaller Pieces, and prevents the Inconvenience and Trouble which would ariſe from the Nouriſhment ſticking about or between them, when it is dry or viſcous.

For the breaking of that part of our Food, which is not liquid, Nature has furniſh'd us with Teeth, and thoſe of two ſorts: For ſome are ordain'd to divide and break off ſmaller Morſels from a larger Maſs; others are made for the grinding thoſe Morſels into much ſmaller parts. The Teeth, which ſerve to break off Pieces of a convenient Magnitude from a larger Maſs, are of two ſorts, accommodated to the Nature of the Subſtance which we eat. Theſe are the *Inciſores*, and the *Dentes Canini.* If the Subſtance, which we have to eat, be not hard, but more eaſily penetrated and divided, then the *Inciſores* are capable of making an Impreſſion upon it, and fix'd firmly enough in the

Jaws

Jaws to break off that part which they take hold of. But if it be more ſolid, and not eaſily penetrated, nor any Piece without difficulty to be ſeparated from that Body, whereof it is a part; then we apply the *Dentes Canini*, or Eye-Teeth, to it, which are not ſpread, nor have ſuch an edge as the *Inciſores*, but are ſharp and pointed like an Awl, and ſo do more readily penetrate a Subſtance that is hard, and which the *Inciſores* can ſcarcely make any Impreſſion upon. And as the Parts of a more ſolid Body are commonly with more difficulty ſeparated, and there muſt be a greater ſtreſs put upon thoſe Teeth which pull it into pieces; ſo theſe Teeth are much more firmly fixed in the Jaws than the *Inciſores*, tho' they have but one ſingle Root. Beſides, the Poſition of all theſe Teeth is accommodated to their uſe, as being planted oppoſite to the Apperture of the Mouth; ſo that they may be conveniently apply'd to the Subſtance which we have to eat, before it is broken, and when it is too large to be admitted within the Mouth.

The Teeth which do by a Compreſſion and Attritition reduce the little Morſels to ſmaller Parts, are from the manner in which they break the Aliment, called *Dentes Molares*, becauſe they do, like ſo many Mill-ſtones, grind the Food between them. And that they might be render'd fit for this purpoſe, they are made broad at that Extremity, which ſtands out of the Gums, by which means they retain ſome Quantity of the Food between them every time the lower Jaw is pulled up and forc'd againſt the *Maxilla ſuperior*. And as they are broad, ſo they are formed with Inequalities and Protuberances; and by the motion of the lower Jaw, from

from one ſide towards the other, they grind what they have between them into pieces. The Poſition of theſe Teeth too is as convenient as that of the *Inciſores*, and the *Dentes Canini*: For being deſign'd to break thoſe pieces of our ſolid Food, which are taken into the Mouth, and theſe pieces, when they are compreſs'd, and mov'd by the *Dentes Molares*, being apt to fly out of the Mouth, if there were no Contrivance to prevent it, they are placed beyond the Aperture of the Mouth, and oppoſite to the Cheeks, which keep the Food within that Cavity, and not only ſo, but preſs it in between the *Dentes Molares* on one ſide, as the Tongue does on the other, until they have ſufficiently broken and divided it.

At the ſame time, whilſt the *Dentes Molares* are breaking the Food, there flows into the Mouth a Salival Juice, which mixes with it, and not only ſerves to moiſten it, and to render it more apt and eaſie to be divided, but ſeems to be the Ferment, by the Benefit of which the Food is diſſolved and digeſted. And therefore it is intimately mixed with it, by the Teeth agitating or ſtirring them together in Maſtication.

This Liquor, which we commonly call the *Saliva*, or Spittle, ſeems to be a Compoſition made of two ſeveral Juices, very different in their Nature: And therefore the ſeveral Parts of it are ſeparated by their proper Glands, and Nature has planted no fewer than four Pair about the Mouth, which ſupply the Juices that make the *Saliva*; to wit, the *Parotides*, and the *Glandulæ Nuckianæ*, the

Glandulæ Maxillares internæ, and *Sublinguales.* Whereas if the *Saliva* were but one more simple Liquor, a less number of Glands might have been sufficient. At least there appears no Reason why one of every Pair should disembogue itself into the Mouth so very near to the Orifice, by which a Gland of some other Pair throws in its Juice; and they are not rather all planted at more equal distances from one another, so to flow in upon every part of the Aliment at the same time.

Not that I suppose, as there are four Pair of salivatory Glands, so there are four sorts of Juices supply'd from them, to make the *Saliva*; but, as I hinted before, that there are only two different Juices that constitute it. And these are not only sufficient, but more proper to excite and secure that Fermentation, which is necessary to Concoction. For we find that most of those Fermentations, which arise upon Mixtures made for Experiments, are produced from the mixture of two things; and it is not so easie to find out three or four such Liquors of a different Nature, as will, upon the mixtion of them all, produce a Fermentation, and from the omission of any one of them discover no Discord or Disposition to ferment: Besides, it is certain that two do better secure the End, which Nature designs. For, if there were three or four different Juices, of which the *Saliva* naturally consists, these must all have their proper Qualities preserved to them, or else the Fermentation, which should arise between them, will not necessarily follow upon their mixture; and it is certain, that there would be more

Danger,

Danger, that one of three or four should be deprived of its Natural Quality, than one of two

What Nature these two Juices are of, I do not pretend positively to determine; but so far as I have been able to make my Conjectures about it from Experiments, I do think one of them to be an acid Juice; the other an oleaginous Liquor, something like Oil of Turpentine. For amongst the many Experiments I have made, there was no one that gave me so much Satisfaction, as that which I made with Oil of Turpentine, and Oil of Vitriol, though I try'd several other things, that will produce a Fermentation upon their Mixture. And it was for this Reason, that I made the Experiment with Oil of Turpentine and the other Oil.

I took a piece of raw Flesh, and having cut it into pieces, but much larger than what our more solid Food is reduc'd to by due Mastication, I mix'd some Crums of Bread with it, then I pour'd in the Oil of Turpentine to them, and upon that the Oil of Vitriol; and having shak'd them together, I digested them about four Hours in *Balneo Mariæ*, and then shaking them again in the Glass, I found the Meat dissolv'd, and they all became a thickish Pulp. I could not but take notice, that Oil of Camphire (though it does not otherwise seem much different in its Nature from Oil of Turpentine) and Oil of Vitriol, which upon mixture will produce an Effervescence as well as the Oil of Turpentine and Oil of Vitriol, yet did not touch the Meat, upon which I poured them, so as in the least to dissolve them. I

 cannot

cannot deny but that an Acid, and a Solution of Salt of Tartar, did dissolve some part of the Flesh-meat, which I mix'd them with, but yet neither so soon, nor so perfectly as the two forementioned Oils. And I do the rather think one of those Juices, which constitute the *Saliva*, to be of the Nature of Oil of Turpentine, than of a fix'd Salt, because it will correct and temper even Oil of Vitriol, so as to render it more tolerable to the Fibres of the Stomach. Not that I suppose the acid part of the *Saliva* to come near to the Acidity of Oil of Vitriol. For though, when they are mix'd, they will make a Liquor that may not be injurious to the Stomach; yet the acid Juice, if it were so corrosive as Oil of Vitriol, would certainly be injurious and painful to the Salivatory Ducts, which convey it to the Mouth before it is mix'd with the oleaginous Liquor. But I only say it is an Acid, and in some degree approaches to the Nature of that Oil. And Nature, which can much better adapt several Causes for the Production of such an Effect than Art, may attain her End by a more temperate Acid; though, at the same time, we may be able to make some probable and true Conjectures about the Nature of those Causes from Experiments.

It being most reasonable to suppose, that there are but two sorts of Juices, of a different Quality, that make the *Saliva*, I do conceive, that four of the eight Salivatory Glands, or two Pair of the four, do supply one of these Juices, and the other four Glands the other. And this seems to be a very good Reason, why they are so planted, and the Orifice of their

Ducts

Ducts ſo order'd, that the Juice, which is ſupply'd by one Gland, is diſcharg'd into the Mouth, very near to the Orifice, by which the Juice of a different Nature is tranſmitted from another, ſo that they muſt neceſſarily meet and mix together. Thus the *Glandulæ Nuckianæ*, and *Parotides*, throw in two different Juices by Orifices, which open into the Mouth very near to one another; and the *Glandulæ Maxillares internæ*, and *Sublinguales*, do below ſupply the ſame kind of Juices by Orifices, that open ſo near to one another as to ſecure the mixture of the two different Juices.

Theſe Glands, I ſay, do between them afford two divers ſorts of Liquors, of ſuch a Nature as are apt to ferment upon their firſt Mixture, but perhaps more conſiderably when they come to be digeſted by the Heat of the Stomach. So that the Colluctation, or Fermentation, which attenuates and concocts the Food in the Stomach, does not ordinarily ariſe between the Aliment and the *Saliva*, but between the ſeveral Parts of the *Saliva* it ſelf. And indeed, if the *Saliva* did not conſiſt of two Juices, whoſe Nature is in ſuch a manner different, as to render them apt to ferment upon their mixture, it would be very hard to conceive how it ſhould ſo readily and indifferently ſerve for the Digeſtion of all Eatables; how it ſhould ferment with, and diſſolve ſo great a variety of Things, not only of a different, but of a contrary Nature; how it ſhould ferment with Acids as well as Alkalies, digeſt things that are cold, as well as hot or temperate; ſome things that are ſalt, others that are insipid, bitter and sweet, mucilaginous, oily, *&c.* But if we suppose, that the Fermentation, which serves for the Digestion of the Food, arises from a peculiar difference in the Nature of two Juices, which constitute the *Saliva*, it will be easie to give a rational Account of our Concoction of innumerable things of a different Nature. And this seems to be as effectual, and a more certain way to attenuate and dissolve the grosser Parts of our Food, than if the Fermentation were made only between the *Saliva* and the Aliment: Besides, the *Saliva* seems to discover a Fermentation upon the mixture of its constituent Juices, even at those times when we do not actually eat; for it is always attended with Bubbles, and a Froth, when it has not been at all agitated in the Mouth, and many of those Bubbles will remain for some considerable time after we have spit it out.

Nature therefore having appointed the *Saliva* for the digestion of the Food, has taken care that it shall be thrown in upon the Aliment on every side. Thus the *Glandulæ Nuckianæ*, and the *Parotides*, supply their Juices to that part of the Food, which lies on the outside of the Gums, between the Cheeks and the Teeth, and the *Glandulæ Maxillares internæ*, and *Sublinguales*, do bestow their Liquor upon the Meat, which is within the Teeth and Gums. Neither has she had a Regard only to that Supply, which is due to all the parts of our Food, but likewise to the mixture of the two different Juices of the *Saliva*, which is necessary to its Fermentation. And therefore, as I have already observ'd, the Orifices

rifices of the Ducts, which belong to one ſort of Glands, are placed near the Aperture of a Duct, which conveys a Juice from one of the other Glands. So the Ducts of the *Glandulæ Nuckianæ*, and the *Ductus Stenoniani*, do on each ſide open into the Mouth, near one another; and the ſalivatory Ducts of the *Glandulæ Sublinguales*, and the *Maxillares internæ*, though they have diſtinct Orifices, empty themſelves under the ſame *Papillæ*; and the Juices, which are ſupply'd by them, meet there, and flow into the Mouth together.

The ſeveral Parts of the *Saliva* being diſcharg'd into the Mouth in ſuch a manner as to meet and begin a Fermentation, the *Saliva* does, partly as it is agitated, with the Food by the Teeth, and ſome other parts of the Mouth; partly by its own Fluidity, inſinuate it ſelf into, and mixes with the Food, and not only moiſtens and ſoftens it, but excites the Fermentation, which is to diſſolve it. And when the Aliment is thus mix'd with the *Saliva*, which ſerves to ferment the whole Maſs, it is then to be convey'd into the Stomach, that great digeſtive Veſſel of the Body, where the Fermentation is not only continued, but improved.

The Nouriſhment being convey'd into the Cavity of the Stomach, is there kept for ſome time in a digeſtive Heat, all which time it is under a Fermentation, produc'd by the different Parts or Juices of the *Saliva*, which are mix'd with it; which Fermentation does firſt agitate the more tenuious or ſubtil parts of the Food, and puts them into motion, and ſo with the Fermentation of its own, and thoſe

Alimentatry Parts, which it firſt communicates a Motion to, improved by the Heat of the Stomach, the *Saliva* muſt neceſſarily act upon the groſſer Parts. For the inteſtine Motion, which is excited in the Maſs, does not give the Particles, which are fermented, the ſame Tendency, but what is ſo various and confus'd, that they muſt inevitably ſtrike not only one againſt another, but againſt thoſe which are more groſs, ſo as to attenuate them, ſometimes by a Colliſion, which ſtrikes off ſmaller Particles from the larger Parts; ſometimes by a Compreſſion, when the Particles which are in Motion, happen to ſtrike directly againſt any groſſer Part, on every ſide of it, ſometimes by a kind of Exploſion. For without doubt the *Saliva*, which is fluid, inſinuates it ſelf into the Interſtices of the more craſs Parts of the Aliment, and whatever is agitated and expanded in thoſe Interſtices, requiring a larger ſpace for the Freedom of its Motion, and offering a Violence to every thing that oppoſes its Tendency, will, like Gun-powder included in a Shell, force its way out, and tear to pieces that Matter, which does endeavour to confine it.

Thus the groſſer Parts are broken and divided, until they are at laſt ſo far attenuated as to mix more equally with the Fluid, and with them to make one Pulp or Chylous Maſs. And although I do not apprehend how the Stomach ſhould by its reciprocal Motions in Inſpiration and Expiration, be able to break and attenuate any Matter, that will not be ſoftned and diſſolved by Agitation in a Liquid; yet it is certain that theſe Motions, cauſed by the

the Diaphragm and Abdominal Muſcles in Reſpiration, do make thoſe Parts, which are broken off, as they are diſſolv'd, mix intimately with the more Liquid; as the Meat which I digeſted with Oil of Turpentine, and Oil of Vitriol, did by Agitation mix more equally with the Oils, and became a Pulpament.

As the Juices, which conſtitute the *Saliva*, do ferment upon their mixture, ſo it is probable, that from their Mixture and Fermentation there reſults ſuch a *Tertium quid*, as is apt to ferment with the Bile. And therefore, when the Aliment has been under the Fermentation, excited by the *Saliva*, a ſufficient time, it is then thrown into the *Duodenum*, where it meets with the bilious Juice, which flows into that Inteſtine from the Liver, from which a new Fermentation ſeems to begin; and the Commotion of the Parts of the Aliment being ſtill continued, does carry on the Buſineſs of Digeſtion until the Food is perfectly concocted: Though it is probable, that this new Fermentation ſerves not only for the more perfect Digeſtion of the Food, but likewiſe for the Separation of the Chyle from the feculent Parts.

Neither do I by a random Gueſs, and an ungrounded Conjecture, ſuppoſe that from the Mixture and Fermentation of the two Juices, which conſtitute the *Saliva*, there reſults a Matter, which is apt to ferment with the Bible. But to me the Notion ſeem'd to be confirmed by an Experiment that I made. For conſidering with my ſelf, that the Bile is generally allow'd to have much of a ſaponary Nature, I made a Solution of Soap in fair Water, and mix'd it with the Oils of Turpentine

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and Vitriol first put together, and from their Mixture I obſerv'd a very eaſie and gentle Fermentation, which continued for a conſiderable time.

A Diſcourſe concerning ſome Influence of Reſpiration *on the* Motion *of the* Heart, *hitherto unobſerved. By* J. Drake, M. D. F. R. S.

THO' divers accurate Treatiſes of the *Heart*, and its Action, have been written by Learned Men of ſeveral Nations, eſpecially by two of our own Country; the Great Dr. *Harvey*, to whoſe happy Sagacity this Nation owes the Glory of the Invention of the *Circulation* of the *Blood*; and the incomparable Dr. *Lower*, to whom we are beholden for a compleat Diſplay of the *Mechanical Structure* of the *Heart*, and a moſt ingenious Rationale of its Action. Yet there remain ſeveral Doubts and Difficulties about it (in my Opinion) not ſufficiently accounted for; towards the reſolving ſome of which, I ſhall offer what my own Thoughts have ſuggeſted to me, and leave it to the Conſideration of the Reader.

The Learned Dr. *Lower* (whoſe accurate Piece on this Argument will inſure his Reputation ſo long as Phyſical Knowledge ſhall laſt in eſteem) has ſo well accounted for the *Syſtole*, or Contraction of the Heart, from the *Mechanical* Structure of it, that he ſeems almoſt to have exhauſted the Subject; and had he he been as happy in discovering the true cause of the *Diastole*, he had left little room for the Industry and Sagacity of others about this *Viscus*.

But having judiciously and solidly explain'd the *Systole*, he contents himself to ascribe the *Diastole* to a motion of *Restitution*, which account gives me no Satisfaction: Because the *Systole* being the proper, and (as himself confesses) the only motion of the Heart, a State of *Contraction* seems to be the natural State, and consequently without External Violence, it shou'd have no *Diastole* at all.

This will appear more plain, if we consider the Circumstances of it, and its Motion, as a Muscle, with respect to other Muscles. That Contraction is the proper Action, and State of all Muscles, is evident from Experience of Fact, as well as Reason. For, if any Muscle be freed from the power of its *Antagonist*, it is immediately *contracted*, and is not by any Action of the Will, or Spirits, to be reduced to a State of *Dilatation*. Thus, if the *Musculi Flexores* of any Joint be divided, the *Extensores* of that Joint being by that means free'd from the contrary Action of their *Antagonists*, that Joint is immediately extended without any consent of the Will, and in that State it remains; and so *Vice versa*, if the *Extensores* be divided. From whence it is plain, that the Muscles have no restitutive Motion, but what they derive from the Action of their *Antagonists*, by which they are balanc'd. Thus likewise the *Sphincters* of the *Gula*, *Anus* and *Vesica*, having no proper *Antagonists*, are always in a State of Contraction, and suffer nothing to pass them,

them, but what is forced through them by the contrary Action of ſome ſtronger Muſcles, which, though not properly to be call'd *Antagoniſts*, yet on all neceſſary Occaſions perform the Office of ſuch.

That the Heart is a Muſcle, furniſh'd and inſtructed for Motion like other Muſcles, is (in my Opinion at leaſt) demonſtrated beyond Contradiction by Dr. *Lower* and others. And, as it is a *Solitary* Muſcle without any proper *Antagoniſt*, and not directly under the power of the Will, nor exerciſing *Voluntary* Motion, it approaches neareſt to the *Sphincter* kind, which only has theſe Conditions in common with it. But in conſtant and regular Alternations of Contraction and Dilatation, it differs exceedingly from all the Muſcles of the Body.

This *reciprocal Æſtus* of the Heart has given the Learned abundance of trouble; who, finding nothing peculiar in the Structure, which ſhou'd neceſſarily occaſion it, nor any *Antagoniſt*, whoſe re-action ſhould produce it, have been extreamly perplex'd to find out the cauſe of it.

But paſſing over the various Opinions of Authors, to avoid being tedious, I ſhall take notice here only of the very Learned Dr. *Lower*'s, in whoſe Account of the *Syſtole*, however ſolid and ingenious, I obſerve ſomething deficient, and whoſe *Hypotheſis* of the *Diaſtole* I think to be precarious and falſe.

This Excellent Author, having by ſound Arguments drawn from the Structure and Mechaniſm of the Heart, eſtabliſh'd the Certainty of its *Muſcular Motion*, reſts ſatisfied, without taking notice of any Assistance, that the Heart receives from any other Part, except from the Brain, by the means of the eight pair of Nerves.

Part 2d. Prop. 67. Prop. 73. The Accurate *Borellus*, in his *Oeconomia Animalis*, computes the *Motive* Power of the *Machine* of the Heart to be equal to, or to surmount that of a Weight of 3000 *l.* The *Obstacles* to the Motion of the Blood thro' the *Arteries* he esteems equivalent to 180,000 *l.* which is 60 times as much as he rates the Force of the Heart at. Then deducting 45,000 *l.* for the adventitious Help of the *Muscular Elastick Coat* of the *Arteries*, he leaves the Heart with a Force of 3,000 *l.* to overcome a resistance

Prop. 76. of 135,000 *l.* that is, with 1, to remove 45.

This stupendous Effect he contents himself to ascribe to the *Energy* of *Percussion*. But, had he proceeded in his Calculatin to the Veins, which he allows to contain constantly a quantity of Blood, quadruple to the Contents of the Arteries, and to which this *Energy* of *Percussion* does either not reach at all, or but very languidly, he might probably have seen a necessity for some other Expedient to remove so insuperable a Difficulty.

But not to insist rigorously on the Exactness of this Calculation, (though the great Abilities of the Author in this way, and his Ingenuity and Modesty, are a sufficient Warrant for the Accuracy of his Computations, and the Fidelity of his Accounts) we may allow a much greater Deduction, than would be justifiable, without lessening the Difficulty. But this Account

count I have taken notice of purely for the sake of the Calculation, which may be of use in the Sequel; the account it self being in other respects more defective than Dr. *Lower's*, to which we will return.

The Doctor, notwithstanding his great Sagacity, appears (to me) to have overlook'd something of very great moment, and importance in the explication of the Action of the Heart. For, tho' it should be granted, that the *Muscular Fibres* of the Heart acted by the Nerves, are the immediate Instruments of its *Constriction* or *Systole*; yet it must not be denied, that the *Intercostal* Muscles and *Diaphragm* are of great service to aid and facilitate this Contraction, by opening a Passage for the Blood through the Lungs, which denied would be an invincible Obstacle.

Neither do they promote it that way only. The manner how they farther assist the Heart in its Contraction, will appear manifestly, if we consider the different Posture, Situation, and Capacity of the Blood-Vessels of the Lungs in the several times of *Elevation* and *Depression* of the *Costæ*.

The *Pulmonary* Artery rises from the *right* Ventricle of the Heart, and runs in one Trunk, till it comes to the *Aspera Arteria*, where it is divided, and sends a Branch along with each Division of the *Aspera Arteria*, according to all the minutest Subdivisions, of which it is likewise subdivided; accompanying all the *Bronchi*, in their whole progress through the Lungs.

The *Pulmonary* Vein, which empties it self into the *Left* Ventricle of the Heart, spreads

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it ſelf on the *Aſpera Arteria* and *Bronchi*, in the ſame manner that the Artery does.

The neceſſary conſequence of this Diſpoſition is, that this Artery and Vein being co-extended with, and faſten'd to the *Bronchi*, muſt needs ſuffer ſuch alteration of *Superficial* Dimenſions, as the *Bronchi* do in the *Elevation* or *Depreſſion* of the *Coſtæ*.

While the Ribs are in a State of *Depreſſion* (whether before Commerce with the External Air or after) the *Annular Cartilages* of the *Bronchi* ſhrink one into another, and by that means their *Dimenſions* are exceedingly contracted. In conformity to this condition of the *Bronchi*, the *Pulmonary* Artery and Vein muſt likewiſe, either by means of their *Muſcular* Coats, contract themſelves to the ſame *Dimenſions*, or lye in *Folds* or *Corrugations*, which is leſs probable.

On the other hand, when the Ribs are elevated, and the *Diaphragm* bears downward, the Air ruſhing into the Lungs, ſhoots out the *Cartilaginous* Rings, and *divaricates* the Branches of the *Trachea*, and by them extends and divaricates the ſeveral Diviſions of the *Pulmonary* Artery and Veins, and thereby lengthens and enlarges their Cavities.

This enlargement of their Cavities is very conſiderable, not only upon the ſcore of the addition, which they receive in length thereby, but alſo upon the account of their *Divarication*. For whereas, when the Ribs are depreſs'd, and the Lungs ſubſide, the Blood-Veſſels are not only contracted, (as I have already obſerv'd) but their Branches, which are exceeding numerous, approach one another, and

and lie in *juxta-poſition*, by which their Cavities are very much compreſs'd and ſtreighten'd: When the Ribs are elevated, and the Lungs turgid with Air, not only the Fibres, by which their Coats in the oppoſite ſtate were contracted, are extended; but thoſe innumerable Veſſels, which lying before in lines almoſt parallel upon one another, compreſs'd one onother, making an *acute* Angle at their Junctures, are divaricated and ſeparated from each other, and make an *obtuſe*, whereby their Channels are widened.

Thus a paſſage is open'd to the Blood, from the *Right* Ventricle of the Heart to the *Left*, through the Lungs, to which it could not otherwiſe paſs; and the oppoſition, which the Blood contain'd in that Ventricle, muſt otherwiſe neceſſarily have made to its Conſtriction, is taken off, and the *Syſtole* thereby facilitated.

Nor is that all. For the *Diaſtole* being caus'd (as I ſhall in the Sequel ſhew) by the force of the Blood ruſhing into the Ventricles, this Ampliation and Extenſion of the *Pulmonary* Artery is a ſort of *Check* or *Counterpoiſe* to it, and prevents an endeavour towards two contrary Actions at once, which muſt neceſſarily fruſtrate both. For the Heart being a *Springy, Compreſſible* Body, whoſe proper Action, which is Contraction, depends on the influx of certain Fluids into its Fibers, or Subſtance; and containing beſides a Fluid in its *Ventricles*, or great Cavities, in one of which is the Mouth of this Artery, the action of this Veſſel muſt in great meaſure reſemble that of a *Syringe*, whoſe extremity is immers'd in Water,

ter, the Enlargement or Expansion of the Chanels of the Artery answering the drawing of the *Embolum*, as the constrictive motion of the Muscle of the Heart does the pressure of the *Atmosphere* upon the *Surface* of the Water, the one making way for the fluid, and the other forcing it to follow, where the resistance is least. In this Sense we may allow a sort of Attraction to the *Pulmonary*-Artery, depending wholly upon the Action of the *Intercostal* Muscles and *Diaphragm*, which we must therefore confess to be very serviceable and instrumental in promoting the *Systole* of the Heart.

But if the Learned Author be deficient in his Account of the *Systole*; that is, if he has not observ'd all the Mechanism and Contrivance of Nature for the Contraction of the Heart; much less sufficiently has he accounted for the *Diastole*, or Dilatation of it, which he ascribes to a motion of *Restitution* of the over-strain'd Fibres, which yet he confesses are made for *Constriction* only. 'Tis true, he immediately after joins the *Influx* of the *Blood* as a concurrent Cause; but from the slight notice that he takes of it, 'tis plain, that he did not so much as dream of any great share it had in that Action. His Words are these:

De Corde, Pag. 75.

Quin & (ut obiter hoc moneam) omnis motus contractione perficiatur, & Cordis Fibræ ad constrictionem solum factæ sint, apparet quoque Cordis motum totum *in* Systole *positum esse; cumque Fibræ ultra tonum suum in omni constrictione ejus tendantur, idcirco ubi nixus iste absolvitur, motu quasi* restitutionis *Cor iterum relaxatur, & sanguine*

guine à Venis influente *rursus distenditur* ; *à* nullo *enim cordis motu, nisi* tensionem suam remittente, *& ab* irruente *sanguine* Diastole *ejus libratis adeo viribus succedit.*

I have transcrib'd the intire Paragraph, because it contains his whole *Hypothesis* of the *Diastole,* and all the notice that he takes of it through his whole Work. But how slender soever this may prove, it is the most substantial that I have any where met with, except a late one of Mr. *Cowper,* which is properly an Improvement of this, and shall be consider'd in the Sequel.

But if Contraction be the sole Action of these Fibres (as this Great Man confesses it to be) and as indeed it is of all *Muscular* Fibres, I wonder how so judicious a Writer came to slip into such an Absurdity, as to call their Distention (vulgarly but improperly call'd Relaxation) a Motion of *Restitution.* For from the Nature of those Fibres, and their disposition in the Structure of the Heart, the natural State of the Heart appears manifestly to be *Tonical,* and its Dilatation a State of Violence ; and consequently, the Constriction is the *true* motion of *Restitution,* and the State to which it will *spontaneously* return, when the Force is taken off, which is the work of the *Intercostal* Muscles and *Diaphragm.*

Thus we are left still to seek for the true Cause of the *Diastole,* which seems to me to be the main and most difficult *Phænomenon,* relating to the Heart and the Circulation of the Blood. But in Mr. *Cowper's* ingenious *Introduction* to his *Anatomy of Humane Bodies,* I

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find the Share which Dr. *Lower* hints the Blood to have in that Action, further prosecuted, and improved into the main Instrument of the Dilatation of the Heart, wherein I agree intirely with him. But as to the manner, and reasons of its being so very instrumental, I can't be so perfectly of his mind.

The Heart (says this accurate Anatomist) *of an Animal bears a great Analogy to the Pendulums of those Artificial Automata, Clocks and Watches, whilst its motion is performed like that of other Muscles, the Blood doing the Office of a* Pondus.

This Explication, being but a Simile without a distinct application to Particulars, is beside so very short, that I can at best but give a conjecture at the meaning; which if I mistake, I shall deserve to be excused, and expect to be better inform'd.

By the *Bloods* doing the Office of a *Pondus*, I suppose he means, that the Blood contributes in the same manner to the motion of the Heart, as the *Weights* do to that of the *Pendulum* of a *Clock*. If so, the Blood, according to him, must be the Instrument of *Constriction*; and *Dilatation* must be the *Natural* State, or *Spontaneous* Motion, to which it wou'd, when under no violence, return; the contrary of which, I presume, will appear e're I have done.

But if he means, that the *Blood* in its reflux, by *gravitating* on the *Auricles* and *Ventricles*, dilates and expands 'em, acting therein as a *Counterpoise* to its contractions as a Muscle, I cou'd wish his Design had not bound him up

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to ſo narrow a compaſs, and that he had given us an explication at large of ſo abſtruſe and ſo important a *Phænomenon*: Becauſe the *Specifick Gravity* of the Blood ſeems to me a cauſe by no means alone adequate to the effect, which it is here ſuppos'd to produce.

For, if the Blood acts only as a *weight* by meer *gravitation*, then that part of it only which deſcends from the Parts above the Heart can be employ'd in that Action. This at the largeſt computation can't amount to Five pound weight, and muſt, according to the computation of *Borellus*, force a Machine, that is able to overcome a reſiſtance of 135,000 *l.* I leave every Man to deduct what he ſhall upon examination find reaſonably to be deducted, and yet ſhall reſt ſecure, that it is not to be effected in the leaſt with ſo ſmall a Weight.

But neither does the *Refluent* Blood gravitate in any ſuch proportion, as I have here aſſign'd. For to make a true eſtimate of its *Gravitation*, we muſt conſider the Circumſtances of the Liquor ſuppos'd to gravitate; in which it very much reſembles Water inclos'd in a recurve Tube, of which, if the length of the two Legs be equal, it may be ſuſpended in the Air full of Water, with the Extremities downwards, without loſing a drop, although the *Diameter* of thoſe Legs ſhould be very unequal. The Caſe of the Arteries and Veins is pretty near a parallel to a Tube, ſo fill'd and inverted. For, if the Arteries and Veins be continued Tubes, (as by the Microſcope they are made to appear) then ſuppoſing their contents to have no other determimination of motion, than their own weight wou'd give them, the contain'd Fluids must be Counterpoises to each other. For the Veins and Arteries being join'd at the smaller Extremities, and the larger of both terminating in the same parallel Line, it is impossible, according to the Laws of *Hydrostaticks*, that the contents of either shou'd overbalance t'other. How far then must it fall short of forcing the natural Power and Resistance of so strong a Muscle as the Heart, by meer Gravitation ?

The Blood indeed has a *Progressive* Motion through its Vessels, wherein it differs from Water, in a recurve Tube, in the Experiment above-stated. But, if the natural Gravitation of the Blood contributes nothing to the Dilatation of the Heart, this progressive Motion will not not be found much more sufficient. For, as this Motion is deriv'd intirely from the Heart's Constriction (as all Accounts hitherto derive it) cou'd the Blood be suppos'd to re-act upon it by the Heart, with all the force first impress'd upon it by the Heart, it would be insufficient, unless we will suppose the *Force communicated* to be superiour to the *Power Communicant*, which is absurd.

But when the just and necessary Deductions for the Impediments, which the Blood meets with in its Progress through the Vessels, shall be made, the remaining Force will be found so exceeding weak, that to prop the Blood through the Veins may be a task alone too great for so small a Power, without charging it with the additional difficulty of forcing the Muscle of the Heart.

Alphonsus

Alphonsus Borellus, after a great deal of solemn pains taken to shew his Care and Exactness, and to possess his Reader of the Truth of his Calculations, casts up the force of the Heart, and the *Muscular* Coat of the Arteries, to be together equal to a weight of 3,750 *l.* and allots them a Resistance equal to 180,000 *l.* to overcome which is 45 to 1. To make up for a disproportion, by his own confession, incredible to those who have not consider'd the Matter as he had done, he flings into the Scale the additional *Force of Percussion*, which he leaves *indefinite*, and thinks sufficient to *force any quiescent finite Resistance whatsoever*.

But as this Account and *Hypothesis* are part of a Posthumous Work (if a liberty of Conjecture may be allow'd in so uncertain a Matter,) I shou'd suspect, that these Papers were left unfinish'd by *Borellus*; or at least, that in many places the last Hand was never put to them. For neither in this Place, nor any other of this Work, does he account for any more than the *Systole* of the Heart, and the resistance which is made to the progressive motion of the Blood in the Arteries only. This alone he found to exceed the Power of the Heart so prodigiously, that he seems to shuffle it off his Hands with a general and precarious Solution, as a difficulty that he was desirous to be rid of. For, having ascrib'd this *stupendous* (as he himself calls it) effect to the *Energy of Percussion*, he takes no care to satisfie his Reader any farther about it, or to refer him, or give him the expectation of Satisfaction any where else; although he has an express Treatise on the *Force of Percussion*, which was written preparatory to this, and to which he frequently refers in other Places of this Work. But what confirms my ſuſpicion, that this part was intended for a farther Reviſe by the Author, is, that he has left the Progreſs of the Blood through the Veins, and the *Diaſtole* of the Heart, abſolutely untouch'd, tho' they are Difficulties of a much greater magnitude than this, which he has attempted to account ſo ſlightly for: For, in theſe he is excluded the benefit of *Percuſſion*, and has yet a greater reſiſtance to overcome without it. Omiſſions of this kind are ſo unuſual with this Author, where-ever he knows himſelf to go upon ſure grounds, that it is to me an Argument, that he doubted the ſufficience of his *Percuſſion*, and reſerv'd theſe important *Phænomena* for farther Conſideration, without plunging himſelf into ſuch an Abſurdity, as to aſcribe to *Percuſſion* any ſuch *Energy* as to be able (ſo broken as it returns to the Heart) by its re-action to force that Power, from whence only it was at firſt deriv'd.

Dr. *Lower*, and Mr. *Cowper*, deliver their Opinions of the Cauſe of the Dilatation of the Heart ſo very ſhort, and without any Arguments to ſupport them, that by expoſing them naked, they ſeem rather to diſcourſe of it tranſiently, as Men oblig'd by the Nature of their Subjects to ſay ſomething of it, than ſolicitous to give any full or ſatisfactory Account; and therefore I ſhall proceed no farther upon them here.

But though the *Hypotheſis* or *Borellus* may, in this Caſe, be found precarious or inſufficient (a Misfor-

(a Misfortune that has befallen him in divers other Particulars) his *Theory* holds still good. At least it ought to be allow'd, in justice to his great Abilities and Exactness, till some Body convicts him of some material Error in his Calculations, which has not as yet been done by any Body, that I know of.

Supposing then the force of the Heart, and of the *Muscular* Coat of the Arteries, as likewise of the resistance, which they must overcome, to be computed with any degree of accuracy, there remains yet such a prodigious disproportion to be accounted for, as requires some more powerful Agent, than any yet assign'd, to make up the deficiency.

What assistance the Heart receives from the action of the *Thorax* towards the facilitating its Contraction, without which assistance there cou'd have been no *Systole*, has been already shewn. But neither the *Intercostal* Muscles, or *Diaphragm*, which are so instrumental in that part of its action, can contribute any thing to the *Diastole*; because they serve only to enlarge the Cavity of the *Thorax*, and thereby to open a passage to the Blood from the Heart, and promote its Constriction.

Whatever therefore the force is, that dilates the Heart, and is the cause of the *Diastole*, it must be equal to that of the Heart, the *Intercostal* Muscles and *Diaphragm*; to all which it acts as an Antagonist. I take no notice of the *Serratus Major Anticus*, and other Muscles; which have an obscure share in the *Elevation* of the *Costæ*, because as much may reasonably be deducted upon the account of the *Obliquus externus Abdominis*, and other Muscles; which having their Insertions on some of the lower *Ribs*, are as instrumental towards

towards the *Depression* of them, and so balance the Account. But the chief use of these is in violent Respiration: In ordinary Respiration their share is small.

Such a real Power (which may in the least be suspected of any share in this Action) is hard, perhaps impossible to be found in the *Machine* of any *Animal* Body; and yet without some such Antagonist, it is as impossible the Circulation of the Blood should be maintain'd. All the Engines yet discover'd within the Body, conspire towards the *Constriction* of the Heart, which is the *State* of *Quiescence*, to which it naturally tends. Yet we find it alternately in a *State* of *Violence*, that is, of *Dilatation*; and this upon necessity, because upon this *Alternation* depends all Animal Life.

Some sufficient Cause External must therefore be found, to produce this great *Phænomenon*; which Cause must be either in the *Air*, or *Atmosphere*, because we have no constant and immediate Commerce with any other *Mediums*.

Some great Physicians observing this, and that depriv'd by whatsoever means of Communication with the *external* Air, we became instantly extinct, have imagin'd, that in the Act of Inspiration certain purer parts of the Air, mixed with the Blood in the Lungs, and was convey'd with it to the Heart, where it nourish'd a sort of *Vital Flame*, which was the Cause of this reciprocal *Æstus* of the Heart. Others not quite so gross, rejecting an *Actual Flame*, have fancied, that these fine Parts of Air mixing with the Blood in the Ventricles of the Heart, produc'd an *Effervescence* which dilated it. But these Fancies have been long

since

ſince exploded and condemn'd upon ample Conviction; and 'tis a Point yet undetermin'd, whether any Air does mix with the Blood at all in the Lungs, or not.

But ſuppoſing, that ſome Air may inſinuate it ſelf into the *Pulmonary* Vein, it can no other way dilate the Heart than by an Efferveſcence in the Left Ventricle, which wou'd not dilate the Right. But this Opinion is contradicted by *Autopſie*, and too laboriouſly confuted by others, to be brought upon the Stage again here.

There remains therefore only the *groſs Body* of the *Atmoſphere* to be conſidered, whis is undoubtedly the *true Antagoniſt* to all thoſe Muſcles, which ſerve for ordinary Inſpiration, and the Conſtriction of the Heart. This will appear more evidently, if we conſider not only the Power, but the Neceſſity of its Action upon *Animal* Bodies, as well as the want of other ſufficient Agents.

The Heart is a *Solitary* Muſcle of very great ſtrength, and the *Intercoſtal* Muſcles and Diaphragm, which likewiſe have no *Antagoniſts*, are a vaſt additional Force, which muſt be balanc'd by the contrary Action of ſome equivalent Power or other. For, tho' the Action of the *Intercoſtal* Muſcles be voluntary, that does not exempt them from the condition of all other Muſcles ſerving for *voluntary* motion, which wou'd be in a State of perpetual Contraction, notwithſtanding any Influence of the Will, were it not for the Libration of *Antagoniſt* Muſcles. This Libration between other Muſcles, is anſwer'd by the *Weight* of the incumbent *Atmoſphere*, which preſſes upon the *Thorax* and other parts of the Body. And, as as in all other voluntary Motions the influence of the Will only gives a prevalence to one of its two Powers before equilibrated, so here it serves to enable those Muscles to lift up a weight too ponderous for their strength not so assisted; and therefore as soon as that assistance is withdrawn, the *Costæ* are again depress'd by the meer *Gravitation* of the *Atmosphere*, which wou'd otherwise remain elevated through the natural Tendency of those Muscles to Contraction.

This is evidently prov'd from the *Torricellian* Experiments, and those made upon Animals in Mr. *Boyle*'s Engine; where, as soon as the Air is withdrawn, and the *pressure* thereby taken off, the Intercostal Muscles and Diaphragm are contracted, and the Ribs elevated in an instant, and can't by any Power of the Will be made to subside, till the Air is again let in to bear them forcibly down.

It were scarce worth while to take notice here of a Mistake of the Learned Dr. *Willis*, were it not for the great Authority of the Man, which is almost sufficient to keep Error in countenance. The Doctor having observ'd, that the Fibres of the *External* and *Internal Intercostal* Muscles ran in a contrary order, as it were, decussating each other, takes occasion from thence to fansie, that there was an opposition in their Office; and that as the *External* serv'd to raise up the Ribs, the *Internal* drew them down again, forgetting at that time, That, when a contractile Body is fasten'd at the several ends to Points unequally moveable, let the Contraction happen in what part or manner soever, the more moveable Point must

De Respirationis Organis & Usu.

muſt be drawn towards the leſs moveable: By which Rule, whether *External* or *Internal Intercoſtals* be contracted, the lower Ribs will be forc'd to approach the upper, that is, be rais'd up.

As in the Elevation of the *Coſtæ*, the Blood, by the paſſage that is open'd for it, is in a manner ſolicited into the Lungs; ſo in the Depreſſion of them, by the ſubſidence of the Lungs, and the Contraction of the Blood-Veſſels, both which are conſequent thereof, the Blood is forcibly driven, as it were with an *Embolum*, through the Pulmonary Vein into the Left Ventricle of the Heart. And this, together with the *general Compreſſion* of the *Body* by the *weight* of the *Atmoſphere*, which ſurrounds and preſſes upon the whole Surface of it, is that Power which cauſes the Blood to mount in the Veins, after the force impreſs'd upon it by the Heart is broken and ſpent, and which is ſufficient to force the Heart from its natural State to Dilatation.

He that is able to compute the weight of a Column of Air, equal to the Surface of the whole Body, will readily grant it a power ſufficient for the Effects, which are here aſcrib'd to it. And when he conſiders, that the Bodies of Animals are compreſſible Machines, he will find that it muſt of neceſſity affect them in the manner here laid down. But though our Bodies be entirely compos'd of *Tubuli*, or Veſſels fill'd with Fluids; yet this preſſure, how great ſoever, being equal, cou'd have no effect upon them, if the ſuperficial Dimenſions were not eaſily variable; becauſe being compreſs'd on all parts with the ſame degree of Force, the contain'd Fluids cou'd not any

where

where begin to recede, and make way for the rest to follow, but wou'd remain as fix'd and immoveable as if they were actually solid. But by the Dilatation of the *Thorax*, room is made for the Fluids to move, and by the Coarctation of it, fresh motion is imprest, which is the main Spring whereby the Circulation is set and kept going.

This reciprocal Dilatation and Contraction of the superficial Dimensions of the Body, seems so necessary to Animal Life, that there is not any Animal so imperfect as to want it, at least none to the inward Structure, of which our Anatomical Discoveries have yet reach'd. For, tho' most kinds of *Fish* and *Insects*, want both *moveable* Ribs and Lungs, and consequently have no dilatable *Thorax*, yet that want is made up to 'em by an *Analogous* Mechanism, answering sufficiently the Necessities of their Life.

Those Fishes which have no Lungs, have *Gills*, which do the *Office* of Lungs, receiving and expelling alternately the Water, whereby the *Blood-Vessels* suffer the same alteration of Dimensions, that they do in the Lungs of more perfect Animals.

The Lungs or *Air-Vessels* of Insects, are yet exceedingly more different in Structure, Distribution, and Situation from those of perfect Animals, than those of Fishes are, and yet in their Use and Action agree perfectly with both; that is, *receiving* and *expelling* the Air, and *varying* the *Dimensions* and *Capacities* of the *Blood-Vessels*. These having no *Thorax*, or separate Cavity for the Heart and Air-Vessels, have the latter distributed through the whole Trunk of their Bodies, by which they communicate

nicate with the *External* Air through ſeveral *Spiracula* or *Vent-holes*, to which are faſten'd ſo many little *Tracheæ*, or Wind-pipes, which thence ſend their Branches to all the Muſcles and *Viſcera*, and ſeem to accompany the Blood-Veſſels all over the Body, as they do in the Lungs only of perfect Animals. By this diſpoſition in every *Inſpiration*, the whole Body of theſe little Animals is inflated, and in every *Expiration* compreſs'd; and conſequently the Blood-Veſſels muſt ſuffer a *Viciſſitude* of Extenſion and Contraction, and a greater motion muſt thereby be impreſs'd upon the Fluids contain'd in them, than the Heart, which does not in thoſe Creatures appear to be Muſcular, ſeems capable of giving.

The only Animal that is exempted from this neceſſary condition of *Breathing*, or *receiving* and *expelling alternately ſome Fluid* into and out of the Body, is a *Fœtus*. But this, while included in the Womb, has little more than a *vegetative* Life, and ought ſcarce to be reckon'd among the number of *Animals*. For, were it not for that ſmall ſhare of *Muſcular* Motion, which it exerciſes in the Womb, it might without abſurdity be accounted for as a Graft upon, or Branch of the Mother.

Concerning the immediate Matter, and Means of Life, and Nutrition, Authors are not agreed, nor is it the buſineſs of this place to reconcile, or decide their Differences, but to account for the Motion of the Blood through the Veſſels only. In order to this, it will be neceſſary to obſerve, that the Pulſation of the Heart in a *Fœtus* is ſo very weak and obſcure, and the Motion of the Blood ſo extream ſlow

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and languid, as to be scarce, if at all perceivable, as has been experienced in the Dissection of Puppies before Respiration had. To produce such a feeble Palpitation, and creeping Motion, no greater force seems to be required, than may be deriv'd from the Communication between the Vessels of the Mother and *Fœtus* in the *Placenta*. I am not ignorant, that divers very Learned Anatomists (whom the Crowd have implicitly follow'd) have absolutely rejected all Communication between these Vessels. But, with submission to Great Authorities, I think they have acted arbitrarily, and without sufficient Warrant from Reason or Experiment: For neither are the Arguments which they bring against it conclusive, nor the Office which they assign to the Umbilical Vessels in lieu of it, proper, or natural to those Vessels, or the reality of the Fact made out by any substantial Reasons. Those that reject this Communication usually do it in favour of one or both of these Opinions, that the Arteries of the *Uterus* do deposite a Nutritive Juice, or a Juice impregnate *with Air* in the *Placenta*, which is suck'd in by the *Umbilical* Vein, and convey'd to the *Fœtus*, for the necessary Uses of Nutrition and Life. Now those that patronize either of these Opinions, lead Nature an unnecessary Dance. For if the *Maternal* Blood does really contain any such *Nutritious*, or any such necessary *Aerial Particles*, why shou'd they be separated and extravasated, to be with difficulty receiv'd into the *Umbilical* Vein, and again

Boyle *of the Elasticity of Air.*
Pechlinus de Aeris & Alimenti defectu.

gain

again mixt with the Blood, when they might more easily have been imparted by the plain simple way of Transfusion from the Arteries of the *Mother* to the Veins of the *Fœtus.* And, that this is the course which Nature takes in this Case, I am perswaded from the easiness and simplicity of the Method, which readily performs what might be perhaps in vain expected from the other, and wou'd over and above find them, what they seem to grope so blindly about for, a first Mover of the Blood in a *Fœtus.*

Those that contend for the conveyance of the *Nutricious* Juice, through the *Umbilical* Vein from the *Placenta*, are forc'd upon two Difficulties next to Absurdities. For first they are oblig'd to make this Vein, which, as all other Veins, seems dedicated to the Re-conveyance of Blood only, the proper and immediate Chanel, thro' which a very different Liquour is to be carried; and next, to give a Power of Attraction or Suction to it; because the *Nutricious* Juice, which it is thus destin'd to carry, is both viscous and stagnant, and has neither force to drive, nor subtilty to penetrate, or insinuate it self into the Capillary Veins; and therefore must be drawn or suck'd as *Milk* is from the *Breast*, to which the *Placenta* and its *Nutricious* Juice are by the Favourers of them expresly compar'd. But if this were the sole use of the *Placenta*, and *Umbilical Vessels*, why were the Umbilical *Arteries* sent along with the Vein? Their business is not to bring any thing back to the *Fœtus*, nor can they contribute any thing to the benefit of the *Mother*; for the *Uterine* Arteries bring all to the *Placenta*, the Umbilical Vein carries it to the *Fœtus*, and the *Uterine* Veins convey back again the Surcharge of the *Mother's* Blood; the Umbilical *Arteries* only, have nothing to do, and are superfluous and impertinent, which is contrary to the constant Practice of Nature. Yet if *Autopsie* did in the least countenance this Hypothesis, some Defence might still be made; but we find in the Umbilical *Vein* of a *Fœtus* nothing but *Florid* Blood, such as in all probability it received immediately from the *Arteries* of the *Mother* without any mixture. And therefore I can't help concluding, that this Opinion engages its Favourers in some Absurdity, without Necessity and without Proof.

They that from the *Placenta* supply the Body of the *Fœtus* with *Air*, are as much distress'd as t'other; for they are forc'd to beg the Question twice, which, even when granted, will not answer their Ends. First, they suppose, that an intimate mixture or confusion of *Air* with the *Blood*, is necessary for the support of Animal Life, a *Postulatum*, which perhaps the former part of this Discourse may have render'd unnecessary; and next, that the *Fœtus* is supply'd with *Air* from, and its *Blood* mix'd with it in the *Placenta*.

But here again they fetch a Compass without necessity or proof. For if a mixture of *Air* were necessary to a *Fœtus*, why should it be separated from the *Mother's* Blood, and not rather both communicated together, since it is so much more easie and commodious? But neither does the *Placenta* seem to be instructed and provided for the separation of *Air*, but of a much grosser *Fluid*, destin'd to some other use, which *Autopsie* confirms: Yet, were both these Opinions

nions true, they are however defective, and the Circular Motion of the Blood unprovided for.

By the way of *Transfuſion*, this great Phænomenon is naturally accounted for, and the Ends, for which the other two Hypotheſes were deviſ'd, might both be anſwer'd with more eaſe. For the *Hyſterick* Arteries tranſmitting their Blood immediately to the *Umbilical* Vein, may very eaſily tranſmit ſuch *Nutricious* Juices or *Aerial* Particles, as are contain'd in the Blood, along with it, without depoſiting them by the way. By this means ſo much of the Impulſe of the Mother's Blood is preſerv'd, as ſuffices to maintain that languid Circulation which a *Fœtus* enjoys. For the Blood being driven through the *Arteries* of the *Uterus* into the *Umbilical Vein*, is convey'd directly to the *Sinus* of the *Porta*, and thence by a ſhort and direct Paſſage through the *Cava* to the Heart; where paſſing through the *Foramen Ovale* to the *Left* Ventricle, and through the *Canalis Arterioſus* from the *Right* and *Pulmonary* Artery, it is all deliver'd without coming at the *Lungs* to the *Aorta*, and from thence again by the *Umbilical Arteries* to the *Veins* of the *Uterus*, making a ſort of *Epicycle* to the main Circulation in the Mother.

As this Opinion is favour'd by the Structure and Diſpoſition of the Blood-Veſſels on both Parts, ſo there is nothing in it difficult to be conceiv'd, or repugnant to Experience. Late Diſcoveries have made it appear, that the Arteries and Veins are continu'd Tubes, and that the latter contain nothing but what they receive from the former, and no Reaſon appears why we shou'd think this Method to be varied in the *Placenta.* On the other hand, if the Arteries of the *Uterus* were continued to the Veins of the *same* part, and those of the *Fœtus* in like manner, without communicating with each other, their Confluence in the *Placenta* seems to be altogether impertinent, and of no use, and the *Umbilical* Arteries and Vein fram'd for no other Service or Purpose, than to give the Blood room for an idle Sally.

Thus the Reasonableness of this old Opinion may be vindicated, but the Certainty of it rests upon stronger Proof. Mr. *Cowper*, to whose happy Industry we owe the Confimation of many ancient Discoveries, and the Benefit of some new ones, has the Honour to re-establish this old, but long exploded Truth. For by pouring *Mercury* into a Branch of the *Uterine Arterie* of a *Cow*, that went into one of the *Cotyledones* of the *Uterus*, he fill'd those Branches of the *Umbilical* Veins, which went from that *Cotyledon* to the *Navel* of the *Fœtus*; which, with a part of the *Uterus*, he keeps prepared by him.

It would be a weak Objection, to alledge, That the Observation and Experiment being made on the *Uterus* of a *Cow*, the Inference would not hold from thence to a *Woman*, the one being *Glanduliferous*, and the other *Placentiferous*; since every one of these *Cotyledones*, or *Uterine Glandules*, is in all respects a little *Placenta*, and all the difference between them is in number, name, and magnitude. Why *Ruminants* differ in this Particular from other *Viviparous* Animals, is beside the Subject of our present Enquiry. But the great Flux of Blood, which constantly follows upon drawing the *Pla-*

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centa from Women (which is frequently so great as to cost them their Lives) is as plain a demonstration to Reason of the *Continuity* of the Vessels, as Mr. *Cowper*'s Experimens is to the Eye.

I have heard it objected by very Learned Men, that if there were such a *Continuity* of Vessels, and such *Transfusion* of Blood, the *Fœtus* must necessarily perish through loss of Blood, upon the separation of the *Placenta* from the *Uterus*; but that, on the contrary, no visible Flux of Blood does follow while the *Fœtus* continues wrapt in the Membrane, in which Condition it may be kept alive some Hours. To this it may be answer'd, that the Circulation in the *Fœtus*, being deriv'd from the Mother, may be suppos'd wholly to cease upon the cutting off the Communication between them, till it is again renew'd more forcibly by *Respiration*. But if we allow the motion already impress'd upon the Blood to be sufficient to keep it going a little while; yet it must needs be so exceeding languid, that the meer resistance of the External Air must be more than enough to hinder any Efflux of Blood from a *Fœtus* before Respiration. How long Life may be preserv'd without an *actual* Circulation of the Blood, is a Question not of this place. But we have been convinc'd by many and notorious Observations and Experiments, that Life has been recover'd a long time after all tokens of Respiration, Circulation, or even Life it self, have disappear'd; so that we can't think the first Solution either impossible or improbable.

I expect to be told, that in the early Days of *Geſtation* in *Viviparous* Animals, there is no *Placenta*, or any Adheſion of the *Umbilical* Veſſels to any part of the *Mother*, and conſequently no ſuch *Transfuſion*; and that in *Oviparous* there is no *continuity*, or *communication* of Veſſels of any kind, during the whole time of *Incubation.*

But theſe Objections carry neither the Weight nor Difficulty along with them, that they may be ſuppos'd to do; for in thoſe Days there is neither *Blood* or *Blood-Veſſels*, and conſequently there can be no *Circulation* of the *Blood*; and the *Embryo*, of what Species ſoever, is no more than a *Vegetable* at that time; nor does the *Fœtus* of any *Viviparous* Creature enjoy any *Circulation*, or ſhew any ſigns of Animal Life, till after thoſe Veſſels, as well as others requiſite to the Circulation, are compleated.

It muſt be confeſs'd, that *Oviparous* Animals are denied the benefit of this Communication; but that want is ſufficiently compenſated by a peculiar Mechaniſm, which directly anſwers the ends of *Reſpiration*, and the *preſſure* of the *Atmoſpere* upon the *Fœtus*. There is at the *obtuſe* end of an Egg a ſmall Cavity fill'd with Air, which is the ſuccedaneous Inſtrument to the *Reſpiratory* Organs. For as ſoon as the Contents begin to be warm'd by the *Incubation* of the Hen, or *any analogous* Heat of *Furnace* or *Dunghil*, the ſeveral Humours of the Egg require a *fermentative* motion, and the *Air* contain'd in the *Cavity* or *Veſicle*, at the *obtuſe* end of the Egg, is rarefied, and the Veſicle extended and enlarg'd, and conſequently the other Contents

tents are compreſt; to which the *fermentative* motion naturally reſiſts. But both Bodies being as well *compreſſible* as *dilatable*, and both having an *expanſive* motion impreſt upon them by *Incubation*, the Compreſſion and Renitency will be mutual, but varied in degree, according as either, through the variation of Circumſtances, ſhall prevail. By this means, an Alternation of Compreſſion and Dilatation will be produc'd in both, anſwering the *reſpiratory* motion, by which a motion will be communicated, which, as ſoon as the Organs by which it ſhould be regulated are compleated, will in the Body of the *Pullus* be *regular* and *circulatory.*

Fabritius ab *Aquapendente*, and after him, our Great Dr. *Harvey*, have aſſign'd divers Uſes to this Cavity or Air Veſicle, the Extravagance of which have perhaps deterr'd others from enquiring ſo much into the Uſe, as the Importance of it requir'd. But though I can't agree to that *Perſpiration*, *Refrigeration*, and *Reſpiration*, which they make it the Inſtrument of; yet perhaps the *Air*, that was inclos'd in that *Cavity*, may through the Augmentation of the Body of the *Pullus*, and its own *Rarefaction* (which is at laſt ſo great as to occupy half the Shell) break the *Membrane*, which ſeparated it from the *Pullus*, and thereby give ſo much *Reſpiration* as to form the *chirping Voice*, which is often heard before the breaking of the Shell, and with it give an addition of Strength to enable it to break the Shell. But how it ſhould reſpire ſooner, is to me inconceivable.

There are many Problems of great ſeeming Difficulty, the Solutions of which flow naturally from what has been laid down here: But intending to proſecute this Subject farther, and to treat of the Impediments of Reſpiration, and the Conſequences of Reſpiration obſtructed or intermitted, I ſhall reſerve them for that Opportunity, and content my ſelf here to attempt the *Harveyan* Problem only, which has given abundance of Authors ſo much perplexity.

That incomparable Philoſopher enquires, *Why a* Fœtus, *taken out of the* Uterus *with the* Membranes *intire, ſhall live in Water ſome Hours without communication with the* External Air; *whereas if it be taken out and ſuffer'd once to breath, it can't afterwards ſurvive a Moment without the benefit of* Reſpiration.

Granting the Fact to be as he has deliver'd it, which yet is not ſo in all Caſes, the main Difficulty is grounded on a Miſtake, which from the ſtating of the Queſtion I find this Great Man to have ſlipt into. For he thinks, that a *Fœtus* is ſooner ſuffocated after having once breath'd, than if it had not breath'd at all, and that by breathing it had contracted ſomething which render'd it more periſhable. *Idem tamen ſecundis exutus*, (ſays he) *ſi ſemel* aerem *intra* Pulmones *attraxerit, poſtea ne momentum quidem temporis abſque eo durare poſſit, ſed confeſtim moriatur.* And preſently after, *Siquidem conſtat, fœtum, poſtquam* eum ſemel *hauſerit*, citius *ſuffocari*; *quam cum ab* illo prorſus *accebatur.* The Doctor obſerving a *Fœtus* to live longer without Reſpiration, and to diſpence better with the want of Air while included in the Membranes intire, than it cou'd afterwards; infers thence, that the Air does in the

the firſt Act of Inſpiration impreſs upon the Lungs ſome quality, which renders it ever after more indiſpenſably neceſſary. But allowing his Obſervation, I muſt yet deny his Inference to be good: For deprive a *Fœtus* of means of reſpiring, and then take it out of the Membranes, and it ſhall be as ſoon ſuffocated, as if it had reſpired before. This proves, that this neceſſity of intercourſe with the Air, by way of the Lungs, is not the Offspring, but the Parent of Reſpiration, and that, that Learned Man was drawn into a Fallacy of *Non cauſa pro cauſa.*

The Reaſon of this Neceſſity is the preſſure of the External Air upon the Surface of the Body, from which it was defended by the Interpoſition of the Membranes, and the Humours contain'd, which are not ſo compreſſible as the Body of the *Fœtus* it ſelf. So ſoon therefore as the *Fœtus* is excluded, and expos'd to the immediate contact of the ambient Atmoſphere, the Veſſels and all the Cavities of the Body muſt neceſſarily be ſo compreſs'd, that the Fluids can't have room for motion, and conſequently the *Fœtus* could have no Life, if Nature had not contriv'd by the motion of the *Thorax* to remove and admit that preſſure alternately, and thereby to impreſs a motion on the Fluids, which is the Spring of Life. But this motion of the *Thorax* being any way ſuppreſs'd, the equal preſſure of the Atmoſphere on all parts, occaſions a total Ceſſation of motion, which is Death.

I ſhall proſecute this Subject no farther now, nor trouble the Reader with any Apology, for diſſenting from thoſe Great Men herein named; becauſe,

because, I hope, I have done it with Modesty, and all the Respect due to so great Authorities, and have assign'd nothing which is not Matter of Fact uncontroverted, or deduc'd from it by plain Mechanical Necessity.

Some

Some Thoughts and Experiments concerning Vegetation. *By* John Woodward, *M. D. of the College of Phyſicians, and R. S. and Profeſſor of Phyſick in* Greſham College.

THE *Ancients* generally intitled the *Earth* to the Production of the *Animals, Vegetables*, and *other Bodies* upon and about it; and that for that Reaſon 'twas, that they gave it ſo frequently the Epithets of *Parent* and *Mother* *. They were of opinion, that it furniſhed forth the *Matter* whereof *thoſe Bodies* conſiſt; and receiv'd it all back again at their Diſſolution for the Compoſure of *others*. Even thoſe who aſſerted *four Elements*, ſuppoſed that the *Earth* was the *Matter* that *conſtituted* thoſe Bodies; and that *Water* and the *reſt*, ſerv'd only for the *Conveyance* and *Diſtribution* of that *Matter*, in order to the *forming* and *compoſition* of them. 'Tis true, *Thales*, a Philoſopher of the firſt Rank in thoſe early Ages, has been thought to have Sentiments very different from theſe; but that without juſt Grounds, as I think I have ſufficiently prov'd in another Paper, which I am ready to produce.

* *Terra Parens.* Γῆ μήτηρ πάντων. *Terra Mater.*

But

But though *Antiquity* thus gave its *Vote* for *Terreſtrial Matter*, ſeveral of the *Moderns*, and ſome of very *great Name* too, both *here* and *abroad*, have gone quite counter, and given *theirs* in behalf of *Water*. The *Dignity* of the *Perſons* that have eſpouſed it, as well as their *Numbers*, renders this Doctrine very conſiderable, and well worth our enquiring into. The great Reſtorer of *Philoſophy* in this laſt Age, my Lord *Bacon*, is of Opinion, *That for Nouriſhment of* Vegetables, *the Water is almoſt all in all; and that the Earth doth but keep the Plant upright, and ſave it from over-heat, and over-cold* †. Others there are who are ſtill more expreſs; and aſſert Water to be the only Principle or Ingredient of all Natural Things. They ſuppoſe that, I cannot tell by what Proceſs of Nature, Water is *tranſmuted* into *Stones*, into *Plants*, and in brief, all other Subſtances whatever. *Helmont*, * particularly, and his *Followers*, are very poſitive in this; and offer ſome *Experiments* to render it credible. Nay, a very *Extraordinary Perſon* of our own *Nation* † tries thoſe *Experiments* over again; and diſcovers a great Propenſity to the ſame Thoughts and Opinion they had; declaring for this *Tranſmutation of Water* into *Plants* and *other Bodies*, though with great Modeſty and Deference, which was his uſual manner.

† *Nat. Hiſtory, Cent.* 5. §. 411.

* *Complexionum atque Miſtion. Element. Figm.*

† Mr. *Boyle*, *Scept. Chym. par.* 2.

The *Experiments* they inſiſt upon are chiefly *two*; the *firſt* is, that *Mint*, and ſeveral *other*

Plants

Plants prosper and thrive very greatly in *Water*. The *other* is this; they take a certain quantity of *Earth*, and *bake* it in an *Oven*; then they weigh it, and put it into an *Earthen Pot*. Having well water'd this *Earth*, they make choice of some fit *Plant*, which, being first carefully *weigh'd*, they *set* in it. There they let it grow, continuing to *water it* for some time, till 'tis much advanced in *bigness*: Then they take it up; and though the *Bulk* and *Weight* of the *Plant* be much greater than when *first set*, yet upon *baking* the *Earth*, and *weighing* it, as at first, they find it little or not at all diminished in *weight*; and therefore conclude, 'tis not the *Earth* but *Water*, that nourishes and is *turn'd* into the Substance of the *Plant*.

I must confess I cannot see how *this Experiment* can ever be made with the *nicety* and *justness* that is requisite, in order to *build* upon it so *much* as *these Gentlemen* do. 'Tis hard to weigh *Earth* in that *quantity*, or *Plants* of the *size* of those they mention, with any great *exactness*; or to *bake* the Earth with that *accuracy*, as to reduce it *twice* to just the *same Driness*. But I may wave all this; for though the *Experiment* be never so easily practicable, and all the Accidents of it exactly as they set forth, yet nothing like what they *infer* can possibly be concluded from it; unless *Water*, which they so plentifully bestow upon the *Plant* in *this Experiment*, be *pure*, *homogeneous*, and not charged with any *terrestrial Mixture*; for if it be, the Plant after all may owe its *Growth* and *Encrease* intirely to *that*.

Some

Some *Waters* are indeed so very *clear* and *transparent*, that one would not easily suspect any *terrestrial Matter* were latent in them; but they may be *highly saturated* with such *Matter*, though the Eye be not presently able to descry or discern it. 'Tis true, *Earth* is an *Opake Body*; but it may be so far dissolved, reduced to so extreme small Particles, and these so *diffused* through the *watry Mass*, as not sensibly to impede *Vision*, or render the Water much the less *diaphanous*. *Silver* is an *Opake*, and indeed a very *dense Body*; and yet, if perfectly *dissolved* in *Spirit* of *Nitre*, or *Aqua Fortis*, that is *rectified* and thorowly *fine*, it does not *darken* the *Menstruum*, or render it less *pellucid* than before*. And other Instances there are, that oftentimes *great quantities* of *Opake Matter* are sustain'd in *Fluids*, without considerably striking the *Eye*, or being perceiv'd by it. So that were there *Water* any where found so *pure*, that the quickest Eye could discover in it no *terrestrial Intermixture*; that would be far short of a *Proof*, that in reality there was *none*.

* *Provided the* Silver *be* pure *and absolutely* refin'd: *For the least admixture of* Copper *will produce* a blue Tincture *in the* Menstruum; *as that of some* other Bodies, *one* different.

But after all, even the *clearest Water* is very far from being *pure* and wholly *defecate*, in any part of the World that I can learn. For ours here, I have had an Opportunity of examining it over a good part of *England*; and cannot say I ever met with any, that, however fresh and newly taken out of the Spring, did not exhibit, even to the naked Eye, great num-

bers

numbers of exceeding ſmall terreſtrial Particles diſſeminated through all parts of it. Thicker and craſſer Water exhibits them in ſtill greater Plenty.

Theſe are of two general kinds. The one a vegetable terreſtrial Matter, conſiſting of very different Corpuſcles; ſome whereof are proper for the formation and increment of one ſort of Plant, and ſome of another; as alſo ſome for the Nouriſhment of one part of the ſame Plant, and ſome of another. The other kind of Particles ſuſtain'd in Water are of a Mineral Nature. Theſe likewiſe are of different ſorts. In ſome Springs we find common Salt, in others *Vitriol*, in others *Alum*, *Nitre*, *Sparr*, *Ochre*, &c. nay, frequently ſeveral of theſe, or other Minerals, all in the ſame Spring; the Water as it drains and paſſes thorough the *Strata* of Stone, Earth, and the like, taking up and bearing along ſuch looſe Mineral Corpuſcles, as it meets with in the Pores and Interſtices of thoſe *Strata*, and bringing them on with it quite to the Spring. All Water whatever is much charg'd with the Vegetable Matter, this being fine, light, and eaſily moveable. For the Mineral, the Water of Springs contains more of it than that of Rivers, eſpecially when at diſtance from their Sources; and that of Rivers more than the Water that falls in Rain. This I have learn'd from ſeveral Trials, which I muſt not give Account of here; my Drift in this place being only to evince the Exiſtence of Terreſtrial Matter in Water.

Any

Any one who desires farther Satisfaction in this, may easily obtain it, if he only put Water into a clear Glass Viol, stopping it close, to keep Dust and other exterior Matter out, and letting it stand, without stiring it for some Days: He will then find a considerable Quantity of terrestrial Matter in the Water, however pure and free it might appear when first put into the Viol. He will in a very short time observe, as I have frequently done, the Corpuscles that were at first, while the Water was agitated and kept in motion, separate, and hardly visible *, by degrees, as the Water permits, by its becoming more still and at rest, assembling and combining together; by that means forming somewhat larger and more conspicuous *Moleculæ*. Afterwards he may behold these joining and fixing each to other, by that means forming large thin Masses, appearing like *Nubeculæ*, or Clouds in the Water; which grow more thick and opake, by the continual appulse and accretion of fresh Matter. If the said Matter be chiefly of the Vegetable kind, it will be sustain'd in the Water; and discover at length a green Colour, becoming still more and more of that Colour, I mean an higher and more saturate Green, as the Matter thickens and encreases. That this *Matter* inclines so much to that *Colour*, is the less strange, since we see so large a share of it, when constituting Vegetables wearing the same Colour in them. But if there be any considerable quantity of meer Mineral Matter in the Water, this, being

† *To say nothing of those that were not discernible.*

of

of a greater ſpecifick Gravity than the Vegetable, as the Particles of it unite and combine in ſuch Number, till they form a *Molecula*, the Impetus of whoſe Gravity ſurpaſſes that of the Reſiſtance of the Water, ſubſides a great deal of it to the *bottom*. Nor does it only fall down it ſelf, but frequently entangling with the *Vegetable Nubeculæ*, forces them down along with it.

The Reaſon why Bodies, when diſſolved and reduced to extreme ſmall Parts, are ſuſtain'd in Liquors that are of leſs ſpecifick Gravity than thoſe Bodies are, hath been pointed at by a late ingenious Member of this Society *. He is indeed far from having adjuſted all the *Momenta* of this Affair; however it muſt be admitted, that, in the *dividing* or *ſolution* of Bodies, their Surfaces do not decreaſe in the ſame Proportion that their Bulk does. Now the Gravity of a Body, which is the Cauſe of its ſinking or tendency downwards, is commenſurate to its Bulk; but the reſiſtance that the Liquor makes, is proportion'd, not to the Bulk, but to the Extent of the Surface of the Body immerſed in it. Whence 'tis plain, a Body may be ſo far divided, that its Parts may be ſuſtain'd in a Fluid, whoſe ſpecifick Gravity is leſs than that of the ſaid Body. Nay, 'tis Matter of Fact, that they frequently are ſo; and we daily ſee *Menſtrua* ſupporting the Parts of *Metals*, and other Bodies, that are of ſix, ten, nay, almoſt twenty times the ſpecifick Gravity of thoſe *Menſtrua*. And as the Parts of Bodies when divided, are thus ſupported in a Fluid; ſo

* Mr. *W. Molineux*, *Philoſophical Tranſ. No.* 181.

P when

when they occur and unite again, they must sink of course, and fall to the Bottom.

Upon the whole, 'tis palpable and beyond reasonable Contest, that *Water* contains in it a very considerable Quantity of terrestrial Matter. Now the Question is, to which of these, the Water, or the Earthly Matter sustain'd in it, Vegetables owe their Growth and Augment: For deciding of which, I conceive the following Experiments may afford some Light; and I can safely say, they were made with due Care and Exactness.

Anno 1691.

I chose several *Glass Vials*, that were all, as near as possible, of the same shape and bigness. After I had put what Water I thought fit into every one of them, and taken an Account of the weight of it, I strain'd and ty'd over the Orifice of each Vial, a Piece of Parchment, having an hole in the middle of it, large enough to admit the Stem of the Plant I design'd to set in the Vial, without confining or streightning it, so as to impede its *Growth*. My Intention in this, was to prevent the inclosed Water from evaporating, or ascending any other way than only through the Plant to be set therein. Then I made choice of several Sprigs of Mint, and other Plants, that were, as near as I could possibly judge, alike fresh, sound, and lively. Having taken the weight of each, I placed it in a Vial, order'd as above; and as the Plant imbib'd and drew off the Water, I took care to add more of the same

ſame from time to time, keeping an Account of the weight of all I added. Each of the Glaſſes were, for better diſtinction, and the more eaſie keeping a Regiſter of all Circumſtances, noted with a different Mark or *Letter*, *A*, *B*, *C*, *&c.* and all ſet in a Row in the ſame Window, in ſuch manner that all might partake alike of *Air*, *Light*, and *Sun*. Thus they continued from *July* the Twentieth, to *October* the Fifth, which was juſt Seventy Seven Days. Then I took them out, weigh'd the Water in each Vial, and the Plant likewiſe, adding to its weight that of all the Leaves that had fallen off during the time it ſtood thus. And Laſtly, I computed how much each Plant had gain'd; and how much Water was ſpent upon it. The Particulars are as follow.

‘(A.) *Common Spear-Mint*, ſet in *Spring-Water.* The Planted weighed when put in, *July* ‘20. juſt 27 Grains; when taken forth, *October* ‘5. 42 Grains: So that in this ſpace of 77 ‘Days, it had gained in weight 15 Grains.

‘The whole Quantity of Water expended, during theſe 77 Days, amounted to 2558 Grains. ‘Conſequently the weight of the Water taken ‘up, was $170\frac{8}{15}$ times as much as the Plant had ‘got in weight.

‘(B.) *Common Spear-Mint, Rain-Water.* The ‘Mint weigh'd, when put in, Gr. $28\frac{1}{4}$; when ‘taken out Gr. $45\frac{3}{4}$, having gain'd in 77 Days ‘Gr. $17\frac{1}{2}$.

'The Dispendium of the Water Gr. 3004, 'which was $171\frac{22}{35}$ times as much as the Plant 'had received in weight.

'(C.) *Common Spear-mint, Thames-water.* The 'Plant when put in, Gr. 28, when taken forth, 'Gr. 54. So that in 77 Days it had gained 'Gr. 26.

'The Water expended, amounted to Gr. '2493. which was $95\frac{23}{26}$ times as much as the 'additional weight of the Mint.

'(D.) *Common Solanum,* or *Night-shade : Spring-'water.* The Plant weigh'd, when put in, Gr. '49; when taken out, 106; having gain'd in 77 'Days 57 Gr.

'The Water expended during the said time, 'was 3708 Gr. which was $65\frac{3}{57}$ times as much 'as the Augment of the Plant.

'*This Specimen* had several *Buds* upon it, when 'first set in the Water. *These* in some Days be-'came fair *Flowers,* which were at length succeed-'ed by *Berries.*

'(E.) *Lathyris seu Cataputia Gerh. Spring-'Water.* It weigh'd, when put in, Gr. 98. 'when taken forth, Gr. $101\frac{1}{2}$. The additional 'weight for the whole 77 Days, being but 'Gr. $3\frac{1}{2}$.

'The Quantity of Water spent upon it during 'that time, Gr. 2501. which is $714\frac{4}{7}$ times as 'much as the Plant was augmented.

Several other Plants *were try'd, that did* not thrive *in* Water, *or succeed any better than the* Cataputia *foregoing :*

But

But 'tis besides my purpose to give a parcular Account *of them here.*

(F, G.) *These Two Vials* were fill'd, the former (F) with *Rain*, the other with *Spring-water*, at the same time as those above-mention'd were; and stood as long as they did. But they had neither of them any Plant; my Design in these being only to inform my self, whether any Water exhaled out of the Glasses, otherwise than *thorow* the Bodies of the Plants. The Orifices of these two Glasses were cover'd with Parchment; each piece of it being perforated with an hole of the same bigness with those of the Vials above. In this I suspended a bit of Stick, about the thickness of the Stem of one of the aforesaid Plants, but not reaching down to the Surface of the included Water. I put them in thus, that the Water in these might not have more Scope to evaporate than that in the other Vials. Thus they stood the whole 77 Days in the same Window with the rest; when, upon Examination, I found none of the Water in these wasted or gone off. Tho' I observed both in these, and the rest, especially after hot Weather, small Drops of Water, not unlike Dew, adhering to the Insides of the Glasses, that Part of them, I mean, that was above the Surface of the enclosed Water.

The Water in these two Glasses that had no Plants in them, at the end of the Experiment, exhibited a larger Quantity of Terrestrial Matter than that in any of those that had the Plants in them did. The Sediment at the bottom of the Vials was greater; and the

Nubeculæ, diffus'd through the Body of the Water, thicker. And of that which was in the others, ſome of it proceeded from certain ſmall Leaves that had fallen from that part of the Stems of the Plants that was within the Water, wherein they rotted and diſſolved. The Terreſtrial Matter in the Rain-water was finer than that in the Spring-water.

Anno 1692.

The Glaſſes made uſe of in this, were of the ſame ſort with thoſe in the former Experiment; and cover'd over with Parchment in like manner. The Plants here were all *Spearmint*; the moſt kindly, freſh, ſprightly Shoots I could chuſe. The Water, and the Plants were weigh'd as above; and the Vials ſet in a Line, in a South Window: where they ſtood from *June* the 2d to *July* 28. which was juſt 56 Days.

'(H.) *Hyde-Park Conduit Water*, alone. The '*Mint* weighed, when put in, 127 Gr. when 'taken out, 255 Gr. The whole Quantity of 'Water expended upon this Plant, amounted 'to 14190 Gr.

'This was all along a very kindly Plant; 'and had run up to above two Foot in height. 'It had ſhot but one conſiderable collateral 'Branch; but had ſent forth many and long 'Roots, from which ſprung very numerous, 'though ſmall and ſhort, leſſer Fibres. Theſe 'leſſer Roots came out of the larger on two op'poſite ſides, for the moſt part; ſo that each

'Root,

'Root, with its *Fibrillæ*, appear'd not unlike
'a small Feather. To these *Fibrillæ* adher'd
'pretty must Terrestrial Matter. In the Wa-
'ter, which was at last thick and turbid, was a
'green Substance, resembling a fine thin *Con-*
'*serva*.

'(I.) The *same Water*, alone. The *Mint*
'weigh'd, when put in, 110 Gr. when taken
'out, 249. Water expended, 13140 Gr.

'This Plant was as kindly as the former, but
'had shot no collateral Branches. Its Roots,
'the Water, and the green Substance, all much
'as in the former.

'(K.) *Hyde-Park Conduit-water*, in which was
'dissolved an Ounce and half of *Common Garden-*
'*earth*. The *Mint* weigh'd, when put in, 76
'Gr. when taken out, 244 Gr. Water expend-
'ed, Gr. 10731.

'This Plant, though it had the Misfortune to
'be annoy'd with many small Insects that hapn'd
'to fix upon it; yet had shot very considerable
'collateral Branches; and at least as many
'Roots as either that in H or I; which had a
'much greater Quantity of Terrestrial Matter
'adhering to the Extremities of them. The
'same green Substance here, that was in the two
'preceding.

'(L) *Hyde-Park Water*, with the same Quan-
'ty of *Garden-mould* as in the former. The
'*Mint* weigh'd, when put in, 92 Gr. when ta-
'ken out, 376 Gr. The Water expended
'14950 Gr.

'This Plant was far more flourishing than any 'of the precedent; had several very considerable 'collateral Branches, and very numerous Roots, 'to which Terrestrial Matter adhered very co'piously.

'The Earth in both these Glasses was very 'sensibly and considerably wasted, and less than 'when first put in. The same sort of green 'Substance here as in those above.

'(M) *Hyde-Park Water,* distilled off with a 'gentle Still. The *Mint* weigh'd, when put in, '114 Gr. when taken out 155. The Water ex'pended, 8803 Gr.

'This Plant was pretty kindly; had two small 'collateral Branches, and several Roots, though 'not so many as that in H or I, but as much 'Terrestrial Matter adhering to them as those 'had. The Water was pretty thick; having 'very numerous small Terrestrial Particles swim'ming in it, and some Sediment at the bottom 'of the Glass. This Glass had none of the green 'Matter above mentioned, in it.

'(N) The Residue of the Water, which re'main'd in the *Still* after that in M, was distill'd 'off. It was very turbid, and as high-colour'd '(reddish) as ordinary Beer. The *Mint* weigh'd, 'when put in, 81 Gr. when taken out, 175 'Gr. Water expended, 4344 Gr. This Plant 'was very lively; and had sent out six collate'ral Branches, and several Roots.

(O.) *Hyde-Park Conduit-water,* in which was dissolved a Drachm of Nitre. The Mint set in this suddenly began to wither and decay; and

and died in a few Days: As likewiſe did two more Sprigs, that were ſet in it, ſucceſſively. In another Glaſs I diſſolv'd an Ounce of good Garden-mould, and a Drachm of Nitre, and in a third, half an Ounce of Wood-aſhes, and a Drachm of Nitre; but the Plants in theſe ſucceeded no better than in the former. In other Glaſſes I diſſolved ſeveral other ſorts of Earths, Clays, Marles, and variety of Manures, *&c.* I ſet Mint in diſtill'd Mint-water; and other Experiments I made, of ſeveral kinds, in order to get Light and Information, what haſtened or retarded, promoted or impeded Vegetation; but theſe do not belong to the Head I am now upon.

(P.) *Hyde-Park Conduit-water.* In this I fix'd a Glaſs-Tube about ten Inches long, the Bore about one ſixth of an Inch in Diameter, fill'd with very fine and white Sand, which I kept from falling down out of the Tube into the Vial, by tying a thin piece of Silk over that end of the Tube that was downwards. Upon Immerſion of the lower end of it into the Water, this by little and little aſcended quite to the upper Orifice of the Tube. And yet, in all the fifty ſix Days which it ſtood thus, a very inconſiderable Quantity of Water had gone off, *viz.* ſcarce twenty Grains; though the Sand continued moiſt up to the top till the very laſt. The Water had imparted a green Tincture to the Sand, quite to the very top of the Tube. And, in the Vial, it had precipitated a greeniſh Sediment, mix'd with black. To the bottom and ſides of the Tube, as far as 'twas immer'd in the Water, ad-

her'd

her'd pretty much of the green Subſtance deſcrib'd above. Other like Tubes I fill'd with Cotton, Lint, Pith of Elder, and ſeveral other porous Vegetable Subſtances; ſetting ſome of them in clear Water; others in Water tinged with Saffron, Cochinele, *&c.* And ſeveral other Trials were made, in order to give a mechanical Repreſentation of the motion and diſtribution of the Juices in Plants; and of ſome other *Phænomena* obſervable in Vegetation, which I ſhall not give the Particulars of here, as being not of uſe to my preſent deſign.

(Q, R, S, *&c.*) Several Plants ſet in Vials, ordered in like manner as thoſe above, in *October*, and the following colder Months. Theſe throve not near ſo much; nor did the Water aſcend in nigh the quantity it did in the better Seaſons, in which the before recited Trials were made.

Some Reflections upon the foregoing Experiments.

1. *In Plants of the ſame kind, the leſs they are in Bulk, the ſmaller the Quantity of the fluid Maſs, in which they are ſet, is drawn off; the Diſpendium of it, where the Maſs is of equal thickneſs, being pretty nearly proportion'd to the Bulk of the Plant.* Thus that in the Glaſs mark'd A, which weigh'd only 27 Grains, drew off but 2558 Grains of the Fluid; and that in B, which weigh'd only 28¼, took up but 3004 Grains; whereas that in H, which weigh'd

weigh'd 127 Grains, ſpent 14190 Grains of the Liquid Maſs.

The Water ſeems to aſcend up the *Veſſels* of Plants, in much the ſame manner as up a Filtre; and 'tis no great wonder that a larger Filtre ſhould draw off more Water than a leſſer; or that a Plant that has more and larger Veſſels, ſhould take up a greater ſhare of the Fluid in which it is ſet, than one that has fewer and ſmaller ones can. Nor do I note this as a thing very conſiderable in it ſelf, but chiefly in regard to what I am about to offer beneath; and that it may be ſeen that, in my other Collations of Things, I made due Allowance for this Difference.

2. *The much greateſt part of the fluid Maſs, that is thus drawn off and convey'd into the Plants, does not ſettle or abide there; but paſſes through the pores of them, and exhales up into the Atmoſphere.* That the Water in theſe Experiments aſcended only through the Veſſels of the Plants, is certain. The *Glaſſes* F and G, that had no Plants in them, though diſpoſed of in like manner as the reſt, remain'd at the End of the Experiment, as at firſt; and none of the Water was gone off. And that the greateſt part of it flies off from the Plant into the Atmoſphere, is as certain. The leaſt Proportion of the Water expended, was to the Augment of the Plant, as 46 or 50 to 1. And in ſome the weight of the Water drawn off, was 100, 200, nay, in one above 700 times as much as the Plant had received of Addition.

This

This so continual an Emission and Detachment of Water, in so great Plenty from the Parts of Plants, affords us a manifest Reason why Countries that abound with Trees, and the larger Vegetables especially, should be very obnoxious to Damps, great Humidity in the Air, and more frequent Rains, than others that are more open and free. The great Moisture in the Air, was a mighty inconvenience and annoyance to those who first settled in *America*; which at that time was much overgrown with Woods and Groves. But as these were burnt and destroy'd, to make way for Habitation and Culture of the Earth, the Air mended and clear'd up apace, changing into a Temper much more dry and serene than before.

Nor does this Humidity go off pure and alone; but usually bears forth with it many Parts of the same Nature with those whereof the Plant, through which it passes, consists. The *Crasser* indeed are not so easily born up into the Atmosphere; but are usually deposited on the Surface of the Flowers, Leaves, and other Parts of the Plants: Hence comes our Manna's, our Honeys, and other Gummous Exsudations of Vegetables. But the finer and lighter Parts are with greater ease sent up into the Atmosphere. Thence they are conveyed to our Organs of Smell, by the Air we draw in Respiration; and are pleasant or offensive, beneficent or injurious to us, according to the Nature of the Plants from whence they arise. And since these owe their Rise to the Water, that ascends out of the Earth through the Bodies of Plants, we cannot be far to seek for the Cause why they are more

numerous

numerous in the Air, and we find a greater quantity of Odors exhaling from Vegetables, in warm, humid Seasons, than in any other whatever.

3. *A great part of the Terrestrial Matter that is mix'd with the Water, ascends up into the Plant as well as the Water.* There was much more Terrestrial Matter at the end of the Experiment, in the Water of the Glasses F and G, that had no Plants in them, than in those that had Plants. The *Garden-mould* dissolved in the Glasses K and L, was considerably diminished, and carried off. Nay, the Terrestrial and Vegetable Matter was born up in the Tubes fill'd with Sand, Cotton, &c. in that Quantity, as to be evident even to Sense. And the Bodies in the Cavities of the other Tubes, that had their lower Ends immers'd in Water, wherein Saffron Cochinele, &c. had been infused, were tinged with Yellow, Purple, &c.

If I may be permitted to look abroad a while, towards our Shores and Parts within the Verge of the Sea, these will present us with a large Scene of Plants, that, along with the Vegetable, take up into them meer mineral Matter also in great abundance. Such are our Sea-Purslains, the several sorts of *Alga's*, of Sampires, and other marine Plants. These contain common Sea-salt, which is all one with the *Fossil*, in such plenty, as not only to be plainly distinguish'd on the Palate, but may be drawn forth of them in considerable Quantity. Nay, there want not those who affirm, there are Plants found that will yield *Nitre*, and

and other mineral Salts; of which indeed I am not so far satisfied, that I can depend on the Thing, and therefore give this only as an hint for Enquiry.

To go on with the Vegetable Matter, how apt and how much dispos'd this, being so very fine end light, is to attend Water in all its Motions, and follow it into each of its Recesses, is manifest, not only from the Instances above alledg'd, but many others. Percolate it withal the Care imaginable; Filter it with never so many Filtrations, yet some Terrestrial Matter will remain. 'Tis true, the Fluid will be thinner every time than other, and more disingaged of the said Matter; but never wholly free and clear. I have filtred Water thorough several wholly free and clear Sheets of thick Paper; and, after that, through very close fine Cloth twelve times doubled. Nay, I have done this over and over; and yet a considerable quantity of this Matter discover'd it self in the Water after all. Now if it thus pass Interstices, that are so very small and fine along with the Water, 'tis the less strange it should attend it in its passage through the Ducts and Vessels of Plants. 'Tis true, filtering and distilling of Water intercepts and makes it quit some of the Earthy Matter it was before impregnated withal: But then that which continues with the Water after this, is fine and light; and such consequently, as is in a peculiar manner fit for the Growth and Nourishment of Vegetables. And this is the Case of Rain-water. The Quantity of Terrestrial Matter it bears up into the Atmosphere, is not great. But

But that which it does bear up, is mainly of that light kind of Vegetable Matter; and that too perfectly dissolved, and reduced to single Corpuscles, all fit to enter the Tubules and Vessels of Plants: On which Account 'tis, that this Water is so very fertile and prolifick.

The Reason, why in this Proposition, I say, only a great part of the Terrestrial Matter that is mix'd with the Water, ascends up with it into the Plant, is, because all of it cannot. The Mineral Matter is a great deal of it, not only gross and ponderous, but scabrous and inflexible; and so not disposed to enter the Pores of the Roots. And a great many of the simple Vegetable Particles by degrees unite, and form some of them small Clods or *Moleculæ*; such as those mention'd in H, K, and L, sticking to the Extremities of the Roots of those Plants. Others of them intangle in a looser manner; and form the *Nubeculæ*, and green Bodies, so commonly observ'd in stagnant Water. These, when thus conjoin'd, are too big to enter the Pores, or ascend up the Vessels of Plants, which singly they might have done. They who are conversant in Agriculture, will easily subscribe to this. They are well aware that, be their Earth never so rich, so good, and so fit for the production of Corn or other Vegetables, little will come of it, unless the Parts of it be separated and loose. 'Tis on this Account they bestow the Pains they do in Culture of it, in Digging, Plowing, Harrowing, and Breaking of the Clodded Lumps of Earth. 'Tis the same way that Sea-salt, Nitre, and other

other Salts, promote Vegetation. I am ſorry I cannot ſubſcribe to the Opinion of thoſe Learned Gentlemen, who imagine Nitre to be eſſential to Plants; and that nothing in the Vegetable Kingdom is tranſacted without it. By all the Trials I have been able to make, the thing is quite otherwiſe; and when contiguous to the Plant, it rather deſtroys than nouriſhes it. But this Nitre and other Salts certainly do; they looſen the Earth, and ſeparate the concreted Parts of it; by that means fitting and diſpoſing them to be aſſumed by the Water, and carried up into the Seed or Plant, for its Formation and Augment. There's no Man but muſt obſerve, how apt all ſorts of Salts are to be wrought upon by Moiſture; how eaſily they liquate and run with it; and when theſe are drawn off, and have deſerted the Lumps wherewith they were incorporated, thoſe muſt moulder immediately, and fall aſunder of Courſe. The hardeſt Stone we meet with, if it happen, as frequently it does, to have any ſort of Salt intermix'd with the Sand, of which it conſiſts, upon being expos'd to an humid Air, in a ſhort time diſſolves and crumbles all to pieces; and much more will clodded Earth or Clay, which is not of near ſo compact and ſolid a Conſtitution as Stone is. The ſame way likewiſe is Lime ſerviceable in this Affair. The Husbandmen ſay of it, that it does not fatten, but only mellows the Ground: By which they mean, that it does not contain any thing in it ſelf that is of the ſame Nature with the Vegetable Mould, or afford any Matter fit for the Formation of Plants; but meerly

meerly softens and relaxes the Earth; by that means rendering it more capable of entering the Seeds and Vegetables set in it, in order to their Nourishment, than otherwise it would have been. The Properties of Lime are well known; and how apt 'tis to be put into Ferment and Commotion by Water. Nor can such Commotio ever happen when Lime is mix'd with Earth, however hard and clodded that may be, without opening and loosening of it.

4. *The Plant is more or less nourish'd and augmented, in Proportion as the Water, in which it stands, contains a greater or smaller Quantity of proper terrestial Matter in it.* The Truth of this Proposition is so eminently discernable through the whole Process of these Trials, that I think no doubt can be made of it. The *Mint* in the Glass C, was of much the same Bulk and Weight with those in A and B. But the Water, in which that was, being River-water, which was apparently stored more copiously with terrestrial Matter, than the Spring or Rain-water, wherein they stood, were; it had thriven to almost double the Bulk that either of them had, and with a less Expence of Water too. So likewise the Mint in L, in whose Water was dissolved a small quantity of good Garden-mould, though it had the disadvantage * to be less, when first set, than either of the Mints in H or I, whose Water was the very same with this in L, but had none of that Earth mix'd with it; yet, in a short time the Plant not only overtook, but much out-strip'd those and at the end of the Experiment was very

* *Confer. Prop.* 1. *supra.*

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conſiderably bigger and heavier than either of them. In like manner the *Mint* in N, though leſs at the beginning than that in M, being ſet in that thick, turbid, feculent Water, that remained behind, after that wherein M was placed, was ſtill'd off, had in fine more than double its original weight and bulk; and receiv'd above twice the additional Encreaſe, than that in M, which ſtood in the thinner diſtill'd Water, had done. And, which is not leſs conſiderable, had not drawn off half the Quantity of Water that that had.

Why, in the beginning of this Article, I limit the Proportion of the Augment of the Plant to the Quantity of proper Terreſtrial Matter in the Water, is, becauſe all, even the Vegetable Matter, to ſay nothing of the Mineral, is not proper for the Nouriſhment of every Plant. There may be, and doubtleſs are, ſome Parts in different Species of Plants, that may be much alike, and ſo owe their Supply to the ſame common Matter; but 'tis plain all cannot. And there are other Parts ſo differing, that 'tis no ways credible they ſhould be form'd all out of the ſame ſort of Corpuſcles. So far from it, that there want not good Indications, as we ſhall ſee by and by, that every kind of Vegetable requires a peculiar and ſpecifick Matter for its Formation and Nouriſhment. Yea, each Part of the ſame Vegetable does ſo; and there are very many and different Ingredients go to the Compoſition of the ſame individual Plant. If therefore the Soil, wherein any Vegetable or Seed is planted, contains all or moſt of theſe Ingredients, and thoſe in due quantity, it will grow and thrive there; otherwiſe 'twill not.

If

If there be not as many ſorts of Corpuſcles as are requiſite for the Conſtitution of the main and more eſſential Parts of the Plant, 'twill not proſper at all. If there be theſe, and not in ſufficient Plenty, 'twill ſtarve, and never arrive to its natural Stature: Or if there be any the leſs neceſſary and eſſential Corpuſcles wanting, there will be ſome failure in the Plant; 'twill be defective in Taſte, in Smell, in Colour, or ſome other way. But though a Tract of Land may happen not to contain Matter proper for the Conſtitution of ſome one peculiar kind of Plant; yet it may for ſeveral others, and thoſe much differing among themſelves. The Vegetative Particles are commix'd and blended in the Earth, with all the diverſity and variety, as well as all the uncertainty, conceivable. I have given ſome Intimations of this elſewhere *, and ſhall not repeat them here, but hope in due time to put them into a much better Light than that they there ſtand in.

* *Nat. Hiſt. Earth*, p. 228. & ſeq.

It is not poſſible to imagine, how one uniform, homogeneous Matter, having its Principles or Original Parts all of the ſame Subſtance, Conſtitution, Magnitude, Figure, and Gravity, ſhould ever conſtitute Bodies ſo egregiouſly unlike, in all thoſe reſpects, as Vegetables of different kinds are; nay, even as the different Parts of the ſame Vegetable. That one ſhould carry a reſinous, another a milky, a third a yellow, a fourth a red Juice, in its Veins; one afford a fragrant, another an offenſive Smell; one be ſweet to the Taſte, another bitter, acid, acerbe, auſtere, *&c.* that one ſhould be nouriſhing, another poiſonous, one purging another aſtringent: In

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brief, that there ſhould be that vaſt difference in them, in their ſeveral Conſtitutions, Makes, Pr perties, and Effects, and yet all ariſe from the very ſame ſort of Matter, would be very ſtrange. And, to note by the by, this Argument makes equally ſtrong againſt thoſe, who ſuppoſe meer Water the Matter, out of which all Bodies are form'd.

The *Cataputia* in the Glaſs E, received but very little Encreaſe, only three Grains and an half all the while it ſtood, though 2501 Grains of Water were ſpent upon it. I will not ſay the Reaſon was, becauſe that Water did not contain in it Matter fit and proper for the Nouriſhment of that peculiar and remarkable Plant. No, it may be the Water was not a proper *Medium* for it to grow in; and we know there are very many Plants that will not thrive in it. Too much of that Liquor, in ſome Plants, may probably hurry the Terreſtrial Matter thorough their Veſſels too faſt for them to arreſt and lay hold of it. Be that as it will, 'tis moſt certain there are peculiar Soils that ſuit particular Plants. In *England*, Cherries are obſerv'd to ſucceed beſt in *Kent*; Apples in *Herefordſhire*; Saffron in *Cambridgeſhire*; Wood in two or three of our *Midland Counties*; and Teazles in *Somerſetſhire*. This is an Obſervation that hath held in all Parts, and indeed in all Ages of the World. The moſt ancient Writers of Husbandry † took notice of it; and are not wanting in their Rules for making choice of Soils ſuited to the Nature of each kind of Vegetable they thought valuable, or worth propagating.

† *Vid. Varronem, Columellam, & reliquos Rei Ruſticæ Scriptores.*

But,

But, which is a further Proof of what I am here endeavouring to advance, that Soil that is once proper and fit for the Production of some one sort of Vegetable, does not ever continue to be so. No, in Tract of time it loses that Property; but sooner in some Lands, and later in others: This is what all who are conversant in these things know very well. If Wheat, for Example, be sown upon a Tract of Land that is proper for that Grain, the first Crop will succeed very well; and perhaps the second, and the third, as long as the Ground is in Heart, as the Farmers speak; but in a few Years 'twill produce no more, if sowed with that Corn: Some other Grain indeed it may, as Barley. And after this has been sown so often, that the Land can bring forth no more of the same, it may afterwards yield good Oats; and, perhaps, Pease after them. At length 'twill become barren; the Vegetative Matter, that at first it abounded withal, being educed forth of it by those successive Crops, and most of it born off. Each sort of Grain takes forth that peculiar Matter that is proper for its own Nourishment. First, the Wheat draws off those Particles that suit the Body of that Plant; the rest lying all quiet and undisturbed the while. And when the Earth has yielded up all them, those that are proper for Barley, a different Grain, remain still behind, till the successive Crops of that Corn fetch them forth too. And so the Oats and Pease, in their Turn; till in fine all is carried off, and the Earth in great measure drain'd of that sort of Matter.

After all which, that very Tract of Land may be brought to produce another Series of the ſame Vegetables; but never till 'tis ſupplied with a new Fund of Matter, of like ſort with that it at firſt contain'd. This Supply is made ſeveral ways: By the Grounds lying fallow for ſome time, till the Rain has pour'd down a freſh Stock upon it: Or, by the Tiller's Care in manuring of it. And for farther Evidence that this Supply is in reality of like ſort, we need only reflect a while upon thoſe Manures that are found by conſtant Experience beſt to promote Vegetation, and the Fruitfulneſs of the Earth. Theſe are chiefly either parts of Vegetables, or of Animals; which indeed either derive their own Nouriſhment immediately from Vegetable Bodies, or from other Animals that do ſo. In particular, the Blood, Urine, and Excrements of Animals; Shavings of Horns, and of Hoofs; Hair, Wool, Feathers; calcin'd Shells; Lees of Wine, and of Beer; Aſhes of all ſorts of Vegetable Bodies; Leaves, Straw, Roots, and Stubble, turn'd into the Earth by Plowing or otherwiſe, to rot and diſſolve there: Theſe, I ſay, are our beſt Manures; and, being Vegetable Subſtances, when refunded back again into the Earth, ſerve for the Formation of other like Bodies.

Not wholly to confine our Thoughts to the Fields, let us look a while into our Gardens; where we ſhall meet with ſtill further Confirmations of the ſame thing. The Trees, Shrubs, and Herbs cultivated in theſe, after they have continued in one Station, till they have derived thence the greater part of the Matter fit for their Augment, will decay and degenerate, unleſs

unless either fresh Earth, or some fit Manure, be applied unto them. 'Tis true, they may maintain themselves there for some time, by sending forth Roots further and further to a great Extent all round, to fetch in more remote Provision; but at last all will fail; and they must either have a fresh Supply brought to them, or they themselves be removed and transplanted to some Place better furnished with Matter for their Subsistence. And accordingly *Gardiners* observe, that Plants that have stood a great while in a Place, have longer Roots than usual; part of which they cut off, when they transplant them to a fresh Soil, as now not of any further use to them. All these Instances, to pass over a great many others that might be alledg'd, point forth a particular Terrestrial Matter, and not Water, for the Subject to which Plants owe their Increase. Were it Water only, there would he no need of Manures; or of transplanting them from place to place. The Rain falls in all Places alike; in this Field and in that indifferently; in one side of an Orchard or Garden, as well as another. Nor could there be any Reason, why a Tract of Land should yield Wheat one Year, and not the next; since the Rain showers down alike in each. But I am sensible I have carried on this Article to too great a length; which yet on so ample and extensive a Subject, 'twas not easie to avoid.

5. *Vegetables are not form'd of Water; but of a certain peculiar Terrestrial Matter.* It hath been shewn, that there is a considerable Quantity of this Matter contain'd both in Rain,

Spring, and River-water: That the much greatest part of the fluid Mass that ascends up into Plants, does not settle or abide there, but passes through the Pores of them, and *exhales* up into the Atmosphere: That a great part of the Terrestrial Matter, mix'd with the Water, passes up into the Plant along with it; and that the Plant is more or less augmented in proportion, as the Water contains a greater or smaller Quantity of that Matter. From all which we may very reasonably infer, that *Earth, and not Water, is the Matter that constitutes Vegetables.* The Plant in E, drew up into it 2501 Grains of the fluid Mass; and yet had received but Grains 3 and a half of Increase from all that. The Mint in L, though it had at first the disadvantage to be much less than that in I; yet being set in Water wherewith Earth was plentifully mix'd, and *that* in I, *only in Water* without any such additional Earth, it had vastly outgrown the other, weighing at last 145 Grains more than that did, and so having gain'd about twice as much as that had. In like manner that in K, though 'twas a great deal less when put in than that in I, and also was impair'd and offended by Insects; yet being planted in Water wherein Earth was dissolved, whereas the Water in which it stood had none, it not only over-took, but considerably surpass'd the other; weghing at last 29 Grains more than that in I, and yet had not expended so much Water as that, by above 2400 Grains. The Plant in N, tho' at first a great deal less than that in M; yet being set in the foul crass Water that was left in the Still, after that, in which M was set, was drawn off, in Conclusion had gain'd in weight above

above double what that in the finer and thinner Water had. The Proportion of the Augment of that Plant that throve moſt was, to the fluid Maſs ſpent upon it, but as 1 to 46. In others, 'twas but as 1 to 60, 100, 200; nay, in the *Cataputia*, 'twas but as 1 to 714. The Mint in B took up 39 Grains of Water a-day, one day with another; which was much more than the whole weight of the Plant originally; and yet, with all this, it gain'd not one fourth of a Grain a-day in weight. Nay, that in H took up 253 Grains a day of the Fluid: Which was near twice as much as its original weight, it weighing, when firſt ſet in the Water, but 127 Grains. And, after all, the daily Encreaſe of the Plant was no more than Grains $2\frac{15}{56}$.

6. *Spring, and Rain-water, contain pretty near an equal Charge of Vegetable Matter; River-water more than either of them.* The Plants in the Glaſſes A, B, and C, were at firſt of much the ſame ſize and weight. At the End of the Experiment, the Mint in A had gain'd 15 Grains out of 2558 Grains of Spring-water; that in B, Grains 17 and an half, out of 3004 Grains of Rain-water; but that in C had got 26 Grains out of only 2493 Grains of River-water. I do not found this Propoſition ſolely upon theſe Trials; having made ſome more, which I do not relate here, that agree well enough with theſe. So that the Proportions here deliver'd, will hold for the main; but a ſtrict and juſt Compariſon is hardly to be expected. So far from it, that I make no doubt, but the Water that falls in Rain, at ſome times, contains a greater ſhare of Terreſtrial Matter than that which falls at others.

A more

A more powerful and intense Heat must needs hurry up a larger quantity of that Matter along with the humid Vapours that form Rain, than one more feeble and remiss ever possibly can. The Water of one Spring may flow forth with an higher Charge of this Matter, than that of another; this depending partly upon the quickness of the Ebullition of the Water, and partly upon the Quantity of that Matter latent in the *Strata*, through which the Fluid passes, and the greater or less laxity of those *Strata*. For the same Reason, the Water of one River may abound with it more than that of another. Nay, the same River, when much agitated, and in commotion, must bear up more of it, than when it moves with less rapidity and violence. That there is a great Quantity of this Matter in Rivers; and that it contributes vastly to the ordinary Fertility of the Earth, we have an illustrious Instance in the *Nile*, the *Ganges*, and other Rivers that yearly overflow the neighbouring Plains. Their Banks shew the fairest and largest Crops of any in the whole World. They are even loaded with the multitude of their Productions; and those who have not seen them, will hardly be induced to believe the mighty Returns those Tracts make in comparison of others, that have not the Benefit of like Inundations.

7. *Water serves only for a Vehicle to the Terrestrial Matter, which forms Vegetables; and does not it self make any addition unto them.* Where the proper Terrestrial Matter is wanting, the Plant is not augmented, though never so much Water ascend into it. The *Cataputia* in E, took

up

up more Water than the Mint in C, and yet had grown but very little, having received only three Grains and an half of additional weight; whereas the other had received no leſs than twenty ſix Grains. The Mint in I, was planted in the ſame ſort of Water as that in K, was; only the latter had Earth diſſolved in the Water; and yet that drew off 13140 Grains of the Water, gaining it ſelf no more than 139 Grains in weight; whereas the other took up but 10731 Grains of the Water, and was augmented 168 Grains in weight. Conſequently that ſpent 2409 Grains more of the Water than this in K, did, and yet was not ſo much encreaſed in weight as this by 29 Grains. The Mint in M, ſtood in the very ſame kind of Water as that in N, did. But the Water in M, having much leſs Terreſtrial Matter in it than that in N had, the Plant bore up 8803 Grains of it, gaining it ſelf only 41 Grains the while; whereas that in N drew off no more than 4344 Grains, and yet was augmented 94 Grains. So that it ſpent 4459 Grains of Water more than that did; and yet was not it ſelf ſo much increaſed in weight, as that was, by 53 Grains. This is both a very fair, and a very concluſive Inſtance; on which Account 'tis that I make oftner uſe of it. Indeed they are all ſo; and to add any thing further on this Head, will not be needful.

'Tis evident therefore Water is not the Matter that compoſes Vegetable Bodies. 'Tis only the Agent that conveys that Matter to them; that introduces and diſtributes it to their ſeveral Parts for their Nouriſhment. That Matter is ſluggiſh and unactive, and would lie eternally confin'd confin'd to its Beds of Earth, without ever advancing up into Plants, did not Water, or some like Instrument, fetch it forth and carry it unto them. That therefore there is that plentitiful Provision, and vast Abundance of it supplied to all Parts of the Earth, is a mark of a natural Providence superintending over the Globe we inhabit; and ordaining a due Dispensation of that Fluid, without the Ministry of which the Noble Succession of Bodies we behold, *Animals*, *Vegetables*, and *Minerals*, would be all at a stand *. But to keep to Plants, 'tis manifest Water, as well on this, as upon the other Hypothesis, is absolutely necessary in the Affair of Vegetation; and it will not succeed without it: Which indeed gave occasion to the Opinion, that Water it self nourished, and was changed into Vegetable Bodies. They saw, though these were planted in a Soil never so rich, so happy, so advantageous, nothing came of it unless there was Water too in a considerable quantity. And it must be allow'd Vegetables will not come on or prosper where that is wanting: But yet what those Gentlemen inferr'd thence, was not, we see, well grounded.

* *Conf. Nat. Hist. Earth*, p. 47. & seq. uti & p. 128, &c.

This Fluid is capacitated for the Office here assign'd it several ways: By the Figure of its Parts; which, as appears from many Experiments, is exactly and mathematically Spherical; their Surfaces being perfectly polite, and without any the least Inequalities. 'Tis evident, Corpuscles of such a Figure are easily susceptible of Motion, yea, far above any others whatever;

ever; and conſequently the moſt capable of moving and conveying other Matter, that is not ſo active and voluble. Then the Intervals of Bodies of that Figure are, with reſpect to their Bulk, of all others the largeſt; and ſo the moſt fitted to receive and entertain foreign Matter in them. Beſides, as far as the Trials hitherto made inform us, the conſtituent Corpuſcles of Water are, each ſingly conſider'd, abſolutely ſolid; and do not yield to the greateſt External Force. This ſecures their Figure againſt any Alteration; and the Intervals of the Corpuſcles muſt be always alike. By the latter, 'twill be ever diſpoſed to receive Matter into it; and by the former, when once received, to bear it on along with it. Water is further capacitated to be a Vehicle to this Matter, by the tenuity and fineneſs of the Corpuſcles of which it conſiſts. We hardly know any Fluid in all Nature, except Fire, whoſe conſtituent Parts are ſo exceeding ſubtle and ſmall as thoſe of Water are. They'll paſs Pores and Interſtices, that neither Air nor any other Fluid will. This enables them to enter the fineſt Tubes and Veſſels of Plants, and to introduce the Terreſtrial Matter, conveying it to all Parts of them; whilſt each, by means of Organs 'tis endowed with for the Purpoſe, intercepts and aſſumes into it ſelf ſuch Particles as are ſuitable to its own Nature, letting the reſt paſs on through the common Ducts. Nay, we have almoſt every where Mechanical Inſtances of much the ſame Tenor. 'Tis obvious to every one, how eaſily and ſuddenly Humidity, or the Corpuſcles of Water ſuſtained in the Air, pervade and inſinuate

ſinuate themſelves into Cords, however tightly twiſted, into Leather, Parchment, Vegetable Bodies, Wood, and the like. This it is that fits them for *Hygrometers*; and to meaſure and determine the different quantities of Moiſture in the Air, in different Places and Seaſons. How freely Water paſſes and carries with it Terreſtrial Matter, through Filtres, Colatures, Diſtillations, &c. hath been intimated already.

8. *Water is not capable of performing this Office to Plants, unleſs aſſiſted by a due Quantity of Heat; and this muſt concur, or Vegetation will not ſucceed.* The Plants that were ſet in the Glaſſes Q, R, S, &c. in *October*, and the following colder Months, had not near the quantity of Water ſent up into them, or ſo great an additional Encreaſe by much, as thoſe that were ſet in *June*, *July*, and the hotter. 'Tis plain Water has no power of moving it ſelf; or riſing to the vaſt height it does in the more tall and lofty Plants. So far from this, that it does not appear from any Diſcovery yet made, that even its own Fluidity conſiſts in the inteſtine Motion of its Parts; whatever ſome, otherwiſe very learned and knowing, Perſons may have thought. There is no need of any thing more, for ſolving all the *Phænomena* of Fluidity, than ſuch a Figure and Diſpoſition of the Parts, as Water has. Corpuſcles of that make, and that are all abſolutely Spherical, muſt ſtand ſo very tickle and nicely upon each other, as to be ſuſceptible of every Impreſſion; and though not perpetually in Motion, yet muſt be ever ready and liable to be put into

into it, by any the slightest Force imaginable. It is true, the Parts of Fire or Heat are not capable of moving themselves any more than those of Water; but they are more subtil, light, and active, than those are, and so more easily put into Motion. In fine, 'tis evident and matter of Fact, that Heat does operate upon, and move the Water, in order to its carrying on the Work of Vegetation: But how 'tis agitated it self, and where the Motion first begins, this is no fit Place to enquire.

That the Concourse of Heat in this Work is really necessary, appears, not only from the Experiments before us, but from all Nature; from our Fields and Forests, our Gardens and our Orchards. We see in *Autumn*, as the Sun's Power grows gradually less and less, so its Effects on Plants is remitted, and their Vegetation slackens by little and little. Its Failure is first discernible in Trees. These are raised highest above the Earth; and require a more intense Heat to elevate the Water, charged with their Nourishment, to the Tops and Extremeties of them. So that for want of fresh Support and Nutriment, they shed their Leaves, unless secur'd by a very firm and hardy Constiturion indeed, as our *ever-Greens* are. Next the Shrubs part with theirs; and then the Herbs and lower Tribes; the Heat being at length not sufficient to supply even these, though so near the Earth, the Fund of their Nourishment. As the Heat returns the succeeding Spring, they all recruit again; and are furnish'd with fresh Supplies and Verdure: But first, those which are lowest and nearest the Earth, Herbs, and they that require a lesser

degree

degree of Heat to raiſe the Water with its Earthy Charge into them: Then the Shrubs and higher Vegetables in their Turns; and laſtly, the Trees. As the Heat increaſes, it grows too powerful, and hurries the Matter with too great Rapidity thorough the finer and more tender Plants: Theſe therefore go off, and decay; and others that are more hardy and vigorous, and require a greater ſhare of Heat, ſucceed in their Order. By which Mechaniſm, provident Nature furniſhes us with a very various and differing Entertainment; and what is beſt ſuited to each Seaſon, all the Year round.

As the Heat of the ſeveral Seaſons affords us a different Face of Things; ſo the ſeveral diſtant Climates ſhew different Scenes of Nature, and Productions of the Earth *. The Hotter Countries yield ordinarily the largeſt and talleſt Trees; and thoſe in too much greater variety than the colder ever do. Even thoſe Plants which are common to both, attain to a much greater Bulk in the Southern than in the Northern Climes. Nay, there are ſome Regions ſo bleak and chill, that they raiſe no Vegetables at all to any conſiderable Size. This we learn from *Greenland*, from *Iſeland*, and other Places of like cold Site and Condition. In theſe no Tree ever appears; and the very Shrubs they afford, are few, little, and low.

* *Conf. Nat. Hiſt. Earth*, Pag. 267. & ſeq.

Again, in the warmer Climates, and ſuch as do furniſh forth Trees and the larger Vegetables, if there happen a remiſſion or diminution of the uſual Heat, their Productions will be impeded and diminſhed in proportion. Our late Colder Summers

Summers have given us proof enough of this· For though the Heat we have had, was ſufficient to raiſe the Vegetative Matter into the lower Plants, into our Corns, our Wheat, Barley, Peaſe and the like; and we have had plenty of Straw-berries, Ras-berries, Currans, Goosberries, and the Fruits of ſuch other Vegetables as are low and near the Earth: Yea, and a moderate ſtore of Cherries, Mulberries, Plumbs, Filberts, and ſome others that grow ſomewhat at a greater Height; yet our Apples, our Pears, Walnuts, and the Productions of the taller * Trees have been fewer, and thoſe not ſo kindly, ſo thoroughly ripen'd, and brought to that Perfection they were in the former more benign and their warm Seaſons. Nay, even the lower Fruits and Grains have had ſome ſhare in the common Calamity; and fallen ſhort both in Number and Goodneſs of what the hotter and kinder Seaſons were won't to ſhew us. As to our Grapes, Abricots, Peaches, Nectarens, and Figs, being tranſplanted hither out of hotter Climes, 'tis the leſs wonder we have of late had ſo general a Failure of them.

** The Dwarf-Apple and Pear-trees have ſucceeded better. And indeed in Trees of the ſame kind, thoſe that keep cloſeſt to the Earth always produce the moſt and beſt Fruit. For which Reaſon 'tis that the Gardiners check and reſtrain the Growth of better Fruit-trees, and prevent their running up to too great a Height.*

Nor is it the Sun, or the ordinary emiſſion of the Subterranean Heat only, that promotes Vegetation; but any other indifferently, according to its Power and Degree: This we are taught by our Stoves, hot Beds, and the like. All

Heat is of like kind; and where-ever is the ſame Cauſe, there will be conſtantly the ſame Effect. There's a Procedure in every part of Nature, that is perfectly regular and geometrical, if we can but find it out; and the further our Searches carry us, the more ſhall we have occaſion to admire this, and the better 'twill compenſate our Induſtry.

An Account of the Measure of the thickness of Gold upon Gilt Wire; together with Demonstration of the exceeding Minuteness of the Atoms or constituent Particles of Gold; as it was read before the Royal Society, *by* E. Halley.

WHAT are the constituent Parts of Matter, and how there comes to be so great a diversity in the weight of Bodies, to all appearance equally solid and dense, such as are Gold and Glass, (whose specifick Gravities are nearly as 7 to 1) seems a very hard Question to those that shall rightly consider it: For from undoubted Experiment, Gravity is in all Bodies proportionable to the Quantity of Matter in each; und there is no such thing as a Propension of some more, others less, towards the Earth's Center; since the Impediment of the Air being removed, all Bodies descend, be they never so loose or compact in Texture, with equal Velocity. It follows therefore, That there is 7 times as much Matter in Gold, as in a piece of Glass of the same Magnitude; and consequently, that at least six parts of seven in the Bulk of Glass, must be Pore or Vacuity: This some Favourers of the Atomical Philosophy have endeavoured to solve, by supposing the primary or constituent Atoms of Gold to be much larger than those of other Bodies, and consequently the Pores fewer; whereas in other Bodies, the great multitude of the interspersed Vacuities does diminish their Weights.

Being desirous to examine this Notion of the Magnitude of Atoms of Gold, I bethought my self of the extreme Ductility of that Metal, which is seen in the beating of it into Leaf, and above all in the drawing fine Gilt-wire, by means whereof, I believed I might most exactly obtain the true thickness of the Coat of Gold, that appears, even with the Microscope, so well to represent Gold it self, that not the least point of Silver appears through it. In order to this, I inform'd my self among the Wire-drawers, what Gold they us'd to their Silver; and they told me, That the very best double Gilt Wire was made out of Cylindrick Ingots, 4 Inches in Circumference, and 28 Inches long, which weigh 16 Pounds Troy; on these they bestow 4 Ounces of Gold, that is, to every 48 Ounces of Silver one of Gold; and that two Yards of the superfine Wire weighs a Grain. Hence at first sight it appear'd, that the length of 98 Yards is in weight 49 Grains, and that a single Grain of Gold covers the said 98 Yards, and that the 10000th part of a Grain is above $\frac{1}{3}$ of an Inch long; which yet may be actually divided into 10, and so the 100000th part of a Grain of Gold be visible without a Microscope. But being desirous to compute the thickness of the Skin of Gold, by means of the specifick Gravities of the Metals, *viz.* Silver $10\frac{1}{3}$, and Gold $18\frac{2}{3}$, I found the Diameter of such Wire the $\frac{1}{386}$ part of an Inch, and its Circumference the $\frac{1}{123}$ part; but

the

the Gold in thickneſs not to exceed the $\frac{1}{134500}$ part of an Inch; whence it may be concluded, that the Cube of the hundredth part of an Inch would contain above 2433000000, (or the Cube of 1345) of ſuch Atoms. And it may likewiſe be marvelled at, that Gold being ſtretcht to ſo great a degree, as is here demonſtrated, ſhould yet ſhew it ſelf of ſo even and united a Texture, as not to let the white Colour of the Silver under it appear through any the leaſt Pores; which argues, that even in this exceeding thinneſs very many of thoſe Atoms may ſtill lie one over the other: Which is a Conſideration may merit the Thoughts of this Honourable Society, as tending to examine that renowned Atomical Doctrine, which has of late much obtain'd among the Learned.

An Account of the ſeveral Species of Infinite Quantity, *and of the Proportions they bear one to the other; as it was read before the* Royal Society, *by* E. Halley.

THAT all Magnitudes infinitely great, or ſuch as exceed any aſſignable Quantity, are equal among themſelves, though it be vulgarly received for a Maxim, is not yet ſo common as it is erroneous; and the Reaſon of the miſtake ſeems to be, That the Mind of Man, coming to contemplate the Extenſions of what exceeds the bounds of its Capacity, and of which the very Idea does include a Negation of Limits; it comes to paſs that we we acquieſce generally, and it ſuffices to ſay ſuch a Quantity is infinite.

But if we come more nearly to examine this Notion, we ſhall find, that there are really beſides infinite *Length* and infinite *Area*, no leſs than three ſeveral ſorts of infinite Solidity; all of which are *Quantitates ſui generis*, having no more relation or proportion the one to the other, than a Line to a Plane, or a Plane to a Solid, or a Finite to an Infinite: But that among themſelves, each of thoſe Species of Infinites are in given Proportions, is what I now intend to make plain, if poſſible.

But

But first, infinite Length, or a Line infinitely long, is to be considered either as beginning at a Point, and so infinitely extended one way, or else both ways from the same Point; in which case the one, which is a beginning Infinity, is the one half of the whole, which is the Summ of the beginning and ceasing Infinity; or, as I may say, of Infinity, *à parte ante*, and *à parte post*: Which is analogus to Eternity in Time or Duration, in which there is always as much to follow as is past, from any point or moment of Time: Nor doth the Addition or Subduction of finite Length or Space of time alter the case either in Infinity or Eternity, since both the one or the other cannot be any part of the whole.

As to infinite *Surface* or *Area*, any right Line, infinitely extended both ways on an infinite Plane, does divide that infinite Plane into equal Parts; the one to the right, and the other to the left of the said Line: But if from any Point in such a Plane, two right Lines be infinitely extended, so as to make an Angle, the infinite Area, intercepted between those infinite right Lines, is to the whole infinite Plane, as the Arch of a Circle, on the Point of Concourse of those Lines, as a Centre, intereepted between the said Lines, is to the Circumference of the Circle; or as the Degrees of the Angle to the 360 Degrees of a Circle. For Example, two right Lines meeting at a right Angle do include, on an infinite Plane, a quarter part of the whole infinite Area of such a Plane.

But if so be, two parallel infinite Lines be supposed drawn on such an infinite Plane, the Area intercepted between them will be likewise infinite; but at the same time will be infinitely less, than that Space which is intercepted between two infinite Lines that are inclined, though with never so small an Angle; for that in the one Case, the given finite distance of the parallel Lines diminishes the Infinity in one Degree of Dimension; whereas in a Sector, there is Infinity in both Dimensions; and consequently, the Quantities are the one infinitely greater than the other, and there is no proportion between them.

From the same Consideration arise the Three several Species of infinite Space or Solidity, as has been said; for a Parallelepepide, or a Cylinder, infinitely long, is greater than any finite Magnitude how great soever; and all such Solids, supposed to be formed on given Bases, are as those Bases, in proportion to one another. But if two of these three Dimensions are wanting, as in the Space intercepted between two parallel Planes infinitely extended, and at a finite distance; or with infinite Length and Breadth, with a finite Thickness; All such Solids shall be as the given finite distances one to another: But these Quantities, though infinitely greater than the other, are yet infinitely less than any of those, wherein all the three Dimensions are infinite. Such are the Spaces intercepted between two inclined Planes infinitely extended; the Space intercepted by the Surface of a Cone, or the sides of a Pyramid likewise infinitely continued, &c. of all which notwithstanding, the Proportions one to another, and to the τὸ πᾶν, or vast Abyss of infinite Space (wherein is the *Locus* of all things that are or can be; or to the Solid of infinite Length, Breadth, and Thickness, taken all manner of ways) are easily assignable. For the Space between two Planes, is to the whole, as the

the Angle of those Planes to the 360 Degrees of the Circle. As for Cones and Pyramids, they are as the Spherical Surface, intercepted by them, is to the Surface of the Sphere; and therefore Cones are as the versed Sines of half their Angles, to the Diameter of the Circle: These three sorts of infinite Quantity are analogous to a Line, Surface and Solid, and after the same manner cannot be compared, or have any proportion the one to the other.

Besides these, there are several other Species of infinite Quantity, arising from the Contemplation of Curves, and their Asymptotes; which, by reason of the difficulty of the Subject, cannot be made so plain to most Readers: But what has been already said, may be sufficient to evince what we undertook to explain.

An Account of Dr. Robert Hook's *Invention of the Marine Barometer, with its Description and Uses; published by order of the Royal Society, by* E. Halley, *R. S. S.*

SInce it was found that the *Torricellian Tube*, commonly call'd the *Mercurial Barometer*, by the rising and falling of the *Quick-silver* therein, doth presage the Changes of the Air, in relation to fair and foul Weather; upon several Years Observation of it, it has been proved and adjusted for that purpose by Dr. *Robert Hook*; and there have been by him many attempts to improve the Instrument, and render the Minute Divisions on the Scale thereof more sensible. He also judging that it might be of great use at Sea, contrived several ways to make it serviceable on Board of Ship; one of which he explain'd to the *Royal Society* at their Weekly Meeting in *Gresham College*, *January* 2. 166$\frac{7}{8}$. Since which time he hath further cultivated the Invention, and some Years ago produced before the said *Society*, the Instrument I am now to describe, which for its subtilty and usefulness, seemeth to to ſurpaſs all other performances of the like Nature.

'Till ſuch time as the Author's preſent Indiſpoſition will give him leave to beſtow freely his Thoughts on this Subject upon the Publick, it is the Opinion of the Society, that ſuch an Account be given of this Contrivance, as may render it known, and recommend it to the Mariners uſe, for which it was principally intended.

The *Mercurial Barometer* requiring a perpendicular Poſture, and the *Quick-ſilver* vibrating therein with great Violence upon any Agitation, is therefore uncapable of being uſed at Sea (tho' it hath lately been contrived to be made portable), ſo it remain'd to find out ſome other Principle, wherein the Poſition of the Inſtrument was not ſo indiſpenſably neceſſary: For this, all thoſe that uſe the Sea are obliged to the great facility Dr. *Hook* has always ſhewn, in applying Philoſophical Experiments to their proper uſes.

It is about forty Years ſince, that the *Thermometers* of *Robert de Fluctibus*, depending on the Dilatation and Contraction of included Air by Heat and Cold, have been diſuſed, upon diſcovery that the Airs preſſure is unequal; that inequality mixing it ſelf with the Effects of the warmth of the Air in that Inſtrument. And inſtead thereof was ſubſtituted the ſeal'd *Thermometer*, including Spirit of Wine (firſt brought into *England*, out of *Italy*, by Sir *Robert Southwell*) as a proper Standard of the temper of the Air, in relation to Heat and Cold; that Ætherial Spirit being of all the known Liquors the moſt ſuſceptible of Dilata-
tion

tion and Contraction, eſpecially with a moderate degree of either Heat or Cold. Now this being allow'd as a Standard, and the other *Thermometer* that includes Air, being graduated with the ſame Diviſions, ſo as at the time when the Air was included, to agree with the Spirit-*Thermometer* in all the degrees of Heat and Cold, noting at the ſame time the preciſe height of the *Mercury* in the common Barometers: It will readily be underſtood, that whenſoever theſe two *Thermometers* ſhall agree, the preſſure of the Air is the ſame it was, when the Air was included, and the Inſtrument graduated: That if in the Air-*Thermometer* the Liquor ſtand higher than the Diviſion marked thereon, correſponding with that on the Spirit-glaſs, it is an indication that there is a greater preſſure of the Air at that time, than when the Inſtrument was graduated. And the contrary is to be concluded, when the Air-glaſs ſtands lower than the Spirit, *viz.* that then the Air is ſo much lighter, and the *Quick ſilver*, in the ordinary Barometer lower than at the ſaid time of Graduation.

And the Spaces anſwering to an Inch of *Mercury*, will be more or leſs, according to the quantity of Air ſo included, and the ſmallneſs of the Glaſs Cane, in which the Liquor riſes and falls, and may be augmented almoſt in any proportion, under that of the Specifick Gravity of the Liquor of the *Thermometer* to *Mercury*. So as to have a Foot or more for an Inch of *Mercury*, which is another great convenience,

It

It has been observed by some, that in long keeping this Instrument, the Air included either finds a means to escape, or deposites some Vapours mixt with it, or else for some other cause becomes less Elastick, whereby, in process of time, it gives the height of the *Mercury* somewhat greater than it ought; but this, if it should happen in some of them, hinders not the usefulness thereof, for that it may at any time very easily be corrected by Experiment, and the rising and falling thereof are the things chiefly remarkable in it, the just height being barely a Curiosity.

In these Parts of the World, long Experience has told us, that the rising of the *Mercury* forebodes fair Weather after foul, and an Easterly or Northerly Wind; and that the falling thereof, on the contrary, signifies Southerly or Westerly Winds, with Rain, or stormy Winds, or both; which latter it is of much more consequence to provide against at Sea than at Land; and in a Storm, the *Mercury* beginning to rise is a sure sign that it begins to abate, as has been experienced in high Latitudes, both to the Northwards and Southwards of the Æquator.

The Form of this Instrument is shown in the Cut, by Tab. 4. Fig. 1. wherein,

A B represents the Spirit-*Thermometer*, graduated from 0, or the freezing Point, through all the possible degrees of the Heat or Cold of the Air, at least in these Climates.

C D, is the Air-*Thermometer*, graduated after the same manner with the like Degrees.

E F,

E F, is a Plate applied to the side of the *Thermometer* CD, graduated into Spaces answering to Inches and parts of an Inch of *Mercury*, in the common Barometers.

G, a Hand standing on the Plate at the height of the *Mercury* thereon, as it was when the Instrument was graduated, as suppose here at $29\frac{1}{2}$ Inches.

LM, a Wire on which the Plate EF, slips up and down, parallel to the Cane of the *Thermometer* CD.

K, any Point at which the Spirit stands at the time of Observation; suppose at 38 on the Spirit-*Thermometer*; Slide the Plate EF till the Hand G stand at 38 on the Air-*Thermometer*, and if the Liquor therein stand at 38 likewise, then is the pressure of the Air the same as at the time of Graduation, *viz.* 29, 5; but if it stand higher, as at 30, at I; then is the pressure of the Air greater; and the division on the sliding Plate against the Liquor, shews the present height of the *Mercury* to be twenty nine Inches seven Tenths. And this may suffice as to the manner of using it.

I had one of these Barometers with me in my late Southern Voyage, and it never failed to prognostick and give early notice of all the bad Weather we had, so that I depended thereon, and made provision accordingly; and from my own Experience I conclude that a more useful Contrivance hath not for this long time been offer for the benefit of Navigation.

These

Theſe Inſtruments are made according to the Direction of Dr. *Hook*, by Mr. *Henry Hunt*, Operator to the Royal Society, who will furniſh any Gentlemen with them, and give them Directions how to uſe them.

A

A Diſcourſe concerning the Proportional Heat of the Sun in all Latitudes, with the Method of collecting the ſame; as it was read before the Royal Society, in one of their late Meetings. By E. Halley.

THere having lately ariſen ſome Diſcourſe about that part of the Heat of Weather, ſimply produced by the Action of the Sun; and I having affirmed, that if that were conſidered, as the only Cauſe of the Heat of the Weather, I ſaw no Reaſon, but that under the Pole the ſolſtitical Day ought to be as hot as it is under the Æquinoctial, when the Sun comes vertical, or over the Zenith: For this Reaſon, that for all the 24 Hours of that Day under the Pole, the Sun's Beams are inclined to the Horizon, with an Angle of $23\frac{1}{2}$ Degrees; and under the Æquinoctial, though he come vertical, yet he ſhines no more than 12 Hours, and is again 12 Hours abſent; and that for 3 Hours 8 Minutes of that 12 Hours, he is not ſo much elevated as under the Pole; ſo that he is not 9 of the whole 24, higher than 'tis there, and is 15 Hours lower. Now the ſimple Action of the Sun is, as all other Impulſes or Stroaks, more or or less forceable, according to the *Sinus* of the Angle of Incidence, or to the Perpendicular let fall on the Plain, whence the vertical Ray (being that of the greatest Heat,) being put *Radius*, the force of the Sun on the Horizontal Surface of the Earth will be to that, as the *Sinus* of the Sun's Altitude at any other time. This being allow'd for true, it will then follow, that the time of the continuance of the Sun's shining being taken for a *Basis*, and the *Sines* of the Sun's Altitudes erected thereon as Perpendiculars, and a Curve drawn through the Extremities of those Perpendiculars, the *Area* comprehended shall be proportionate to the Collection of the Heat of all the Beams of the Sun in that space of time. Hence it will follow, that under the Po'e the Collection of all the Heat of a tropical Day, is proportionate to a Rectangle of the *Sine* of $23\frac{1}{2}$ *gr.* into 24 Hours, or the Circumference of a Circle; that is, the *Sine* of $23\frac{1}{2}$ *gr.* being nearly 4 Tenths of *Radius*; as $\frac{8}{10}$ into 12 Hours. On the Polar Heat is equal to that of the Sun containing 12 Hours above the Horizon, at 53 *gr.* height, than which the Sun is not 5 Hours more elevated under the Æquinoctial.

But that this Matter may the better be understood, I have exemplified it by a Scheme, *(Tab. 4. Fig. 2.)* wherein the *Area* ♑ *G H H*, is equal to the *Area* of all the *Sines* of the Sun's Altitude under the Æquinoctial, erected on the respective Hours from Sun-rise to the Zenith; and the *Area* ♋ *H H* ♋ is in the same proportion to the Heat of the same 6 Hours under the Pole on the Topical Day; and ☉ *H H Q*, is proportional to the collected Heat of 12

Hours, or half a Day under the Pole, which ſpace ⊙ *H H Q*, is viſibly greater than the other *Area H ♃ G H*, by as much as the *Area H G Q* is greater than the *Area* ♃ G ⊙; which, that it is ſo, is viſible to ſight, by a great exceſs; and ſo much in proportion does the Heat of the 24 Hours Sun-ſhine under the Pole, exceed that of the 12 Hours under the Æquinoctial: Whence, *Cæteris paribus*, it is reaſonable to conclude, that were the Sun perpetually under the Tropick, the Pole would be at leaſt as warm, as it is now under the Line it ſelf.

But whereas the Nature of Heat is to remain in the Subject, after the Cauſe that heated is removed, and particularly in the Air; under the Æquinoctial, the 12 Hours abſence of the Sun does very little ſtill the Motion impreſſed by the paſt Action of his Rays, wherein Heat conſiſts, before he ariſe again: But under the Pole the long abſence of the Sun for 6 Months, wherein the extremity of Cold does obtain, has ſo chill'd the Air, that it is as it were frozen, and cannot, before the Sun has got far towards it, be any way ſenſible of his preſence, his Beams being obſtructed by thick Clouds, and perpetual Fogs and Miſts, and by that Atmoſphere of Cold, as the late Honourable Mr. *Boyle* was pleaſed to term it, proceeding from the everlaſting Ice, which in immenſe Quantities does chill the Neighbouring Air, and which the too ſoon retreat of the Sun leaves unthawed, to encreaſe again, during the long Winter that follows this ſhort interval of Summer. But the differing Degrees of Heat and Cold, in differing Places, depend in great meaſure upon the Accidents of the Neighbourhood of high Mountains,

tains, whose height exceedingly chills the Air brought by the Winds over them; and of the Nature of the Soil, which variously retains the Heat, particularly the Sandy, which in *Africa*, *Arabia*, and generally where such Sandy Desarts are found, do make the Heat of the Summer incredible to those that have not felt it.

In the prosecution of this first Thought, I have solved the Problem generally, *viz.* to give the proportional Degree of Heat, or the Sum of all the *Sines* of the Sun's Altitude, while he is above the Horizon in any oblique Sphere, by reducing it to the finding of the Curve Surface of a Cylindrick Hoof, or of a given part thereof.

Now this Problem is not of that difficulty as appears at first sight, for in *Tab.* 4. *Fig.* 3. let the Cylinder ABCD be cut obliquely with the Ellipse BKDI, and by the Center thereof H, describe the Circle IKLM; I say, the Curve Surface IKLB is equal to the Rectangle of IK and BL, or of HK and 2 BL or BC: And if there be supposed another Circle, as NQPO, cutting the said Ellipse in the Points P, Q; draw PS, QR, parallel to the Cylinders Axe, till they meet with the aforesaid Circle IKLM in the Points R, S, and draw the Lines RTS, QVP bisected in T and V. I say again, that the Curve Surface RMSQDP is equal to the Rectangle of BL or MD and RS, or of 2 BL or AD and ST or VP; and the Curve Surface QNPD is equal to RS x MD——the Arch RMS x SP, or the Arch MS x 2 SP: Or it is equal to the Surface RMSQDP, substracting the Surface RMSQNP. So likewise the Curve Surface QBPO is equal to the Sum of the Surface RMSQDP, or RS x MD, and of the Surface RLSQOP, or the Arch LS x 2 SP.

This is the most easily demonstrated from the Consideration, That the Cylindrick Surface IKLB is to the inscrib'd Spherical Surface IKLE, either in the whole, or in its Analogous Parts, as the tangent BL is to the Arch EL, and from the Demonstrations of *Archimedes de Sphæra & Cylindro, Lib.* I. *Prop.* XXX, and XXXVII, XXXIIX. which I shall not repeat here, but leave the Reader the pleasure of examining it himself; nor will it be amiss to consult Dr. *Barrow*'s Learned Lectures on that Book, Publish'd at *London*, *Anno* 1684, *viz. Probl.* IX. and the Corollaries thereof.

Now to reduce our Case of the Sum of all the *Sines* of the Sun's Altitude in a given Declination and Latitude to the aforesaid Problem, let us consider (*Tab.* 4. *Fig.* 4.) which is the *Analemma* projected on the Plain of the *Meridian*, Z the Zenith, P the Pole, HH the Horizon, æ æ the Æquinoctial, ♋ ♋, ♑ ♑ the two Tropicks, ♋ I the *Sine* of the Meridian Altitude in ♋; and equal thereto, but perpendicular to the Tropick, erect ♋ 1, and draw the Line T 1 intersecting the Horizon in T, and the Hour Circle of 6, in the Point 4, and 6 4 shall be equal to 6R, or to the *Sine* of the Altitude at 6: And the like for any other Point in the Tropick, erecting a Perpendicular thereat, terminated by the Line T 1: Through the Point 4 draw the Line 4, 5, 7 parallel to the Tropick, and representing a Circle equal thereto; then shall the Tropick ♋ ♋ in *Fig.* 4. answer to the Circle NOPQ, in *Fig.* 3. the Circle 4, 5, 7, shall answer the Circle IKLM, T 4 1 shall answer to the Elliptick Segment QIBKP, 6 R or 6 4 shall answer to SP, SP, and ♋ 1 to BL, and the Arch ♋ T, to the Arch LS, being the semidiurnal Arch in that Latitude and Declination; the *Sine* whereof, tho' not expressible in *Fig.* 4. must be conceived as Analogous to the Line TS or UP in *Fig.* 3.

The Relation between these two Figures being well understood, it will follow from what precedes, That, *the sum of the* Sines *of the Meridian Altitudes of the Sun in the two Tropicks, (and the like for any two opposite Parallels) being multiplied by the* Sine *of the semidiurnal Arch, will give an* Area *Analogous to the Curve Surface* R(M S Q D P; *and thereto adding in Summer, or substracting in Winter, the Product of the length of the semidiurnal Arch, (taken according* ~~to~~ Van Ceulen's *Numbers) into the difference of the abovesaid* Sines *of the Meridian Altitude: The sum in one case, and difference in another, shall be as the Aggregate of all the* Sines *of the Sun's Altitude, during his appearance above the Horizon; and consequently of all his Heat and Action on the Plain of the Horizon in the proposed Day.* And this may also be extended to the parts of the same Day; for if the aforesaid Sum of the *Sines* of the Meridian Altitudes, be multiplied by half the Sum of the *Sines* of the Sun's Horary distance from Noon, when the Times are before and after Noon; or by half their difference, when both are on the same side of the Meridian; and thereto in Summer, or therefrom in Winter, be added or substracted the Product of half the Arch answerable to the proposed interval of Time, into the difference of the *Sines* of Meridian Altitudes, the Sum in one case and Difference in the other, shall be proportional to all the Action of the Sun during that space of time.

I fore-see it will be Objected, that I take the *Radius* of my Circle on which I erect my Perpendiculars always the same, whereas the Parallels of Declination are unequal; but to this I answer, That our said Circular Bases ought not to be Analogous to the Parallels, but to the Times of Revolution, which are equal in all of them.

It may perhaps be useful to give an Example of the Computation of this Rule, which may seem difficult to some. Let the Solsticical Heat in ♋ and ♑ be required at *London, Lat.* 51° 32′.

38°-28′	*Co-Lat.*	*Diff. Ascen.*	33°0-1′1.
23 -30	*Decl.* ☉	*Arch. Semid. æstiv.*	123-11.
61 -58	*Sinus*= ,8826 4	*Ar. Sem. hyb.*	56-49. S. ,638923
14 -58	*Sinus*= ,258257	*Arch. æstiv. mensura*	2,149955
	Summa 1,140931	*Arc. hyb. mensura*	991683
	Diff. ,624417		

Then 1 ,140931 in ,836923, + 624417 in 2 ,149955=2,29734. And 1,140931 in 836929 −,624417 in ,991638= 33895.

So that 2,29734 will be as the Tropical Summers Day Heat, and 0,33895 as the Action of the Sun in the Day of the Winter Solstice.

After this manner I computed the following Table for every tenth Degree of Latitude, to the Æquinoctial and Tropical Sun, by which an Estimate may be made of the intermediate Degrees.

Lat.

Lat.	Sun in ♈ ♎	Sun in ♋	Sun in ♑
0	20000	18341	18341
10	19696	20290	15834
20	18794	21737	13166
30	17321	22651	10124
40	15321	23048	6944
50	12855	22991	3798
60	10000	22773	1075
70	6840	23543	000
80	3473	24673	000
90	0000	25055	000

Those that desire more of the Nature of this Problem, as to the Geometry thereof, would do well to compare the XIII. *Prop. Cap.* V. of the Learned Treatise, *De Calculo Centri Gravitatis*, by the Reverend Dr. *Wallis*, Published *Anno* 1670.

From this Rule there follow several Corollaries worth Note: As I. That the Æquinoctial Heat, when the Sun comes Vertical, is as twice the Square of *Radius*, which may be proposed as a Standard to compare with, in all other Cases. II. That under the Æquinoctial, the Heat is as the *Sine* of the Sun's Declination. III. That in the Frigid Zones when the Sun sets not, the Heat is as the Circumference of a Circle into the *Sine* of the Altitude at 6. And consequently, that in the same Latitude these Aggregates of Warmth, are as the *Sines* of the Sun's Declinations; and in the same Declination of *Sol*, they are as the *Sines* of the Latitude, and generally they are as the *Sines* of the Latitude into the *Sines* of Declination. IV. That the Æquinoctial Days Heat is every where as the Co-sine of the Latitude. V. In all places where the Sun sets, the difference between the Summer and Winter Heats, when the Declinations are contrary, is equal to a Circle into the *Sine* of the Altitude at six in the Summer Parallel, and consequently those differences are as the *Sines* of Latitude into, or multiplied by the *Sines* of Declination. VI. From the Table I have added, it appears, that the Tropical Sun under the Æquinoctial, has, of all others, the least Force. Under the Pole it is greater than any other Days Heat whatsoever, being to that of the Æquinoctial as 5 to 4.

From the Table and these Corollaries may a general *Idea* be conceived of the Sum of all the Actions of the Sun in the whole Year, and that part of the Heat that arises simply from the Presence of the Sun be brought to a Geometrical Certainty: And if the like could be performed for Cold; which is something else than the bare Absence of the Sun, as appears by many Instances, we might hope to bring what relates to this part of *Meteorology* to a perfect Theory.

Con-

Concerning the Diſtance of the Fix'd Stars. By the Honourable Francis Roberts, Eſq; S. R. S.

THE Ancient Aſtronomers, who had no other way of computing the Diſtances of the Heavenly Bodies, but by their Parallax to the Semi-diameter of the Earth; and being never able to diſcover any in the fix'd Stars, did from thence rightly enough infer, that their Diſtance was very great, and much exceeding that of the Planets, but could go no farther otherwiſe than by uncertain gueſs.

Since the *Pythagorean* Syſtem of the World has been reviv'd by *Copernicus*, (and now by all Mathematicians accepted for the true one) there ſeem'd Ground to imagine that the Diameter of the Earth's Annual Courſe (which, according to our beſt Aſtronomers, is at leaſt 40000 times bigger than the Semi-diameter of the Earth) might give a ſenſible Parallax to the fix'd Stars, though the other could not, and thereby determine their Diſtance more preciſely.

But though we have a Foundation to build on ſo vaſtly exceeding that of the Ancients, there are ſome Conſiderations may make us ſuſpect that even this is not large enough for our purpoſe.

Monſieur

Monsieur *Hugens* (who is very exact in is Astronomical Observations) tells us, he could never discover any visible Magnitude in the fix'd Stars, though he used Glasses which magnified the apparent Diameter above 100 times.

Now, since in all likelyhood the fix'd Stars are Suns, (perhaps of a different Magnitude) we may as a reasonable *Medium* presume they are generally about the bigness of the Sun.

Let us then (for Example) suppose the Dog-Star to be so. The Distance from us to the Sun being about 100 times the Sun's Diameter (as is demonstrable from the Sun's Diameter being 32 Minutes) it is evident, that the Angle under which the Dog-Star is seen in Mr. *Hugens*'s Telescope, must be near the same with the Angle of its Parallax to the Sun's Distance, or Semi-diameter of the Earth's Annual Course; so that the Parallax to the whole Diameter, can be but double such a quantity, as even to Mr. *Hugens's* nice Observation is altogether insensible.

The Distance therefore of the fix'd Stars seems hardly within the reach of any of our Methods to determine; but from what has been laid down, we may draw some Conclusions that will much illustrate the prodigious vastness of it.

1. That the Diameter of the Earth's Annual Orb (which contains at least 160 Millions of Miles) is but as a Point in comparison of it; at least it must be above 6000 times the Distance of the Sun: For if a Star should appear thro' the aforesaid Telescope half a Minute broad (which is a pretty sensible Magnitude) the true apparent Diameter would not exceed 18 3d Minutes, which is less than the 6000th part of the apparent Diameter of the Sun, and consequently the

the Sun's Diſtance not the 6000th part of the Diſtance of the Star.

2. That could we advance towards the Stars 99 Parts of the whole Diſtance, and have only $\frac{1}{100}$ Part remaining, the Stars would appear little bigger to us than they do here; for they would ſhew no otherwiſe than they do through a Teleſcope, which magnifies an Hundred-fold.

3. That at leaſt Nine Parts in Ten of the Space between us and the fix'd Stars, can receive no greater Light from the Sun, or any of the Stars, than what we have from the Stars in a clear Night.

4. That Light takes up more time in travelling from the Stars to us, than we in making a *Weſt-India* Voyage (which is ordinarily perform'd in ſix Weeks.) That a Sound would not arrive to us from thence in 50000 Years, nor a Cannon-bullet in a much longer time. This is eaſily computed, by allowing (according to Mr. *Newton)* Ten Minutes for the Journey of Light from the Sun hither, and that a Sound moves about 1300 Foot in a Second.

The

The Famous Mr. Isaac Newton's *Theory of the* Moon.

THIS *Theory* which hath been long expected by all the true Lovers of *Astronomy*, was communicated from Mr. *Newton* to Dr. *Gregory*, *Astronomy* Professor at *Oxford*, and by him published in his *Astron. Elem. Philos.* and *Geomet.* p. 336. From whence, as it was lately translated into *English*, I thought fit to insert it here.

By this Theory, what by all Astronomers was thought most difficult and almost impossible to de done, the Excellent Mr. *Newton* hath now effected; *viz.* to determine the Moon's Place even in her Quadratures, and all other Parts of her Orbit, besides the Syzygys, so accurately by Calculation, that the Difference between that and her true Place in the Heavens, shall scarce be above two minutes in her Syzygys, or above three in her Quadratures, and is usually so small, that it may well enough be reckon'd only as a Defect in the Observation. And this Mr. *Newton* experienced, by comparing it with very many Places of the Moon, observ'd by Mr. *Flamsteed*, and communicated to him.

The Royal Observatory at *Greenwich*, is to the West of the Meridian of *Paris*, 2 degrees, 19 minutes. Of *Uraniburgh*, 12 degrees, 51 minutes, 30 seconds. And of *Gedanum*, 18 degees, 48 minutes.

The

The mean Motions of the Sun and Moon, accounted from the Vernal Æquinox at the Meridian of *Greenwich*, I make to be as followeth.

The last Day of *December* 1680, at Noon (*Old Stile)* the mean Motion of the Sun was 9 Signs, 20 degrees, 34 minutes, 46 seconds. Of the Sun's Apogæum, was 3 S. 7 deg. 23 min. 30 seconds.

That the mean Motion of the Moon at that time, was 6 S. 1 degree, 45 minutes, 45 seconds. And of her Apogee, 8 S. 4 degrees, 28 minutes, 5 seconds. Of the ascending Node of the Moon's Orbit, 5 S. 24 deg. 14 min. 35 seconds, *&c.*

And on the last Day of *December*, 1700. at Noon, the mean Motion of the Sun was 9 S. 20 degrees, 43 minutes, 50 seconds. Of the Sun's Apogee, 3 S. 7 degrees, 44 minutes, 30 seconds. The mean Motion of the Moon was 10 S. 15 degrees, 19 minutes, 50 seconds. Of the Moon's Apogee, 11 S. 8 degrees, 18 minutes, 20 seconds. And of her ascending Node, 4 S. 27 degrees, 24 minutes, 20 seconds. For in 20 *Julian* Years, or 7305 Days, the Sun's Motion is 20 Revol. 0 S. 0 degrees, 9 minutes, 4 seconds. And the Motion of the Sun's Apogee, 21 minutes, 0 seconds.

The Motion of the Moon in the same time, is 267 Revol. 4 S. 13 degrees, 34 minutes, 5 seconds. And the Motion of the Lunar Apogee, is 2 Revol. 3 S. 3 degrees, 50 minutes, 15 seconds. And the Motion of her Node, 1 Revol. 0 S. 26 degrees, 50 minutes, 15 seconds.

All which Motions are accounted from the Vernal Æquinox: Wherefore if from them there be subtracted the Recession or Motion of the Æquinoctial Point, in *Antecedentia*, during that space, which is 16 minutes, 40 seconds, there will

will remain the Motions in reference to the fix'd Stars in 20 *Julian* Years; *viz.* the Sun's 19 Revol. 11 S. 29 degrees, 52 minutes, 24 seconds. Of his Apogee, 4 minutes, 20 seconds. And the Moon's 267 Revol. 4 S. 13 degrees, 17 minutes, 25 seconds. Of her Apogee, 2 Revol. 3 S. 3 degrees, 33 minutes, 35 seconds. And of the Node of the Moon, 1 Revol. 0 S. 27 degrees, 6 minutes, 55 seconds.

According to this Computation, the *Tropical Year* is 365 Days, 5 Hours, 48 Minutes, 57 Seconds. And the *Sydereal Year* is 365 Days, 6 Hours, 9 Minutes, 14 Seconds.

These mean Motions of the Luminaries are affected with various Inequalities: Of which,

1. There are the Annual Equations of the aforesaid mean Motions of the Sun and Moon, and of the Apogee and Node of the Moon.

The Annual Equation of the mean Motion of the Sun, depends on the Eccentricity of the Earth's Orbit round the Sun, which is $16\frac{11}{12}$ of such Parts, as that the Earth's mean Distance from the Sun shall be 1000: Whence 'tis call'd the *Equation of the Centre*; and is, when greatest, 1 degree, 56 minutes, 20 seconds.

The greatest Annual Equation of the Moon's mean Motion, is 11 degrees, 49 seconds; of her Apogee, 20 minutes, and of her Node, 9 minutes, 30 seconds.

And these four Annual Equations are always mutually proportional one to another: Wherefore when any of them is at the greatest, the other three will also be greatest; and when any one lessens, the o-

ther

ther three will alſo be diminiſhed in the ſame *Ratio*.

The Annual Equation of the Sun's Centre being given, the three other correſponding Annual Equations will be alſo given; and therefore a Table of that will ſerve for all. For if the Annual Equation of the Sun's Centre be taken from thence, for any Time, and be call'd P, and let $\frac{1}{10}$ P = Q, Q + $\frac{1}{60}$ Q = R, $\frac{1}{6}$ P = D, D + $\frac{1}{30}$ D = E, and D − $\frac{1}{50}$ D = 2 F; then ſhall the Annual Equation of the Moon's mean Motion for that time be R, that of the Apogee of the Moon will be E, and that of the Node F.

Only obſerve here, That if the Equation of the Sun's Centre be required to be added; then the Equation of the Moon's mean Motion muſt be ſubtracted, that of her Apogee muſt be added, and that of the Node ſubducted, And on the contrary, if the Equation of the Sun's Centre were to be ſubducted, the Moon's Equation muſt be added, the Equation of her Apogee ſubducted, and that of her Node added.

There is alſo an *Equation of the Moon's mean Motion*, depending on the ſituation of her Apogee, in reſpect of the Sun; which is greateſt when the Moon's Apogee is in an Octant with the Sun, and is nothing at all when it is in the Quadratures or Syzygys, This Equation, when greateſt, and the Sun in *Perigæo*, is 3 Minutes, 56 Seconds. But if the Sun be in *Apogæo*, it will never be above 3 Minutes 34 Secounds. At other Diſtances of the Sun from the Earth, this Equation, when greateſt, is reciprocally as the Cube of ſuch Diſtance. But

when

when the Moon's Apogee is any where but in the *Octants*, this Equation grows less, and is mostly at the same distance between the Earth and Sun, as the Sine of the double Distance of the Moon's Apogee, from the next Quadrature or Syzygy, to the Radius.

This is to be added to the Moon's Motion, while her Apogee passes from a Quadrature with the Sun to a Syzygy; but this is to be subtracted from it, while the Apogee moves from the Syzygy to the Quadrature.

There is moreover another *Equation of the Moon's Motion*, which depends on the Aspect of the Nodes of the Moon's Orbit with the Sun: And this is greatest, when her Nodes are in *Octants* to the Sun, and vanishes quite, when they come to their Quadratures or Syzygys. This Equation is proportional to the Sine of the double Distance of the Node from the next Syzygy, or Quadrature; and at greatest, is but 47 seconds. This must be added to the Moon's mean Motion, while the Nodes are passing from their Syzygys with the Sun, to their Quadratures with him; but subtracted while they pass from the Quadratures to the Syzygys.

From the Sun's true Place, take the equated mean Motion of the Lunar Apogee, as was above shew'd, the Remainder will be the Annual Argument of the said Apogee. From whence the *Eccentricity of the Moon*, and the *second Equation* of her Apogee may be computed after the manner of the following (*which takes place also in the Computation of any other intermediate Equations.*

Let

Tab. 3. Fig. 6. Let T represent the Earth, T S, a Right Line joining the Earth and Sun, T A C B, a Right Line drawn from the Earth to the middle or mean Place of the Moon's Apogee, equated, as above: Let the Angle S T A be the Annual Argument of the aforesaid Apogee, T A the least Eccentricity of the Moon's Orbit, T B the greatest. Bissect A B in G; and on the Centre C, with the Distance A C describe a Circle A F B, and make the Angle B C F = to the double of the Annual Argument. Draw the Right Line T F, that shall be the Eccentricity of the Moon's Orbit; and the Angle B T F, is the second Equation of the Moon's Apogee required.

In order to whose Determination, let the mean Distance of the Earth from the Moon, or the Semi-diameter of the Moon's Orbit, be 100000; then shall its greatest Eccentricity T B be 66782 such Parts; and the least T A, 43319. So that the greatest Equation of the Orbit, *viz.* when the Apogee is in the Syzygys, will be 7 degrees, 39 minutes, 30 seconds, or perhaps 7 degrees, 40 minutes, (for I suspect there will be some Alteration, according to the Position of the Apogee in *Cancer* and *Capricorn.*) But when it is Quadrate to the Sun, the greatest Equation aforesaid will be 4 degrees, 57 minutes, 56 seconds; and the greatest Equation of the Apogee, 12 degrees, 15 minutes, 4 seconds.

Having from these Principles made a Table of the Equation of the Moon's Apogee, and of the Eccentricities of her Orbit to each degree of the Annual Argument, from whence the Eccentricity T F, and the Angle B T F (*viz.* the second and the principal Equation of

T the

the Apogee) may easily be had for any Time required; let the Equation thus found be added to the first Equated Place of the Moon's Apogee, if the Annual Argument be less than 90 degrees, or greater than 180 degrees, and less than 270; otherwise it must be subducted from it; and the Sum or Difference shall be the Place of the Lunar Apogee secondarily equated; which being taken from the Moon's Place equated a third time, shall leave the mean Anomaly of the Moon corresponding to any given Time. Moreover, from this mean Anomaly of the Moon, and the before-found Eccentricity of her Orbit, may be found (by means of a Table of Equations of the Moon's Centre made to every degree of the mean Anomaly, and some Eccentricities, (*viz.* 45000, 50000, 55000, 60000, and 65000) the *Prostaphæresis*, or Equation of the Moon's Centre, as in the common way: And this being taken from the former Semi-circle of the middle Anomaly, and added in the latter to the Moon's Place thus thrice equated, will produce the Place of the Moon a fourth time equated.

The greatest Variation of the Moon (*viz.* that which happens when the Moon is in an Octant with the Sun) is nearly, reciprocally as the Cube of the Distance of the Sun from the Earth. Let that be taken 37 minutes, 25 seconds, when the Sun is *in Perigæo*, and 33 minutes, 40 seconds, when he is *in Apogæo*: And let the Differences of this Variation in the Octants be made reciprocally, as the Cubes of the Distances of the Sun from the Earth; and so let a Table be made of the aforesaid Varia-

tion

tion of the Moon in her Octants (or its Logarithms) to every Tenth, Sixth, or Fifth Degree of the mean Anomaly: And for the Variation out of the Octants, make, as Radius to the Sine of the double Distance of the Moon from the next Syzygy, or Quadrature :: so let the afore-found Variation in the Octant be to the Variation congruous to any other Aspect; and this added to the Moon's Place before found in the first and third Quadrant (accounting from the Sun) or subducted from it in the second and fourth, will give the Moon's Place equated a fifth time.

Again, as Radius to the Sine of the Summ of the Distances of the Moon from the Sun, and of her Apogee from the Sun's Apogee (or the Sine of the Excess of that Summ above 360 degrees,) :: so is 2 minutes, 10 seconds, to a sixth Equation of the Moon's Place, which must be subtracted, if the aforesaid Summ or Excess be less than a Semi-circle; but added, if it be greater. Let it be made also, as Radius to the Sine of the Moon's distance from the Sun:: so 2 degrees, 20 secants, to a seventh Equation; which when the Moon's Light is increasing, add; but when decreasing, subtract; and the Moon's Place will be equated a seventh time, and this is her Place *in her proper Orbit.*

Note here, the Equation thus produced by the mean Quantity 2 degrees, 20 seconds, is not always of the same magnitude; but is increased and diminished, according to the Position of the Lunar Apogee. For if the Moon's Apogee be in Conjunction with the

Sun's, the aforesaid Equation is about 54 seconds greater: But when the Apogees are in Opposition, 'tis about as much less; and it librates between its greatest Quantity 3 minutes, 14 seconds, and its least, 1 minute, 26 seconds. And this is, when the Lunar Apogee is in Conjunction, or Opposition with the Sun's: But in the Quadratures, the aforesaid Equation is to be lessen'd about 50 seconds, or 1 minute, when the Apogees of the Sun and Moon are in Conjunction; but if they are in Opposition, for want of a sufficient number of Observations, I cannot determine, whether it is to be lessen'd or increas'd. And even as to the Argument or Decrement of the Equation, 2 minutes, 20 seconds, above mentioned, I dare determine nothing certain, for the same Reason, *viz.* the want of Observations accurately made.

If the sixth and seventh Equations are augmented or diminished in a reciprocal *Ratio* of the distance of the Moon from the Earth; *i. e.* in a direct *Ratio* of the Moon's Horizontal Parallax, they will become more accurate: And this may be readily done, if Tables are first made to each minute of the said Parallax, and to every sixth or fifth degree of the Argument of the sixth Equation for the Sixth, as of the distance of the Moon from the Sun, for the Seventh Equation.

From the Sun's Place, take the mean motion of the Moon's ascending Node, equated as above; the Remainder shall be the Annual Argument of the Node, whence its second Equation may be computed after the following manner in the preceding Figure.

Let

Let T, as before, represent the Earth; T S a Right Line, conjoining the Earth and Sun: Let also the Line T A C B, be drawn to the Place of the ascending Node of the Moon, as above equated; and let S T A be the Annual Argument of the Node. Take T A from a Scale, and let it be to A B :: as 56 to 3, or as 11 $\frac{2}{3}$ to 1. Then bissect B A in C, and on C as a Centre, with the Distance C A, describe a Circle, as A F B, and make the Angle B C F, equal to double the Annual Argument of the Node before-found: So shall the Angle B T F, be the second Equation of the ascending Node; which must be added, when the Node is passing from the Quadrature to a Syzygy with the Sun; and subducted, when the Node moves from a Syzygy towards a Quadrature. By which means, the true Place of the Node of the Lunar Orbit will be gained: Whence from Tables made after the common way, the *Moon's Latitude, and the Reduction of her Orbit to the Ecliptick*, may be computed, supposing the Inclination of the Moon's Orbit to the Ecliptick, to be 4 degrees, 59 minutes, 35 seconds, when the Nodes are in Quadrature with the Sun; and 5 degrees, 17 minutes, 20 seconds, when they are in the Syzygys.

And from the Longitude and Latitude thus found, and the given Obliquity of the Ecliptick, 23 degrees, 29 minutes, the Right Ascension and Declination of the Moon will be found.

The Horizontal Parallax of the Moon, when she is in the Syzygys, at a mean distance from the Earth, I make to be 57 minutes, 30 seconds; and her Horary Motion, 33 minutes, 32 seconds, 32 thirds; and her apparent Diameter 31 minutes, 30 seconds. But in her Quadratures at a mean Distance from the Earth, I make the Horizontal Parallax of the Moon to be 59 minutes, 40 seconds, her Horary Motion 32 minutes, 12 seconds, 2 thirds, and her apparent Diameter, 31 minutes, 3 seconds. The Moon in an Octant to the Sun, and at a mean distance, hath her Centre distant from the Centre of the Earth about 60 $\frac{1}{3}$ of the Earth's Semidiameters.

The Sun's Horizontal Parallax I make to be 10 seconds, and its apparent Diameter at a mean distance from the Earth, I make 32 minutes, 15 seconds.

The Atmosphere of the Earth, by dispersing and refracting the Sun's Light, casts a Shadow, as if it were an Opake Body, at least to the height of 40 or 50 Geographical Miles (by a Geographical Mile, I mean the sixtieth part of a Degree of a great Circle, on the Earth's Surface.) This Shadow falling upon the Moon in a Lunar Eclipse, makes the Earth's Shadow be the larger or broader. And to each Mile of the Earth's Atmosphere, is correspondent a Second in the Moon's Disk, so that the Semi-diameter of the Earth's shadow projected upon the Disk of the Moon, is to be increased about 50 seconds: Or, which is all one, in a Lunar Eclipse, the Horizontal Parallax of the Moon is to be increased in the Ratio of about 70 to 69.

Thus far the Theory of this Incomparable Mathematician. And if we had many Places of the Moon accurately observ'd, especially about her Quadratures, and these well compar'd par'd with her Places, at the ſame time calculated according to this Theory; it would then appear, whether there yet remain any other ſenſible Equations; which when accounted for, might ſerve to improve and enlarge this Theory.

An Estimate of the Degrees of the Mortality *of Mankind, drawn from curious* Tables *of the* Births *and* Funerals *at the City of* Breslaw; *with an Attempt to ascertain the Price of* Annuities *upon* Lives. *By Mr.* E. Halley, *R. S. S.*

THE Contemplation of the *Mortality* of *Mankind*, has besides the *Moral*, its *Physical* and *Political* Uses, both which have been some Years since most judiciously consider'd by the Curious Sir *William Petty*, in his *Natural* and *Political* Observations on the Bills of *Mortality* of *London*, own'd by Captain *John Graunt*: And since in a like Treatise on the Bills of *Mortality* of *Dublin*. But the Deduction from those Bills of *Mortality* seemed even to their Authors to be defective: First, In that the *Number* of the People was wanting. Secondly, That the *Ages* of the People dying was not to be had. And Lastly, That both *London* and *Dublin*, by reason of the great and casual Accession of *Strangers* who die therein, (as appeared in both, by the great Excess of the *Funerals* above the *Births*) rendred them incapable of being Standards for this purpose; which requires, if it were possible, that the People we treat of, should not at all be

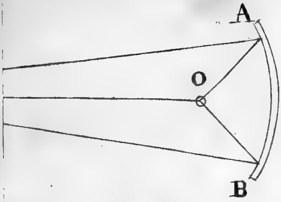
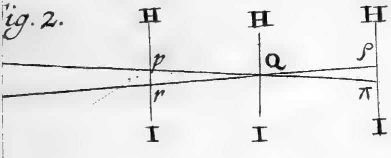


Fig. 2.



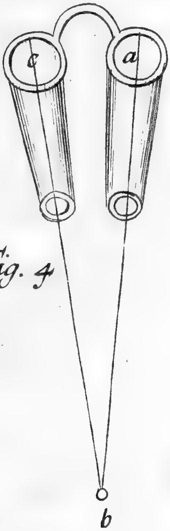


Fig. 4

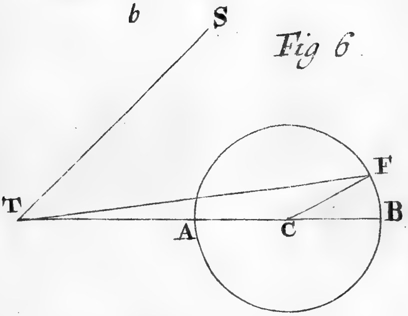


Fig 6.

Fig. 1

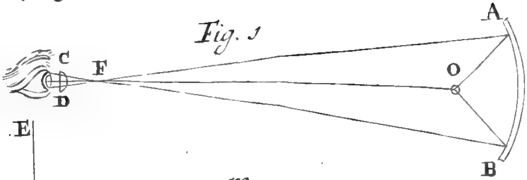


Fig. 2.

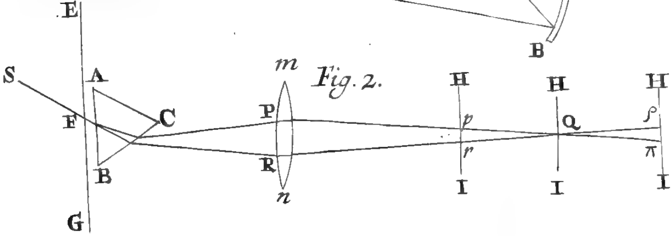


Fig 3

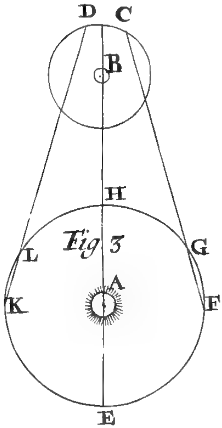


Fig. 4

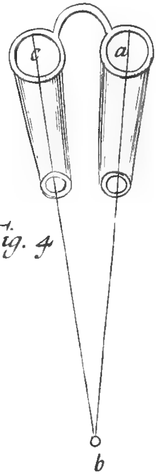


Fig 5

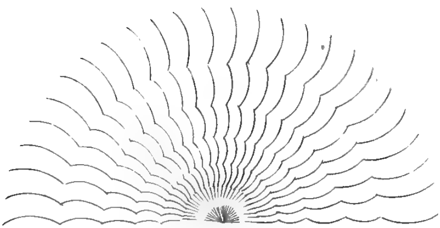
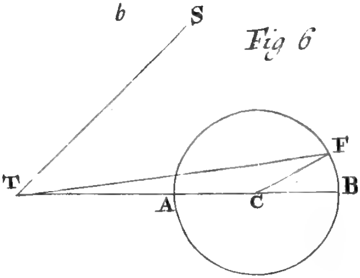


Fig 6



be changed, but die where they were born, without any adventitious Increase from Abroad, or Decay by Migration elsewhere.

This *Defect* seems in a great measure to be satisfied by the late curious Tables of the Bills of *Mortality* at the City of *Breslaw*, lately communicated to this Honourable Society by Mr. *Justell*, wherein both the Ages and Sexes of all that die, are Monthly delivered, and compared with the number of the *Births*, for Five Years last past, *viz.* 1687, 88, 89, 90, 91, seeming to be done with all the Exactness and Sincerity possible.

This City of *Breslaw* is the Capital City of the Province of *Silesia*; or, as the *Germans* call it, *Schlesia*, and is situated on the Western Bank of the River *Oder*, anciently call'd *Viadrus*, near the Confines of *Germany* and *Poland*, and very nigh the Latitude of *London*. It is very far from the Sea, and as much a *Mediterranean* Place as can be desired, whence the Confluence of Strangers is but small, and the Manufacture of Linnen employs chiefly the poor People of the Place, as well as of the Country round about; whence comes that sort of Linnen we usually call your *Sclesiæ Linnen*; which is the chief, if not the only Merchandize of the Place. For these Reasons, the People of this City seem most proper for a *Standard*; and the rather, for that the *Births* do a small matter exceed the Funerals. The only thing wanting, is the Number of the whole People, which in some measure I have endeavour'd to supply, by the comparison of the *Mortality* of the People of all Ages, which I shall from the said Bills trace out with all the Accuracy possible.

It

It appears that in the Five Years mentioned, *viz.* from 87 to 91 inclusive, there were born 6193 Persons, and buried 5869; that is, born *per Annum* 1238, and buried 1174; whence an *Increase* of the People may be argued of 64 *per Annum*, or of about a 20th part, which may perhaps be balanc'd by the Levies for the *Emperor*'s Service in his Wars. But this being contingent, and the Births certain, I will suppose the People of *Breslaw* to be increased by 1238 *Births* annually. Of these it appears by the same Tables, that 348 do die *yearly* in the *first Year* of their *Age*, and that but 890 do arrive at a full *Year's Age*; and likewise, that 198 do die in the *Five Years* between 1 and 6 compleat, taken at a *Medium*; so that but 692 of the Persons *born* do survive *Six* whole *Years*. From this *Age* the Infants being arrived at some degree of Firmness, grow less and less *Mortal*; and it appears, that of the whole People of *Breslaw* there die *yearly*, as in the following Table, wherein the upper Line shews the *Age*, and the next under it, the *Number* of Persons of that Age *dying yearly*.

7. 8 9. . 14 . 18 . 21 . 27 . 28 . . 35.
11. 11. 6. $5\frac{1}{2}$. 2. $3\frac{1}{2}$ 5 6 $4\frac{1}{2}$ $6\frac{1}{2}$ 9 . 8 . 7 . 7

36. 42: 45 39 54 . 55 . 56 . 63
8. $9\frac{1}{2}$ 8. 9. 7. 7. 10 11 . 9 . 9 10. 12

70 71 . 72 77 81 84 . 90 91.
$9\frac{1}{2}$ 14 9 . 11 $9\frac{1}{2}$ 6 . 7 . 3 . 4 . 2 . 1. 1. 1.

98 . 99 . 100.
0 . $\frac{1}{5}$. $\frac{3}{5}$

And where no Figure is placed over, it is to be understood of those that die between the Ages of the precedent and consequent *Column.*

From this Table it is evident, that from the Age of 9 to about 25, there does not die above 6 *per Annum* of each Age, which is much about 1 *per Cent.* of those that are of those *Ages* : And whereas in the 14, 15, 16, 17 *Years*, there appear to die much fewer, as 2 and $3\frac{1}{2}$; yet that seems rather to be attributed to Chance, as are the other Irregularities in the Series of Ages, which would rectifie themselves, were the number of Years much more considerable, as 20 instead of 5. And by our own Experience in *Christ-Church Hospital*, I am inform'd there die of the *Young Lads*, much about 1 *per Cent. per Annum*, they being of the aforesaid *Ages*. From 25 to 50, there seem to die from 7 to 8 and 9 *per Annum* of each Age; and after that to 70, they growing more *crasie*, though the number be much diminished, yet the *Mortality increases*, and there are found to die 10 or 11 of each Age *per Annum* : From thence the number of the Living being

ing grown very ſmall, they gradually decline till there be none left to *die*; as may be ſeen at one View in the Table.

From theſe Conſiderations I have form'd the *adjoined Table*, whoſe Uſes are manifold, and give a more juſt *Idea* of the *State* and *Condition* of *Mankind*, than any thing yet extant that I know of. It exhibits the *Number* of *People* in the City of *Breſlaw* of all Ages, from the *Birth* to extreme *Old Age*, and thereby ſhews the Chances of *Mortality* at all *Ages*, and likewiſe how to make a certain Eſtimate of the Value of *Annuities* for *Lives*, which hitherto has been only done by an imaginary *Valuation*: Alſo the *Chances* that there are that a *Perſon* of any *Age* propoſed does live to any other *Age* given; with many more, as I ſhall hereafter ſhew. This *Table* does ſhew the *Number* of Perſons that are living in the *Age* current annexed thereto, as follows:

Age.

Age. Curt.	Per-sons.	Age. Curt.	Per-sons.	Age. Curt.	Per-sons.	Age. Curt.	Per-sons.	Age. Curt.	Per-sons.	Age. Curt.	Per-sons.
1	1000	8	680	15	628	22	586	29	539	36	481
2	855	9	670	16	622	23	579	30	531	37	472
3	798	10	661	17	616	24	573	31	523	38	463
4	760	11	653	18	610	25	567	32	515	39	454
5	732	12	646	19	604	26	560	33	507	40	445
6	710	13	640	20	598	27	553	34	499	41	436
7	692	14	634	21	592	28	546	35	490	42	427
Age. Curt.	Per-sons.	Age. Curt.	Per-sons.	Age. Curt.	Per-sons.	Age. Curt.	Per-sons.	Age. Curt.	Per-sons.	Age. Curt.	Per-sons.
43	417	50	346	57	272	64	202	71	131	78	58
44	407	51	335	58	262	65	192	72	120	79	49
45	397	52	324	59	252	66	182	73	109	80	41
46	387	53	313	60	242	67	172	74	98	81	34
47	377	54	302	61	232	68	162	75	88	82	28
48	367	55	292	62	222	69	152	76	78	83	23
49	357	56	282	63	212	79	142	77	68	84	20

Age.	Persons.
7	5547
14	4584
21	4270
28	3964
35	3604
42	3708
49	2709
56	2194
63	1694
70	1204
77	692
84	253
100	107
	34000
Sum	Total.

Thus

Thus it appears, that the whole People of *Breſlaw* does conſiſt of 34000 *Souls*, being the Sum *Total* of the Perſons of all Ages in the *Table*: The firſt uſe hereof is to ſhew the Proportion of *Men* able to bear *Arms* in any *Multitude*, which are thoſe between 18 and 56, rather than 16 and 60; the one being generally too weak to bear the *Fatigues* of *War*, and the Weight of *Arms*; and the other too craſie and infirm from *Age*, notwithſtanding particular Inſtances to the contrary. Under 18 from the *Table*, are found in this City 11997 Perſons, 3950 above 56, which together make 15947. ſo that the Reſidue to 34000 being 18053, are Perſons between thoſe *Ages*. At leaſt one half thereof are Males, or 9027: So that the whole Force this City can raiſe of *Fencible Men*, as the *Scotch* call them, is about 9000, or $\frac{9}{34}$, or ſomewhat more than a quarter of the *Number* of *Souls*; which may parhaps paſs for a Rule for all other places.

The *Second Uſe* of this *Table*, is, to ſhew the differing degrees of *Mortality*, or rather *Vitality*, in all *Ages*; for if the Number of Perſons of any *Age* remaining after one Year, be divided by the difference between that and the number of the *Age* propoſed, it ſhews the *Odds* that there is, that a Perſon of that *Age* does not die in a *Year*. As for Inſtance, a Perſon of 25 *Years* of *Age* has the Odds of 560 to 7, or 80 to 1, that he does not *die* in a *Year*: Becauſe that of 567, living of 25 *Years* of *Age*, there do die no more than 7 in a *Year*, leaving 560 of 26 Years old.

So

So likewiſe for the *Odds*, that any Perſon does not die before he attain any propoſed *Age*: Take the *number* of the remaining Perſons of the *Age* propoſed, and divide it by the difference between it and the number of thoſe of the *Age* of the Party propoſed; and that ſhews the *Odds* there is between the Chances of the Party's living or dying. As for Inſtance; What is the *Odds* that a Man of 40 lives 7 Years: Take the number of Perſons of 47 Years, which in the Table is 377, and ſubtract it from the number of Perſons of 40 Years, which is 445, and the *difference* is 68: Which ſhews that the *Perſons dying* in that 7 Years, are 68, and that it is 377 to 68, or $5\frac{1}{2}$ to 1, that a Man of 40 does live 7 Years. And the like for any other *nnmber* of *Years*.

Uſe III. But if it be enquired at what number of *Years*, it is an even Lay that a Perſon of any *Age* ſhall die, this Table readily performs it: For if the *number* of Perſons *living* of the *Age* propoſed, be *halfed*, it will be found by the *Table* at what Year the ſaid *Number* is reduced to half by *Mortality*; and that is the *Age*, to which it is an even Wager, that a Perſon of the *Age* propoſed ſhall arrive before he *die*. As for Inſtance; A Perſon of 30 Years of *Age* is propoſed, the number of that *Age* is 531, the half thereof is 265, which number I find to be between 57 and 58 Years; ſo that a Man of 30 may reaſonably expect to live between 27 and 28 Years.

Uſe IV. By what has been ſaid, the *Price* of *Inſurance* upon Lives ought to be regulated, and the difference is diſcovered between the

Price

Price of insuring the *Life* of a *Man* of 20 and 50. For Example; It being 100 to 1, that a Man of 20 dies not in a Year, and but 38 to 1, for a Man of 50 Years of Age.

Use V. On this depends the Valuation of *Annuities* upon *Lives*; for it is plain, that the *Purchaser* ought to pay for only such a part of the Value of the *Annuity*, as he has Chances that he is living; and this ought to be computed yearly, and the Sum of all those yearly Values being added together, will amount to the Value of the *Annuity* for the *Life* of the Person proposed. Now the present Value of Money payable after a Term of Years, at any given Rate of Interest, either may be had from Tables already computed; or almost as compendiously, by the Table of Logarithms: For the Arithmetical Complement of the Logarithm of Unity, and its yearly Interest, (that is, of 1, 06 for Six *per Cent.* being 9, 974694.) being multiplied by the number of Years proposed, gives the present Value of One Pound payable after the end of so many Years. Then by the foregoing Proposition, it will be as the number of Persons living after that Term of Years, to the number dead; so are the Odds that any one Person is alive or dead. And by consequence, as the Sum of both, or the number of Persons living of the *Age* first proposed, to the number remaining after so many Years, (both given by the Table) so the present Value of the yearly Sum payable after the Term proposed, to the Sum which ought to be paid for the Chance the Person has to enjoy such an *Annuity* after so many Years. And this being repeated for every

every Year of the Person's Life, the Sum of all the present Values of those Chances is the true Value of the Annuity. This will without doubt appear to be a most laborious Calculation; but it being one of the principal Uses of this Speculation, and having found some *Compendia* for the Work, I took the pains to compute the following Table, being the short Result of a not ordinary number of Arithmetical Operations: It shews the Value of Annuities for every Fifth Year of Age, to the Seventieth, as follows.

Age.	Years Pur.	Age.	Years Pur.	Age.	Years Pur.
1	10,28	25	12,27	50	9,21
5	13,40	30	11,72	55	8,51
10	13,44	35	11,12	60	7,60
15	13,33	40	10,57	65	6,54
20	12,78	45	9,91	70	5,32

This shews the great Advantage of putting Money into the present *Fund* lately granted to Their Majesties, giving 14 *per Cent. per Annum*, or at the Rate of 7 Years Purchase for a Life; when young Lives, at the usual Rate of Interest, are worth above 13 Years Purchase. It shews likewise the Advantage of young Lives over those in Years; a Life of Ten Years being almost worth $13\frac{1}{2}$ Years Purchase, whereas one of 36 is worth but 11.

Use V. Two Lives are likewise valuable by the same Rule; for the number of Chances of each single Life, found in the Table, being multiplied together, become the Chances of the Two Lives. And after any certain

U Term

Term of Years, the Product of the two remaining Sums is the Chances that both the Persons are living. The Product of the two Differences, being the numbers of the Dead of both Ages, are the Chances that both the Persons are dead. And the two Products of the remaining Sums of the one Age multiplied by those dead of the other, shew the Chances that there are, that each Party survives the other: Whence is derived the Rule to estimate the Value of the Remainder of one Life after another. Now as the Product of the Two Numbers in the Table for the Two Ages proposed, is to the difference between that Product, and the Product of the two numbers of Persons deceased in any space of time; so is the Value of a Sum of Money to be paid after so much time, to the Value thereof under the Contingency of Mortality. And as the aforesaid Product of the two Numbers answering to the Ages proposed, to the Product of the Deceased of one Age multiplied by those remaining alive of the other; so the Value of a Sum of Money to be paid after any time proposed, to the Value of the Chances, that the one Party has that he survives the other, whose number of Deceased you made use of, in the second Term of the Proportion. This perhaps may be better understood, by putting N for the number of the younger Age, and n for that of the Elder; Y, y the Deceased of both Ages respectively, and R, r for the Remainders; and $R + Y = N$, and $r + y = n$. Then shall Nn be the whole Number of Chances; $Nn - Yy$ be the Chances that one of the two Persons is living,

living, Yy the Chances that they are both dead; Ry the Chances that the elder Perſon is dead, and the younger living; and rY the Chances, that the elder is living, and the younger dead. Thus two Perſons of 18 and 35 are propoſed, and after 8 Years theſe Chances are required. The Numbers for 18 and 35, are 610 and 490; and there are 50 of the Firſt Age dead in 8 Years, and 73 of the Elder Age. There are in all 610 × 490, or 298900 Chances; of theſe there are 50 × 73, or 3650, that they are both dead. And as 298900, to 298900 — 3650, or 295250: So is the preſent Value of a Sum of Money to be paid after 8 Years, to the preſent Value of a Sum to be paid, if either of the two live. And as 560 × 73, ſo are the Chances that the Elder is dead, leaving the Younger; and as 417 × 50, ſo are the Chances that the Younger is dead, leaving the Elder. Wherefore as 610 × 490 to 560 × 73, ſo is the preſent Value of a Sum to be paid at 8 Years end, to the Sum to be paid for the Chance of the Younger's Survivance; and as 610 × 490 to 417 × 50, ſo is the ſame preſent Value to the Sum to be paid for the Chance of the Elder's Survivance.

This poſſibly may be yet better explained, by expounding theſe Products by Rectangular Parallelograms, as in *Fig. 7.* wherein *A B* or *C D* repreſents the number of Perſons of the younger Age, and *D E*, *B H* thoſe remaining alive after a certain Term of Years; whence *C E* will anſwer the number of thoſe dead in that time: So *A C*, *B D* may repreſent the number of the elder Age; *A F*, *B I* the Survivors after the same Term; and *C F, D I*, those of that Age that are dead at that time. Then shall the whole Parallelogram *A B C D* be *N n*, or the Product of the two Numbers of Persons, representing such a number of Persons of the two Ages given; and by what was said before, after the Term proposed, the Rectangle *H D* shall be as the number of Persons of the younger Age that survive, and the Rectangle *A E* as the number of those that die. So likewise the Rectangles *A I, F D* shall be as the Numbers, living and dead, of the other Age. Hence the Rectangle *H I* shall be as an equal number of both Ages surviving. The Rectangle *F E* being the Product of the Deceased, or *Y y*, an equal number of both dead. The Rectangle *G D* or *R y*, a number living of the younger Age, and dead of the elder: And the Rectangle *A G* or *r Y* a number living of the elder Age, but dead of the younger. This being understood, it is obvious, that as the whole Rectangle *A D* or *N n* is to the *Gnomon* *F A B D E G* or *N n*—*Y y*, so is the whole number of Persons or Chances, to the number of Chances that one of the two Persons is living: And as *A D* or *N n* is to *F E* or *Y y*, so are all the Chances, to the Chances that both are dead; whereby may be computed the Value of the Reversion after both Lives. And as *A D* to *G D* or *R y*, so the whole number of Chances, to the Chances that the younger is living, and the other dead; whereby may be cast up what Value ought to be paid for the Reversion of one Life after another, as in the Case of providing for Clergy-men's Widows, and others, by such Reversions.

Reverſions. And as $A\,D$ to $A\,G$, or $r\,Y$, ſo are all the Chances, to thoſe that the elder ſurvives the younger. I have been the more particular, and perhaps tedious, in this Matter, becauſe it is the Key to the Caſe of Three Lives, which of it ſelf would not have been ſo eaſie to comprehend.

VII. If Three Lives are propoſed, to find the Value of an Annuity during the continuance of any of thoſe three Lives; the Rule is, *As the Product of the continual Multiplication of the Three Numbers, in the Table, anſwering to the Ages propoſed, is to the difference of that Product, and of the Product of the Three Numbers of the Deceaſed of thoſe Ages, in any given Term of Years: So is the preſent Value of a Sum of Money, to be paid certainly after ſo many Years, to the preſent Value of the ſame Sum to be paid, provided one of thoſe Three Perſons be living at the Expiration of that Term.* Which Proportion being yearly repeated, the Sum of all thoſe preſent Values will be the Value of an Annuity granted for three ſuch Lives. But to explain this, together with all the Caſes of Survivance in Three Lives: Let N be the Number in the Table for the younger Age, n for the ſecond, and ν for the elder Age; let Y be thoſe dead of the younger Age in the Term propoſed, y thoſe dead of the ſecond Age, and υ thoſe of the elder Age; and let R be the Remainder of the younger Age, r that of the middle Age, and ϱ the Remainder of the elder Age. Then ſhall $R + Y$ be equal to N, $r + y$ to n, and $\varrho + \upsilon$ to ν, and the continual Product of the three Numbers N, n, ν, ſhall be equal to the continual Product of

$R + Y \times r + y \times \varrho + v$, which being the whole Number of Chances for three Lives, is compounded of the eight Products following. (1) $R\, r\, \varrho$, which is the Number of Chances that all three of the Persons are living. (2) $r\, \varrho\, Y$, which is the Number of Chances that the two elder Persons are living, and the younger dead. (3) $R\, \varrho\, y$ the Number of Chances that the middle Age is dead, and the younger and elder living. (4) $R\; r\; v$ being the Chances that the two younger are living, and the elder dead. (5) $\varrho\; Y\, y$ the Chances that the two younger are dead, and the elder living. (6) $r\, Y\, v$ the Chances that the younger and elder are dead, and the middle Age living. (7) $R\, y\, v$, which are the Chances that the younger is living, and the two other dead. And Lastly and Eighthly, $Y\, y\, v$, which are the Chances that all three are dead. Which latter subtracted from the whole Number of Chances $N\, n\, v$, leaves $N\, n\, v - Y\, y\, v$ the Sum of all the other seven Products; in all of which one or more of the three Persons are surviving.

To make this yet more evident, I have added *Fig.* 8. wherein these eight several Products are at one view exhibited. Let the rectangled Parallelepipedon *A B C D E F G H* be constituted of the sides *A B*, *G H*, &c. proportional to *N* the Number of the younger Age; *A C*, *B D*, &c. proportional to *n*; and *A G*, *C E*, &c. proportional to the Number of the elder, or *v*. And the whole Parallelepipedon shall be as the Product *N n v*, or our whole Number of Chances. Let *B P* be as *R*, and *A P* as *Y*; let *C L* be as *r*, and *L n* as as y; and GN as ϱ, and NA as v; and let the Plain $PRea$ be made parallel to the Plain $ACGE$; the Plain $NVbY$ parallel to $ABCD$; and the Plain $LXTQ$ parallel to the Plain $ABGH$. And our first Product $Rr\varrho$ shall be as the Solid $STWIFZeb$. The Second, or $r\varrho Y$ will be as the Solid $EYZeQSMI$. The Third, $R\varrho y$, as the Solid $RHOVWIST$. And the Fourth, Rrv, as the Sold $ZabDWXIK$. Fifthly, ϱYy, as the Solid $GQRSIMNO$. Sixthly, rYv, as $IKLMGYZA$. Seventhly, Ryv, as the Solid $IKPOBXVW$. And Lastly, $AIKLMNOP$ will be as the Product of the 3 Numbers of Persons dead, or Yyv. I shall not apply this in all the Cases thereof, for brevity sake; only to shew in one how all the rest may be performed, let it be demanded what is the Value of the Reversion of the younger Life after the two elder proposed. The proportion is as the whole Number of Chances, or Nnv to the Product Ryv; so is the certain present Value of the Sum payable after any Term proposed, to the Value due to such Chances as the younger Person has to bury both the elder, by the Term proposed; which therefore he is to pay for. Here it is to be noted, that the first Term of all these Proportions is the same throughout, *viz.* Nnv. The second changing yearly according to the Decrease of R, r, ϱ, and Increase of Y, y, v. And the third are successivelo the present Values of Money payable after one, two, three, *&c.* years, according to the Rate of Interest agreed on. These Numbers, which are in all Cases of Annuities of necessary Use, I have put into the following Table, they being Decimal

Values of one Pound payable after the Number of Years in the Margent, at the Rate of 6 *per Cent.*

Years.	Pres. Value of 1 *l.*	Years.	Pres. Value of 1 *l.*	Years.	Pres. Value of 1 *l.*
1	0,9434	19	0,3305	37	0,1158
2	0,8900	20	0,3118	38	0,1092
3	0,8396	21	0,2941	39	0,1031
4	0,7921	22	0,2775	40	0,0972
5	0,7473	23	0,2618	45	0,0726
6	0,7050	24	0,2470	50	0,0543
7	0,6650	25	0,2330	55	0,0406
8	0,6274	26	0,2198	60	0,0303
9	0,5919	27	0,2074	65	0,0227
10	0,5584	28	0,1956	70	0,0169
11	0,5268	29	0,1845	75	0,0126
12	0,4970	30	0,1741	80	0,0094
13	0,4688	31	0,1643	85	0,0071
14	0,4423	32	0,1550	90	0,0053
15	0,4173	33	0,1462	95	0,0039
16	0,3936	34	0,1379	100	0,0029
17	0,3714	35	0,1301		
18	0,3503	36	0,1227		

It were needless to advertise, that the great trouble of working so many Proportions will be very much alleviated by using Logarithms; and that instead of using $N n v - Y y v$ for the second Term of the Proportion in finding the Value of Three Lives, it may suffice to use only $Y y v$, and then deducting the fourth Term so found out of the third, the Remainder shall be the present Value sought; or all

these

these fourth Terms being added together, and deducted out of the Value of the certain Annuity for so may Years, will leave the Value of the contingent Annuity upon the Chance of Mortality of all those Three Lives. For Example; Let there be Three Lives of 10, 30, and 40 Years of Age proposed, and the Proportions will be thus;

As 661 in 531 in 445 or 156190995, or *Nnv* to 8 in 8 in 9, or 576, or *Yyu* for the first Year, so 0,9434. to 0,00000348.
To 15 in 16 in 18, or 4320, for the second Year, so 0,8900. to 0,00002462.
To 21 in 24 in 28, or 14112 for the third Year, so 0,8396. to 0,00008128.
To 27 in 32 in 38, for the fourth Year, so 0,7921. to 0,00016650.
To 33 in 41 in 48, for the fifth Year, so 0,7473. to 0,00031071.
To 39 in 50 in 58, for the sixth Year, so 0,7050. to 0,00051051.

And so forth to the 60th Year, when we suppose the elder Life of Forty certainly to be expired; from whence till Seventy we must compute for the First and Second only, and from thence to Ninety for the single youngest Life. Then the Sum Total of all these Fourth Proportionals being taken out of the Value of a certain Annuity for 90 Years, being 16,58 Years Purchase, shall leave the just Value to be paid for an Annuity during the whole Term of the Lives of Three Persons of the Ages proposed. And note, that it will

will not be neceſſary to compute for every Year ſingly; but that in moſt Caſes every 4th or 5th Year may ſuffice, interpoling for the intermediate Years *ſecundum artem.*

It may be objected, that the different *Salubrity* of Places does hinder this Propoſal from being *univerſal*; nor can it be denied. But by the Number that die, being 1174. *per Annum* in 34000, it does appear that about a 30th part die yearly, as Sir *William Petty* has computed for *London*; and the Number that die in Infancy, is a good Argument that the Air is but indifferently ſalubrious. So that by what I can learn, there cannot perhaps be one better Place propoſed for a Standard. At leaſt 'tis deſired, that in Imitation hereof the Curious in other Cities would attempt ſomething of the ſame Nature, than which nothing perhaps can be more uſeful.

Were this *Calculus* founded on the Experience of a very great number of Years, it would be very well worth the while to think of Methods for facilitating the Computation of the Value of two, three, or more Lives; which, as propoſed in my former, ſeems (as I am inform'd) a Work of too much Difficulty for the ordinary Arithmetician to undertake.

I have ſought, If it were poſſible, to find a Theorem that might be more conciſe than the Rules there laid down, but in vain; for all that can be done to expedite it, is, by Tables of Logarithms ready computed, to exhibt the *Rationes* of *N* to *Y* in each ſingle Life, for every third, fourth, or fifth Year of Age, as occaſion ſhall require; and theſe Logarithms being added to the Logarithms of the

preſent

preſent Value of Money payable after ſo many Years, will give a Series of Numbers, the Sum of which will ſhew the Value of the Annuity ſought. However, for each Number of this Series, two Logarithms for a ſingle Life, three for two Lives, and four for three Lives, muſt neceſſarily be added together. If you think the Matter, under the Uncertainties I have mentioned, to deſerve it, I ſhall ſhortly give you ſuch a Table of Logarithms, as I ſpeak of, and an Example or two of the uſe thereof: But by Vulgar Arithmetick, the Labour of theſe Numbers were immenſe; and nothing will more recommend the uſeful Invention of Logarithms to all Lovers of Numbers, than the advantage of Diſpatch in this and ſuch like Computations.

Beſides the Uſes mentioned, it may perhaps not be an unacceptable thing to infer from the ſame Tables, how unjuſtly we repine at the ſhortneſs of our Lives, and think our ſelves wronged if we attain not old Age; whereas it appears hereby, that the one half of thoſe that are born are dead in Seventeen Years time, 1238 being in that time reduced to 616. So that inſtead of murmuring at what we call an untimely Death, we ought with Patience and Unconcern to ſubmit to that Diſſolution which is the neceſſary Condition of our periſhable Materials. and of our nice and frail Structure and Compoſition: And to account it as a Bleſſing that we have ſurvived, perhaps by many Years, that Period of Life, whereat the one half of the whole Race of Mankind does not arrive.

A second Observation I make upon the said Table, is that the Growth and Increase of Mankind is not so much stinted by any thing in the Nature of the *Species*, as it is from the cautious difficulty most People make to adventure on the State of *Marriage*, from the Prospect of the Trouble and Charge of providing for a Family. Nor are the poorer sort of People herein to be blamed, since their difficulty of subsisting is occasion'd by the unequal Distribution of Possessions, all being necessarily fed from the Earth, of which yet so few are Masters. So that besides themselves and Families, they are yet to work for those who own the Ground that feeds them: And of such does by very much the greater part of Mankind consist; otherwise it is plain, that there might well be four times as many Births as we now find. For by Computation from the Table, I find that there are nearly 15000 Persons above 16, and under 45, of which at least 7000 are Women capable to bear Children. Of these notwithstanding there are but 1238 born yearly, which is but little more than a sixth part: So that about one in six of these Women do breed yearly; whereas were they all married, it would not appear strange or unlikely, that four of six should bring a Child every Year. The Political Consequences hereof I shall not insist on; only the Strength and Glory of a King being in the multitude of his Subjects, I shall only hint, that above all things, Celibacy ought to be discouraged, as, by extraordinary Taxing and Military Service: And those who have numerous Families of Children to be countenanced and encouraged by such Laws as the *Jus trium Liberorum* among the *Ro-*

mans.

mans. But especially, by an effectual Care to provide for the Subsistence of the Poor, by finding them Employments, whereby they may earn their Bread, without being chargeable to the Publick.

A

A Diſcourſe concerning Gravity, *and its Properties, wherein the* Deſcent *of* Heavy Bodies, *and the Motion of* Projects *is briefly, but fully handled: Together with the* Solution *of a* Problem *of great Uſe in* Gunnery. *By* E. Halley.

NATURE, amidſt the great Variety of *Problems*, wherewith She exerciſes the Wits of Philoſophical Men, ſcarce affords any one wherein the Effect is more viſible, and the Cauſe more concealed, than in thoſe of the *Phænomena* of *Gravity*. Before we can go alone, we muſt learn to defend our ſelves from the Violence of its Impulſe, by not truſting the *Center* of *Gravity* of our Bodies beyond our reach; and yet the acuteſt Philoſophers, and the ſubtileſt Enquirers into the Original of this Motion, have been ſo far from ſatisfying their Readers, that they themſelves ſeem little to have underſtood the Conſequences of their own *Hypotheſes*.

Des Cartes his Notion, I muſt needs confeſs to be to me incomprehenſible, while he will have the Particles of his *Cæleſtial Matter*, by being reflected on the Surface of the *Earth*, and ſo aſcending therefrom, to drive down into their Places thoſe *Terreſtrial Bodies* they find above

above them: This is, as near as I can gather, the Scope of the 20, 21, 22, and 23 *Sections* of the laſt Book of his *Principia Philoſophiæ*; yet neither he, nor any of his Followers, can ſhew how a Body ſuſpended in *Libero Æthere*, ſhall be carried downwards by a continual Impulſe tending upwards, and acting upon all its Parts equally: And beſides the Obſcurity wherewith he expreſſes himſelf, particularly, *Sect.* 23. does ſufficiently argue according to his own Rules, the confuſed *Idea* he had of the thing he wrote.

Others, and among them Dr. *Voſſius*, aſſert the Cauſe of the *Deſcent* of *heavy Bodies*, to be the *Diurnal Rotation* of the *Earth* upon its *Axis*, without conſidering, that according to the Doctrine of Motion fortified with Demonſtration, all Bodies moved *in Circulo*, would recede from the Center of their Motion; whereby the contrary to *Gravity* would follow, and all looſe Bodies would be caſt into the Air in a *Tangent* to the *Parallel* of *Latitude*, without the intervention of ſome other Principle to keep them faſt, ſuch as is that of *Gravity*. Beſides, the Effect of this Principle is throughout the whole Surface of the Globe found nearly equal; and certain Experiments have proved it rather leſs near the *Æquinoctial*, than towards the *Poles*; which could not be by any means, if the *Diurnal Rotation* of the *Earth* upon its *Axis* were the Cauſe of *Gravity*; for where the Motion was ſwifteſt, the Effect would be moſt conſiderable.

Others aſſign the Preſſure of the *Atmoſphere*, to be the Cauſe of this Tendency towards the Center of the Earth; but unhappily they have miſtaken

mistaken the Cause for the Effect; it being from undoubted Principles plain, that the *Atmosphere* has no other Pressure but what it derives from its *Gravity*; and that the Weight of the upper Parts of the *Air*, pressing on the lower Parts thereof, do so far bend the Springs of that *Elastick* Body, as to give it a Force equal to the Weight that compress'd it, having of it self no force at all: And supposing it had, it will be very hard to explain the *Modus*, how that Pressure should occasion the Descent of a Body circumscribed by it, and pressed equally above and below, without some other Force to draw, or thrust it downwards. But to demonstrate the contrary of this Opinion, an *Experiment* was long since shewn before the *Royal Society*, whereby it appeared, that the *Atmosphere* was so far from being the Cause of *Gravity*, that the Effects thereof were much more vigorous, where the Pressure of the *Atmosphore* was taken off; for a long *Glass-Receiver* having a light Down-feather included, being evacuated of Air, the Feather, which in the Air would hardly sink, did *in vacuo* descend with nearly the same *Velocity*, as if it had been a Stone.

Some think to illustrate this Descent of Heavy Bodies, by comparing it with the Vertue of the *Loadstone*; but setting aside the difference there is in the manner of their Attractions, the *Loadstone* drawing only in and about its Poles, and the Earth near equally in all Parts of its Surface, this Comparison avails no more than to explain *ignotum per æque ignotum*.

Others

Others aſſign a certain *Sympæthetical Attraction* between the Earth and its Parts, whereby they have, as it were, a deſire to be united, to be the Cauſe we enquire after: But this is ſo far from explaining the *Modus*, that it is little more, than to tell us in other Terms, that Heavy Bodies deſcend, becauſe they deſcend.

This, I ſay, not that I can pretend to ſubſtitute any Solution of this Important Philoſophical Problem, that ſhall more happily explicate the Appearances of Gravity; only it may be ſerviceable to thoſe with whom the Credit of great Authors ſways much, and who too readily aſſent *in Verba Magiſtri*, to let them ſee that their Books are not always infallible: Beſides, the detection of Errors is the firſt and ſureſt Step towards the diſcovery of Truth.

Though the efficient Cauſe of *Gravity* be ſo obſcure, yet the final Cauſe thereof is clear enough; for it is by this ſingle *Principle*, that the *Earth* and all the *Cœleſtial Bodies* are kept from *Diſſolution*; the leaſt of their *Particles* not being ſuffer'd to recede far from their *Surfaces*, without being immediately brought down again by Virtue of this *Natural Tendency*; which, for their Preſervation, the Infinite Wiſdom of their *Creator* has ordained to be towards each of their *Centers*; nor can the *Globes* of the *Sun* and *Planets* otherwiſe be deſtroy'd, but by taking from them this Power of keeping their Parts united.

The Affections or Properties of *Gravity*, and its manner of acting upon *Bodies falling*, have been in a great meaſure diſcovered, and moſt of them made out by *Mathematical Demonſtra-*

tion in this our *Century*, by the accurate diligence of *Galilæus*, *Torricellius*, *Hugenius*, and others, and now lately by our worthy Countryman, Mr. *Isaac Newton*, which Properties it may be very material here to enumerate, that they may serve for a Foundation to all those that shall be willing to spend their Thoughts in search of the true Cause of this *Descent of Bodies.*

The first Property is, That by this Principle of *Gravitation*, all Bodies do descend towards a Point, which either is, or else is very near to the Center of Magnitude of the Earth and Sea, about which the Sea forms it self exactly into a *Spherical Surface*, and the *Prominences* of the Land, considering the Bulk of the whole, differ but insensibly therefrom.

Secondly, That this Point or Center of *Gravitation*, is fix'd within the *Earth*, or at least has been so, ever since we have any *Authentick History*: For a Consequence of its Change, though never so little, would be the over-flowing of the low Lands on that side of the *Globe* towards which it approached, and the leaving new Islands bare on the opposite side, from which it receded; but for this Two Thousand Years it appears, that the low Islands of the *Mediterranean Sea* (near to which the ancientest Writers liv'd) have continued much at the same height above the Water, as they now are found; and no *Inundations* or *Recesses* of the *Sea* arguing any such Change, are recorded in History; excepting the *Universal Deluge*, which can no better way be accounted

accounted for, than by ſuppoſing this Center of *Gravitation* removed for a time, towards the middle of the then inhabited Parts of the World; and a change of its Place, but the Two Thouſandth Part of the *Radius* of this *Globe*, were ſufficient to bury the Tops of the higheſt Hills under Water.

Thirdly, That in all Parts of the *Surface* of the *Earth*, or rather in all Points equidiſtant from its *Center*, the Force of *Gravity* is nearly equal; ſo that the length of the *Pendulum* vibrating *Seconds of Time*, is found in all Parts of the World to be very near the ſame. 'Tis true at St. *Helena*, in the *Latitude* of 16 Degrees *South*, I found that the *Pendulum* of my Clock, which vibrated *Seconds*, needed to be made ſhorter than it had been in *England*, by a very ſenſible Space (but which at that time I neglected to obſerve accurately) before it would keep time; and ſince the like Obſervations have been made by the *French Obſervers*, near the *Æquinoctial*: Yet I dare not affirm, that in mine it proceeded from any other Cauſe, than the great Height of my Place of Obſervation above the *Surface* of the *Sea*, whereby the *Gravity* being diminiſhed, the length of the *Pendulum* vibrating *Seconds*, is proportionably ſhort'ned.

Fourthly, That *Gravity* does equally affect all *Bodies*, without regard either to their *Matter*, *Bulk*, or *Figure*; ſo that the Impediment of the *Medium* being removed, the moſt compact and moſt looſe, the greateſt and ſmalleſt *Bodies* would deſcend the ſame *Spaces* in equal

 Times;

Times; the Truth thereof will appear from the Experiment I before-cited. In these two last Particulars, is shewn the great difference between *Gravity* and *Magnetism*, the one affecting only *Iron*, and that towards its *Poles*, the other all *Bodies* alike in every part. As a *Corollary*, from hence it will follow, that there is no such thing as *positive Levity*, those things that appear light, being only comparatively so; and whereas several things rise and swim in *Fluids*, 'tis because, Bulk for Bulk, they are not so heavy as those *Fluids*; nor is there any Reason why *Cork*, for Instance, should be said to be light, because it swims on Water, any more than *Iron*, because it swims on *Mercury*.

Fifthly, That this Power increases as you descend, and decreases as you ascend from the Center, and that in the Proportion of the Squares of the *Distances* therefrom *reciprocally*, so as at a double Distance to have but a quarter of the Force; this Property is the Principle on which Mr. *Newton* has made out all the *Phænomena* of the *Cœlestial Motions*, so easily and naturally, that its Truth is past Dispute. Besides that, it is highly rational, that the *attractive* or *gravitating* Power should exert it self more vigorously in a small Sphere, and weaker in a greater, in proportion as it is contracted or expanded; and if so, seeing that the *Surfaces* of *Spheres* are as the *Squares* of their *Radii*, this Power, at several Distances, will be as the *Squares* of those *Distances reciprocally*; and then its whole Action upon each *Spherical Surface*, be it great or small, will be always equal. And this is evidently the Rule of *Gravitation* towards

towards the *Centers* of the *Sun*, *Jupiter*, *Saturn* and the *Earth*, and thence is reaſonably inferred, to be the general Principle obſerved by *Nature*, in all the reſt of the *Cœleſtial Bodies*.

Theſe are the principal Affections of *Gravity*, from which the Rules of the *Fall* of *Bodies*, and the *Motion* of *Projects* are *Mathematically* deducible. Mr. *Iſaac Newton* has ſhew'd how to define the Spaces of the *Deſcent* of a *Body*, let fall from any given height, down to the *Center*, ſuppoſing the *Gravitation* to increaſe, as in the fifth Property; but conſidering the ſmallneſs of heighth, to which any *Project* can be made aſcend, and over how little an *Arch* of the *Globe* it can be caſt by any of our *Engines*, we may well enough ſuppoſe the *Gravity* equal throughout, and the Deſcents of *Projects* in parallel Lines, which in Truth are towards the *Center*, the difference being ſo ſmall as by no means to be diſcovered in *Practice*. The *Oppoſition* of the *Air*, 'tis true, is conſiderable againſt all light Bodies moving through it, as likewiſe againſt ſmall ones (of which more hereafter) but in great and ponderous Shot, this Impediment is found by *Experience* but very ſmall, and may ſafely be neglected.

Propoſitions concerning the Deſcent of Heavy Bodies, and the Motion of Projects.

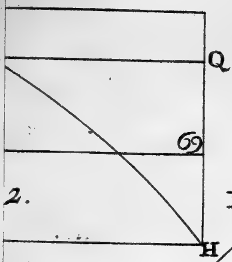
Prop. I. The *Velocities* of *Falling Bodies*, are proportionate to the Times from the beginning of their *Falls*.

This follows, for that the Action of *Gravity* being *continual*, in every Space of Time, the falling Body receives a new Impulſe, equal to what it had before, in the ſame Space of Time, received from the ſame Power : For Inſtance, in the firſt Second of Time, the falling Body has acquired a *Velocity*, which in that time would carry it to a certain Diſtance, ſuppoſe 32 Foot, and were there no new Force, would deſcend at that rate with an *equable Motion* : But in the next Second of Time, the ſame Power of *Gravity* continually acting thereon, ſuperadds a new *Velocity* equal to the former ; ſo that at the end of two Seconds, the *Velocity* is double to what it was at the end of the firſt, and after the ſame manner may it be proved to be triple, at the end of the third Second, and ſo on. Wherefore the *Velocities* of *falling Bodies*, are proportionate to the Time of their *Falls*, *Q. E. D.*

Prop. II. The *Spaces* deſcribed by the Fall of a Body, are as the *Squares* of the Times, from the beginning of the *Fall.*

Demonſtration. Let A B (*Fig.* 9. *Tab.* 4.) repreſent the *Time* of the *Fall* of a *Body*, B C perpendicular to A B, the *Velocity* acquired at the end of the *Fall*, and draw the Line A C ; then divide the Line A B repreſenting the Time, into as many equal Parts as you pleaſe, as b, b, b, b, &c. and through theſe Points draw the Lines bc, bc, bc, bc, &c. parallel to B C, 'tis manifeſt that the ſeveral Lines, bc, repreſent the ſeveral *Velocities* of the falling Body, in ſuch Parts of the *Time* as A b is of A B, by the former Propoſition. It is evident likewiſe, that the

Area



2.

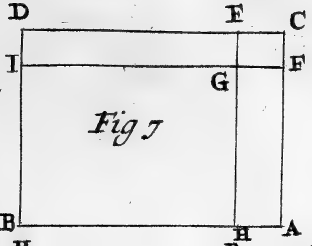


Fig 7

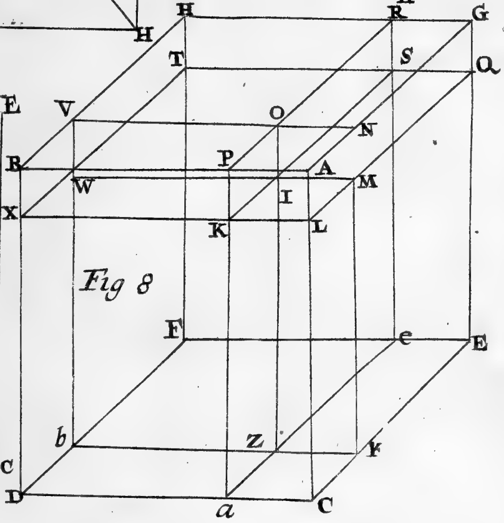
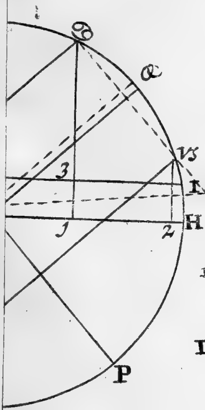


Fig 8



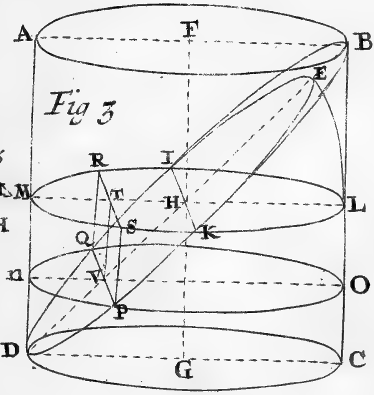
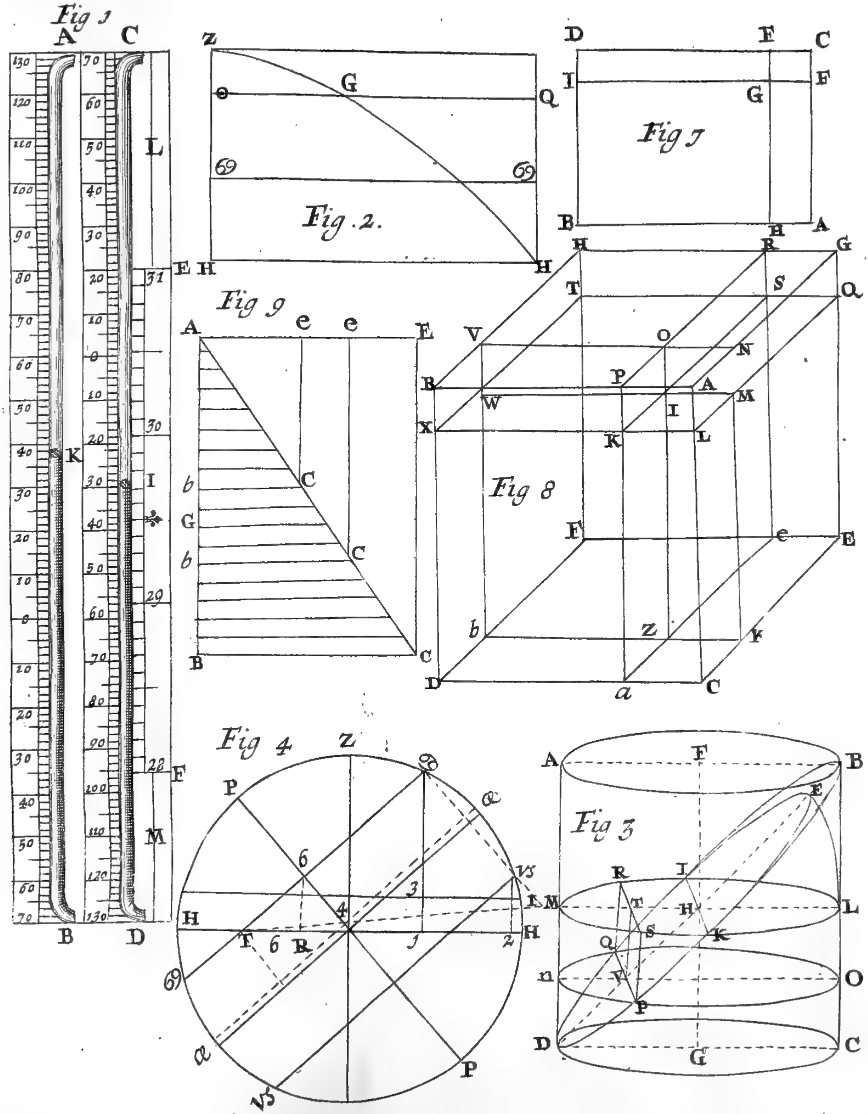


Fig 3

Plate 4. pag 310



Area ABC is the Sum of all the Lines be being taken, according to the Method of *Indivisibles*, infinitely many; so that the *Area* A B C represents the Sum of all the *Velocities*, between none and B C supposed infinitely many; which Sum is as the Space descended in the Time represented by A B. And by the same Reason the *Areas* A b c, will represent the Spaces descended in the Times A b; so then the Spaces descended in the Times A B, A b, are as the *Areas* of the *Triangles* A B C, A b c, which by the 20th of the 6 of *Euclid*, are as the *Squares* of their *Homologous Sides* A B, A b, that is to say, of the *Times*: Wherefore the Descents of *falling Bodies*, are as the *Squares* of the Times of their *Fall*, *Q. E. D.*

Prop. III. The *Velocity* which a *falling Body* acquires in any Space of time, is double to that, wherewith it would have moved the Space, descended by an equable Motion, in the same *time*.

Domonstration. Draw the Line E C parallel to A B, and A E parallel to B C in the same *Fig.* 9. and compleat the *Parallelogram* A B C E, it is evident that the *Area* thereof may represent the Space, a *Body* moved equably with the *Velocity* B C would describe in the Time A B, and the *Triangle* A B C represents the *Space* describ'd by the *Fall* of a *Body*, in the same Time A B, by the second Proposition. Now the *Triangle* A B C is half of the *Parallelogram* A B C E; and consequently the Space described by the *Fall*, is half what would have been described by an *equable Motion* with the *Velocity* B C, in the same Time; wherefore the *Velocity* BC at the end of the *Fall*, is double to that *Velocity*, which in the Time A B, would have described the *Space fallen*, represented by the *Triangle* ABC with an *equable Motion*, *Q. E. D.*

Prop. IV. All *Bodies* on or near the Surface of the *Earth*, in their *Fall*, descend so, as at the end of the first Second of Time, they have described 16 Feet, 1 Inch, *London Measure*, and acquired the *Velocity* of 32 Feet, 2 Inches, in a Second.

This is made out from the 25th Proposition of the second Part of that excellent Treatise of Mr. *Hugenius de Horologio Oscillatorio*; wherein he demonstrates the time of the least *Vibrations* of a *Pendulum*, to be to the Time of the *Fall* of a *Body*, from the heigth of half the length of the *Peudulum*, as the *Circumference* of a *Circle* to its *Diameter*; whence, as a *Corollary*, it follows, That as the *Square* of the *Diameter* to the *Square* of the *Circumference*, so half the length of the *Pendulum* vibrating *Seconds*, to the *Space* described by the *Fall* of a *Body* in a *Second* of *Time*: And the Length of the *Pendulum* vibrating *Seconds*, being found 39, 125, or $\frac{1}{8}$ Inches, the *Descent* in a *Second* will be found by the aforesaid *Analogy* 16 Foot and 1 Inch; and, by the third Proposition, the *Velocity* will be double thereto; and near to this it hath been found by several Experiments, which by reason of the *swiftness* of the *Fall*, cannot so exactly determine its *Quantity*. The Demonstration of *Hugenius* being the Conclusion of a long Train of *Consequences*, I shall for brevity sake omit; and refer you to his Book, where these things are more amply treated of.

From

From theſe Four *Propoſitsons*, all *Queſtions* concerning the *Perpendicular Fall of Bodies*, are eaſily *ſolved*, and either *Time*, *Height*, or *Velocity* being aſſign'd, one may readily find the other two. From them likewiſe is the Doctrine of *Projects* deducible, aſſuming the two following *Axioms*; *viz*. That a *Body* ſet a moving, will move on continually in a right *Line* with an *equable Motion*, unleſs ſome other Force or Impediment intervene, whereby it is accelerated, or retarded, or deflected.

Secondly, That a *Body* being agitated by two *Motions* at a time, does by their *compounded Forces* paſs through the ſame *Points*, as it would do, were the two *Motions divided* and acted *ſucceſſively*. As for Inſtance, Suppoſe a *Body* moved in the Line G F, *(Fig.* 1. *Tab.* 5.*)* from G to R, and there ſtopping, by another *Impulſe*, ſuppoſe it moved in a *Space* of *Time* equal to the former, from R towards K, to V. I ſay, the *Body* ſhall paſs through the Point to V, though theſe two *ſeveral Forces* acted both in the *ſame time*.

Prop. V. The *Motion* of all *Projects* is in the *Curve* of a *Parabola*: Let the *Line* G R F (in *Fig*. 1.) be the *Line* in which the *Project* is directed, and in which by the firſt *Axiom* it would move equal *Spaces* in equal *Times*, were it not deflected downwards by the Force of *Gravity*. Let G B be the *Horizontal Line*, and G C a *Perpendicular* thereto. Then the *Line* G R F being divided into equal Parts, anſwering to equal *Spaces* of *Time*, let the *Deſcents* of the *Project* be laid down in *Lines parallel* to G C, proportioned as the *Squares* of the *Lines* G S, G R, G L, G F, or as the *Squares* of the *Times*, from

from S to T, from R to V, from L to X, and from F to B, and draw the *Lines* T H, V D, X Y, B C parallel to G F; I say, the Points T, V, X, B, are Points in the *Curve* described by the *Project*, and that that *Curve* is a *Parabola*. By the second *Axiom*, they are Points in the *Curve*; and the Parts of the *Descent* G H, G D, G Y, G C, = to S T, R V, L X, F B, being as the *Squares* of the *Times* (by the *Second Proposition*) that is, as the *Squares* of the *Ordinates*, H T, D U, Y X, B C, equal to G S, G R, G L, G F, the *Spaces* measured in those Times; and there being no other *Curve* but the *Parabola*, whose Parts of the *Diameter* are as the *Squares* of the *Ordinates*, it follows that the *Curve* describ'd by a *Project*, can be no other than a *Parabola*: And saying, as R U the *Descent* in any *time*, to G R or U D the *direct Motion* in the same *time*, so is U D to a *third* proportional; that *third* will be the *Line* call'd by all Writers of *Conicks*, the *Parameter* of the *Parabola* to the *Diameter* G C, which is always the same in *Projects* cast with the same *Velocity*: And the *Velocity* being defined by the Number of *Feet* moved in a *Second* of Time, the *Parameter* will be found by dividing the *Square* of the *Velocity*, by 16 *Feet*, 1 *Inch*, the *Fall* of a *Body* in the same *Time*.

Lemma.

The *Sine* of the double of any *Arch*, is equal to twice the *Sine* of that *Arch* into its *Co-sine*, divided by *Radius*; and the *versed Sine* of the *double* of any *Arch* is equal to twice the *Square* of the *Sine* thereof divided by *Radius*.

Let

Let the *Arch* B C (in *Fig.* 2. *Tab.* 5.) be double the *Arch* B F, and A the *Center*; draw the *Radii* A B, A F, A C, and the *Chord* B D C, and let fall B E perpendicular to A C, and the *Angle* E B C, will be equal to the *Angle* A B D, and the *Triangle* B C E, will be like to the *Triangle* B D A; wherefore it will be as A B to A D, so B C or twice B D, to B E; that is, as *Radius* to *Co-sine*, so twice *Sine* to *Sine* of the double *Arch*. And as A B to B D, so twice B D or B C to E C, that is, as *Radius* to *Sine*, so twice that *Sine*, to the *Versed Sine* of the double *Arch*; which two *Analogies* resolved into *Equations*, are the *Propositions* contained in the *Lemma* to be proved.

Prop. VI. The *Horizontal* Distances of *Projections* made with the same *Velocity*, at several *Elevations* of the *Line* of Direction, are as the *Sines* of the doubled *Angles* of *Elevation*.

Let G B (*Fig.* 1.) the *Horizontal* Distance be $= z$, the *Sine* of the *Angle* of *Elevation*, F G B, be $= s$, its *Co-sine* $= c$, *Radius* $= r$, and the *Parameter* $= p$. It will be as c to s; so z to $\frac{sz}{c} =$ F B $=$ G C, and by reason of the *Parabola* $\frac{psz}{c} =$ to the *Square* of C B, or G F; Now as c to r, so is z to $\frac{zr}{c} =$ G F, and its *Square* $\frac{zzrr}{cc}$ will be therefore $=$ to $\frac{psz}{c}$: Which *Equation* reduced will be $\frac{psc}{rr} = z$. But by the former *Lemma* $\frac{2sc}{r}$ is equal to the *Sine* of the double

ble *Angle*, whereof s is the *Sine*: Wherefore 'twill be as *Radius* to *Sine* of double the *Angle* FGB, ſo is half the *Parameter*, to the *Horizontal Range* or *Diſtance* ſought; and at the ſeveral *Elevations*, the *Ranges* are as the *Sines* of the double *Angles* of *Elevation*, *Q. E. D.*

Corollary.

Hence it follows, that half the *Parameter* is the greateſt *Randon*, and that that happens at the *Elevation* of 45 Degrees, the *Sine* of whoſe double is *Radius*. Likewiſe that the *Ranges* equally diſtant above and below 45 are equal, as are the *Sines* of all double *Arches*, to the *Sines* of their doubled *Complements*.

Prop. VII. The *Altitudes* of *Projections* made with the ſame *Velocity*, at ſeveral *Elevations*, are as the *verſed Sines* of the doubled *Angles* of *Elevation*: As c is to s; ſo is $\frac{psc}{rr}=$GB to $\frac{pss}{rr}=$BF: and UK $=$ RU $=\frac{\text{BF},}{4}$ the *Altitude* of the *Projection* $=\frac{psc}{4rr}$. Now by the foregoing *Lemma* $\frac{2ss}{r}=$ to the *verſed Sine* of the double *Angle*, and therefore it will be as *Radius*, to *verſed Sine* of double the *Angle* FGB, ſo an 8th of the *Parameter* to the height of the *Projection* VK; and ſo theſe heights at ſeveral *Elevations*, are as the ſaid *verſed Sines*, *Q. E. D.*

Corollary.

Corollary.

From hence it is plain, that the greatest *Altitude* of the perpendicular *Projection* is a 4th of *Parameter*, or half the greatest *Horizontal Range*; the *versed Sine* of 180 Degrees being $= 2r$.

Prop. VIII. The *Lines* G F, or Times of the Flight of a *Project* cast with the same Degree of *Velocity* at different *Elevations*, are as the *Sines* of the *Elevations*.

As c is to r; so is $\frac{psc}{rr} =$ G B by the 6 Prop. to $\frac{ps}{r}$ G F; that is, as *Radius* to *Sine* of *Elevation*, so the *Parameter* to the *Line* G F; so the *Lines* G F are as the *Sines* of *Elevation*, and the *Times* are proportional to those *Lines*; wherefore the *Times* are as the *Sines* of *Elevation*: *Ergo constat propositio.*

Prop. IX. Problem. A *Projection* being made as you please, having the Distance and Altitude, or Descent, of an Object, through which the Project passes, together with the *Angle* of *Elevation* of the *Line* of *Direction*; to find the *Parameter* and *Velocity*, that is (in *Fig.* 1.) having the *Angle* F G B, G M, and M X.

Solution. As *Radius* to *Secant* of F G B, so G M the *Distance* given to G L; and as *Radius* to *Tangent* of F G B, so G M to L M. Then L M — M X in *Heights*, or + M X in *Descents*; or else M X — M L, if the *Direction* be below the *Horizontal Line*, is the *Fall* in the *Time* that the direct *Impulse* given in G would have carried the

the Project from G to L=LX=GY ; then by Reason of the *Parabola*, as L X or G Y, is to G L or Y X, so is G L to the *Parameter* sought. To find the *Velocity* of the *Impulse* : by Prop. 2, and 4, find the Time in Seconds that a Body would fall the Space L X; and by that dividing the Line G L, the *Quote* will be the *Velocity*, or Space moved in a Second sought, which is always a mean Proportional between the *Parameter*, and 16 Feet, 1 Inch.

Prop. X. Problem 2. Having the *Parameter*, Horizontal Distance, and Height or Descent of an *Object*, to find the Elevations of the Line of Direction necessary to hit the given *Object*; that is, having G M, M X, and the greatest *Random* equal to half the *Parameter* ; to find the *Angles* F G B.

Let the *Tangent* of the *Angle* sought be $=t$, the *Horizontal Distance* G M$=b$, the Altitude of the *Object* M X$=h$, the *Parameter*$=p$, and *Radius* $=r$, and it will be,

As r to t, so b to $\frac{tb}{r}=$ M L and $\frac{tb}{r}\mp h$

$\left\{\begin{matrix}\text{in ascents}\\\text{in descents}\end{matrix}\right\}=$ L X, and

$\frac{ptb}{r}\mp ph=$ G L *quad.* $=$ X Y *quad. ratione Parabolæ*; but

$bb\mp\frac{ttbb}{rr}=$ G L *quad.* 47. 1. *Euclid.* Wherefore

$\frac{ptb}{r}\mp ph=bb\mp\frac{ttbb}{rr}$ which Equation transposed, is

$\frac{ttbb}{rr}=\frac{ptb}{r}\mp ph-bb$, divided by bb is $\frac{tt}{rr}$

$\frac{tt}{rr} = \frac{pt}{br} \mp \frac{ph}{bb} - 1$. this Equation shews the Question to have 2 Answers, and the Roots thereof are $\frac{t}{r} = \frac{p}{2b} \mp \sqrt{\frac{pp \mp 4ph}{4bb} - 1}$; from which I derive the following Rule.

Divide half the *Parameter* by the Horizontal distance, and keep the Quote; *viz.* $\frac{p}{2b}$ then say, as *square* of the *distance* given to the half *Parameter*, so half *Parameter* $\mp$ double height descent to the *square* of a *Secant* $= \frac{pp \mp 4ph}{4bb}$. The *Tangent* answering to that *Secant*, will be $\sqrt{\frac{pp \mp 4ph}{4bb} - 1}$ or Square of Radius, so then the sum and difference of the aforefound *Quote*, and this *Tangent* will be the Roots of the *Equation*, and the *Tangents* of the *Elevations* sought.

Note here, that in *Descents*, if the *Tangent* exceed the *Quote*, as it does when ph is more than bb, the *direction* of the lower *Elevation* will be below the *Horizon*, and if $ph = bb$, it must be directed *Horizontal*, and the *Tangent* of the upper *Elevation* will be $\frac{pr}{b}$: Note likewise, that if $4bb + 4ph$ in *Ascents*, or $4bb - 4ph$ in *Descents*, be equal to pp, there is but one *Elevation* that can hit the *Object*, and its *Tangent* is $\frac{pr}{2b}$. And if $4bb + 4ph$ in *Ascents*,

or

or $4bb - 4ph$ in *descents*, do exceed pp, the *Object* is without the reach of a *Project* cast with that *Velocity*, and so the thing impossible.

From this *Equation* $4bb \mp 4ph = pp$ are determined the utmost limits of the reach of any *Project*, and the Figure assigned, wherein are all the *heights* upon each *Horizontal distance* beyond which it cannot pass; for by reduction of that *Equation*, h will be found $= \frac{1}{4}p - \frac{bb}{p}$ in *heights*, and $\frac{bb}{p} - \frac{1}{4}p$ in *descents*; from whence it follows, that all the Points h are in the *Curve* of the *Parabola*, whose *Focus* is the Point from whence the *Project* is cast, and whose *Latus rectum*, or *Parameter ad Axem* is $= p$. Likewise from the same *Equation* may the least *Parameter* or *Velocity* be found capable to reach the *Object* proposed; for $bb = \frac{1}{4}pp \mp ph$ being reduced, $\frac{1}{2}p$ will be $= \sqrt{bb + hh} \pm h \begin{cases}\text{in ascents}\\ \text{in descents}\end{cases}$ which is the *Hozontal Range* at 45 degrees, of a Project cast with the least Velocity that would just reach the *Object*, and the *Elevation* requisite will be easily had; for dividing the so found *Semi-parameter* by the *Horizontal distance* given b, the *Quote* into *Radius* will be the *Tangent* of the *Elevation* sought. This Rule may be of good use to all *Bombardiers* and *Gunners*, not only that they may use no more Powder than is necessary, to cast their *Bombs* into the place assigned, but that they may shoot with much more certainty, for that a small Error committed in the *Elevation* of the *Piece*, will produce no sensible Difference in the fall of the Shot:

Shot: For which Reasons the *French* Engineers in their late Sieges have used Mortar-pieces inclin'd constantly to the *Elevation* of 45, proportioning their Charge of Pouder according to the distance of the *Object* they intend to strike on the Horizon.

And this is all that need to be said concerning this *Problem* of shooting upon *Heights* and *Descents*. But if a *Geometrical* Construction thereof be required; I think I have one that is as easy as can be expected, which I deduce from the foregoing *Analytical Solution*, *viz.* $\frac{t}{r} = \frac{p}{2b} \pm \frac{\sqrt{\frac{1}{4}pp \pm ph - bb}}{bb}$, and 'tis this, having made the right Angle GDF, (*Tab.* 5. *Fig.* 3.) make DF $= \frac{1}{2}p$, or greatest Range, and GD $= b$ the Horizontal Distance, and DB $= h$ the perpendicular heighth of the Object; to be laid upwards from D, if the Object be above the Horizon, or downwards if below it. Parallel to GD draw FA, and make it equal to GB the Hypothenusal Distance of the Object; and with the Center A and Radius FB $= \frac{1}{2}p \pm h$, sweep an Arch, which shall if the thing be possible, intersect the indeterminate Perpendicular DF in two Points K and L, to which draw the Lines, GL, GK; I say, the Angles DGK, DGL, are the Elevations requisite to strike the Object B.

Demonstration. The Square of FK or FL, is equal to FB q — GBq: or $\overline{\frac{1}{2}p \pm h}|^2 - bb - hh$ or $\frac{1}{4}pp \pm ph - bb$, and therefore $\sqrt{\frac{1}{4}pp \pm ph - bb}$ is $=$ FK $=$ FL, and by Consequence DK,

$DL = \frac{1}{2}p \pm \sqrt{\frac{1}{4}pp \pm ph - bb}$. And as DG: DK and DL :: Radius : Tangents sought, which coincides with our Algebraical Expression thereof.

Prop. XI. To determine the Force or *Velocity* of a *Project*, in every Point of the *Curve* it describes.

To do this we need no other *Præcognita*, but only the third Proposition, *viz.* That the *Velocity* of *falling Bodies*, is double to that which in the same time, would have described the Space *fallen* by an equable Motion: For the *Velocity* of a Project, is compounded of the constant equal *Velocity* of the impressed Motion, and the *Velocity* of the *Fall*, under a given *Angle*, *viz.* the Complement of the *Elevation* : For Instance, in *Fig.* 2. in the time wherein a Project would move from G to L, it descends from L to X, and by the third *Proposition* has acquired a *Velocity*, which in that time would have carried it by an equable Motion from L to Z, or twice the Descent L X; and drawing the Line G Z, I say, the *Velocity* in the Point X, compounded of the *Velocities* G L and L Z under the Angle G L Z, is to the *Velocity* impress'd in the Point G, as G Z is to G L ; this follows from our second *Axiom*, and by the 20 and 21 *Prop. lib.* 1. *conic. Midorgii*, X O parallel and equal to G Z shall touch the *Parabola* in the Point X. So that the *Velocities* in the several Points, are as the lengths of the *Tangents* to the *Parabola* in those Points, intercepted between any two *Diameters* : And these again are as the *Secants* of the *Angles*, which those *Tangents* continued make with the *Horizontal* Line G B. From what is here laid down, may

may the comparative Force of a *Shot* in any two Points of the *Curve*, be either *Geometrically* or *Arithmetically* discover'd.

Corollary.

From hence it follows, that the force of a Shot is always least at U, or the *Vertex* of the *Parabola*, and that at equal distances therefrom, as at T and X, G and B its force is always equal, and that the least force in U is to that in G and B, as *Radius* to the Secant of the *Angle* of *Elevation* F G B.

These *Propositions* considered, there is no question relating to *Projects*, which, by the help of them, may not easily be Solved; and tho' it be true that most of them are to be met withal, in *Galileus*, *Torricellius* and others, who have taken them from those Authors, yet their Books being Foreign, and not easy to come by, and their *Demonstrations* long and difficult, I thought it not amiss to give the whole *Doctrine* here in *English*, with such short *Analytical* Proof of my own, as might be sufficient to evince their Truth.

The Tenth *Proposition* contains a *Problem*, untouch'd by *Torricellius*, which is of the greatest use in *Gunnery*, and for the sake of which this *Discourse* was principally intended: It was first Solved by Mr. *Anderson*, in his Book of the Genuine Use and Effects of the *Gun*, Printed in the Year 1674; but his Solution required so much Calculation, that it put me upon search, whether it might not be done more easily, and thereupon in the Year 1678 I found out the Rule I now Publish, and from it the *Geometrical* Construction: Since which time there has a large *Treatise* of this

Subject, Intituled, *L'Art dejetter les Bombes*, been Published by *Monsieur Blondel*, wherein he gives the Solutions of this *Problem* by *Messieurs Buot, Romer* and *de la Hire*: But none of them being the same with Mine, or, in my Opinion, more easy, and most of them more Operose, and besides mine finding the *Tangent*, which generally determines the *Angle* better than its *Sine*, I thought my self obliged to Print it for the use of all such, as desire to be informed in the *Mathematical* part of the Art of *Gunnery*.

Now these Rules were rigidly true, were it not, as I said before, for the Opposition of the Medium, whereby not only the direct imprest Motion is continually retarded, but likewise the increase of the *Velocity* of the *Fall*, so that the Spaces described thereby, are not exactly as the Squares of the Times: But what this Opposition of the *Air* is, against several *Velocities, Bulks*, and *Weights*. is not so easie to determine. 'Tis certain that the weight of *Air* to that of *Water*, is nearly as 1 to 800, whence the weight thereof, to that of any *Project* is given; 'tis very likely, that to the same *Velocity* and *Magnitude*, but of different Matter, the *Opposition* should be *reciprocally* as the weights of the Shot; as likewise that to Shot of the same *Velocity* and Matter, but of different *Sizes*, it should be as the *Diameters reciprocally*: Whence generally the *Opposition* to Shot with the same *Velocity*, but of differing *Diameters*, and *Materials*, should be as their *Specifick Gravities* into their *Diameters reciprocally*; but whether the *Opposition*, to differing *Velocities* of the same Shot, be as the *Squares* of those *Velocities*, or as the *Velocities* themselves, or otherwise, is yet a harder Question. However it be, 'tis certain,

tain, that in large Shot of *Metal*, whoſe weight many Thouſand times ſurpaſſes that of the *Air*, and whoſe force is very great, in proportion to the *Surface* wherewith they preſs thereon; this *Oppoſition* is ſcarce diſcernable; For by ſeveral *Experiments* made with all Care and Circumſpection with a *Mortarpiece*, Extraordinary well fix'd to the Earth on purpoſe, which carried a ſolid Braſs Shot of four Inches and a half *Diameter*, and of about fourteen Pound Weight, the *Ranges* above and below forty five *Degrees* were found nearly equal; if there were any difference, the under *Ranges* went rather the fartheſt, but thoſe differences were uſually leſs than the Errors committed in ordinary Practice, by the unequal Goodneſs and Dryneſs of the ſame ſort of Powder, by the Unfitneſs of the Shot to the Bore, and by the Looſneſs of the Carriage.

In a ſmaller Braſs-Shot of about an Inch and half Diameter, caſt by a Croſs-Bow which ranged it, at moſt about four Hundred Foot, the Force being much more equal than in the Morterpiece, this difference was found more Curiouſly: and Conſtantly and moſt Evidently, the under Ranges out-went the upper. From which Trials I conclude, that although in ſmall and light Shot, the Oppoſition of the Air, ought and muſt be accounted for; yet in Shooting of great and weighty Bombs, there need be very little or no allowance made; and ſo theſe Rules may be put in practice to all Intents and Purpoſes, as if this Impediment were abſolutely remov'd.

A Proposition of general Use in the Art of Gunnery, shewing the Rule of laying a Mortar to pass, in order to strike an Object above or below the Horizon.

It was formerly the Opinion of those concerned in Artillery, that there was a certain requisite of Powder for each Gun, and that in Mortars, where the distance was to be varied, it must be done by giving a greater or lesser Elevation to the Piece. But now our later Experience has taught us that the same thing may be more certainly and readily performed by increasing and diminishing the quantity of Powder, whether regard be had to the Execution to be done, or to the Charge of doing it. For when Bombs are discharged with great Elevations of the Mortar, they fall too Perpendicular, and bury themselves too deep in the Ground, to do all that damage they might, if they came more Oblique, and broke upon or near the Surface of the Earth; which is a thing acknowledg'd by the Besieged in all Towns, who unpave their Streets, to let the Bombs bury themselves, and thereby stifle the force of their Splinters. A Second Convenience is, that at the extream Elevation, the Gunner is not obliged to be so curious in the direction of his Piece, but it will suffice to be within a Degree or two of the Truth; whereas in the other Method of Shooting he ought to be very curious. But a Third, and no less considerable Advantage is, in the saving the Prince's Powder, which in so great and so numerous Discharges, as we have lately seen, must needs amount to a considerable Value. And for Sea-Mortars, it is scarce

scarce practicable otherwise to use them, where the agitation of the Sea continually changes the Direction of the Mortar, and would render the Shot very uncertain, were it not that they are placed about 45 Degrees Elevation, where several Degrees above or under, make very little difference in the Effect.

In the precedent Discourse, I considered all the Propositions relating to the Motion of Projectiles, and gave a Solution to this Problem; *viz.* *To hit an Object above or below the Horizontal Line with the greatest Certainty and least Force.* That is, that the Horizontal distance of the Object being put $= b$, and the Perpendicular Heighth $= h$, the Charge requisite to strike the Object with the greatest Advantage, was that which with an Elevation of 45° would cast the Shot on the Horizontal Line, to the distance of $\sqrt{bb + hh}$, when the Object was above the Horizon; or if it were below it, the Charge must be lesser, so as to reach on the Horizon, at 45° Elevation, no greater a Distance than $\sqrt{bb + hh} - h$; that is, in the one Case, the Sum of the Hypothenusal Distance of the Object from the Gun, and the Perpendicular Heighth thereof above the Gun; and in the other Case, when the Object is below the Horizon, the difference of the same *per* 47. 1 *Eucl.* And I then shew'd how to find the Elevation proper for the Gun so charged, *viz.* As the Horizontal Distance of the Object, to the Sum or Difference of the Hypothenusal Distance and Perpendicular Height: So Radius to the Tangent of the Elevation sought. But I was not at that time aware that the aforesaid Elevation did constantly bisect the Angle between the Perpendicular and the Object, as is demonstrated from the Difference and Sum of the *Tangent* and *Secant* of any Arch being always equal to the *Tangent* and *Cotangent* of the half Complement thereof to a Quadrant. Having discovered this, I think nothing can be more compendious, or bids fairer to compleat the Art of Gunnery, it being as easie to shoot with a Mortar at any Object on demand, as if it were on the Level; neither is there need of any Computation, but only simply laying the Gun to pass, in the middle Line between the Zenith and the Object, and giving it its due Charge. Nor is there any great need of Instruments for this purpose: For if the Muzzle of the Mortar be turned truly Square to the Bore of the Piece, as it usually is or ought to be, a piece of Looking-glass Plate applied parallel to the Muzzle, will by its Reflection give the true Position of the Piece, the Bombardeer having no more to do, but to look perpendicularly down on the Looking-glass, along a small Thread with a Plumbet, and to raise or depress the Elevation of the Piece, till the Object appear reflected on the same Point of the *Speculum*, on which the Plumbet falls; for the Angle of Incidence and Reflection being equal, in this Case a Line at Right Angles to the *Speculum*, as is the *Axis* of the Chase of the Piece, will bisect the Angle between the Perpendicular and the Object, according as our Proposition requires. So that it only remains by good and valid Experiments to be assured of the Force of Gunpowder, how to make and conserve it equal, and to know the Effect thereof in each Piece; that is, how far differing Charges will cast the same Shot out

of

of it; which may moſt conveniently be engraven on the outſide thereof, as a ſtanding Direction to all Gunners, who ſhall from thence forward have occaſion to uſe that Piece: And were this Matter well aſcertained, it might be worth the while to make all Mortars of the like Diameter as near as may be, alike in length of Chaſe, Weight, Chamber, and all other Circumſtances.

This Diſcovery that the utmoſt Range on an inclined Plane, is, when the *Axis* of the Piece makes equal Angles with the Perpendicular and the Object; compared with what I have demonſtrated of the ſame Problem in the aforeſaid Diſcourſe does lead to and diſcover two very ready Theorems; the one, to find the greateſt Horizontal Range at 45° Elevation, by any Shot made upon any inclined Plane, with any Elevation of the Piece whatſoever: And the other to find the Elevations proper to ſtrike a given Object, with any Force greater than what ſuffices to reach it with the aforeſaid middle Elevation. Both which being performed by one ſingle Proportion, may be very ſerviceable to ſuch as are concerned in the Practice of Gunnery, but are unwilling to trouble themſelves with tedious and difficult Rules. The two Propoſitions are theſe.

PROP. I.

A Shot being made on an inclined Plane, having the Horizontal Diſtance of the Object it ſtrikes, with the Elevation of the Piece, and the Angle at the Gun between the Object and the Perpendicular; to find the greateſt Horizontal Range of that Piece, laden with the ſame Charge; that

that is, half the *Latus rectum* of all the *Parabolæ* made with the same *Impetus*.

RULE.

Take half the Distance of the Object from the *Nadir*, and take the Difference of the given Elevation from that half; the Versed Sine of twice that Difference subtract from the Versed Sine of the Distance of the Object from the *Zenith*: Then shall the Difference of those Versed Sines be to the Sine of the Distance of the Object from the *Zenith*, as the Horizontal Distance of the Object strook, to the greatest Horizontal Range at 45°.

PROP. II.

Having the greatest Horizontal Range of a Gun, the Horizontal Distance and Angle of Inclination of an Object to the Perpendicular, to find the two Elevations necessary to strike that Object.

RULE.

Halve the Distance of the Object from the *Nadir*; this half is always equal to the half Sum of the two Elevations we seek. Then say, *As the greatest Horizontal Range is to the Horizontal Distance of the Object: So is the Sine of the Angle of Inclination or Distance of the Object from the Perpendicular, to a fourth Proportional; which fourth being subtracted from the Versed Sine of the Distance of the Object from the* Zenith, *leaves the Versed Sine of the Difference of the Elevations sought*;

sought; which Elevations are therefore had by adding and subtracting the half Difference to and from the aforesaid half Sum.

I shall not need to speak of the Facility of these Solutions, I shall only observe that they are both General, without Exception or Caution, and derived from the Knowledge that these two Elevations are equidistant above and below the Line, bisecting the Angle between the Object and the *Zenith.*

A

A Discourse concerning the Measure of the Airs Resistance to Bodies moved in it. By the Learned John Wallis, *S. T. D. and R. S. S.*

1. THAT the Air (and the like of any other *Medium*) doth considerably give Resistance to Bodies moved in it; and doth thereby abate their Celerity and Force;) is generally admitted. And Experience doth attest it: For otherwise, a Cannon-Bullet projected Horizontally, should (supposing the Celerity and Force undiminished) strike as hard against a Perpendicular Wall, erected at a great distance, as near at hand; which we find it doth not.

2. But at what Rate, or in what Proportion, such Resistance is; and (consequently, at what Rate the Celerity and Force is continually diminished) seems not to have been so well examined. Whence it is, that the Motion of a Project (secluding this Consideration) is commonly reputed to describe a Parabolick Line; as arising from an Uniform or equal Celerity in the Line of Projection, and a Celerity uniformly accelerated in the Line of Descent; which two so compounded, do create a Parabola.

3. In order to the Computation hereof, I firſt premiſe this *Lemma*, (as the moſt rational that doth occur for my firſt footing,) That (ſuppoſing other things equal) the Reſiſtance is proportional to the Celerity. For in a double Celerity, there is to be removed (in the ſame time) twice as much Air, (which is a double Impediment) in a treble, thrice as much; and ſo in other Proportions.

4. Suppoſe we then the Force impreſſed (and conſequently the Celerity, if there were no Reſiſtance) as 1; the Reſiſtance as r. (which muſt be leſs than the Force, or elſe the Force would not prevail over the Impediment, to create a Motion.) And therefore the effective Force at a firſt Moment, is to be reputed as $1 - r$: That is, ſo much as the Force impreſſed, is more than the Impediment or Reſiſtance.

5. Be it as $1-r$ to 1; ſo one to m. (which m is therefore greater than 1.)

6. And therefore the effective Force (and conſequently the Celerity) as to a firſt Moment, is to be $\frac{1}{m}$ of what it would be, had there been no Reſiſtance.

7. This $\frac{1}{m}$ is alſo the remaining Force after ſuch firſt Moment; and this remaining Force is (for the ſame Reaſon) to be proportionally abated as to a ſecond Moment; that is, we are to take $\frac{1}{m}$ thereof, that is $\frac{1}{mm}$ of the impreſſed Force. And for a third Moment (at equal diſtance of time) $\frac{1}{mmm}$; for a fourth $\frac{1}{m^4}$; and ſo onward infinitely.

8. Becauſe

8. Becauſe the length diſpatched (in equal times) is proportional to the Celerities; the Lines of Motion (anſwering to thoſe equal Times) are to be as $\frac{1}{m}$, $\frac{1}{m^2}$, $\frac{1}{m^3}$, $\frac{1}{m^4}$, &c. of what they would have been, in the ſame Times, had there been no Reſiſtance.

9. This therefore is a Geometrical Progreſſion; and (becauſe of m greater than 1) cotinually decreaſing.

10. This decreaſing Progreſſion infinitely continued (determining in the ſame Point of Reſt, where the Motion is ſuppoſed to expire) is yet of a finite Magnitude; and equal to $\frac{1}{m-1}$, of what it would have been in ſo much Time, if there had been no Reſiſtance. As is demonſtrated in my Algebra, *Chap.* 95. *Prop.* 8. For (as I have elſewhere demonſtrated) the Sum or Aggregate of a Geometrical Progreſſion is $\frac{VR-A}{R-1}$ (ſuppoſing V the greateſt Term, A the leaſt, and R the common Multiplier.) That is $\frac{VR}{R-1} - \frac{A}{R-1}$. Now in the preſent Caſe, (ſuppoſing the Progreſſion infinitely continued) the leaſt Term A, becomes infinitely ſmall, or $=0$. And conſequently $\frac{A}{R-1}$ doth alſo vaniſh, and thereby the Aggregate becomes $=\frac{VR}{R-1}$. That is

(as

(as will appear by dividing VR by $R-1$;) $V+\frac{V}{R}+\frac{V}{RR}+\frac{V}{R^3}+$ &c. $=\frac{V\,R}{R-1}$; (supposing the Progression to begin at $V=1$.) That is (dividing all by R, that so the Progression may begin at $\frac{V}{R}=\frac{1}{m}$:) $\frac{V}{R-1}=\frac{V}{R}+\frac{V}{RR}+\frac{V}{R^3}+$ &c, That is, in our present Case (because of $V=1$, & $R=m$:) $\frac{1}{m}+\frac{1}{mm}+\frac{1}{m^3}$ &c. $=\frac{1}{m-1}$. That is, (putting $n=m-1$) $\frac{1}{n}$ of what it would have been if there had been no Resistance.

$$
\begin{array}{r|l}
R-1V) & R\left(V+\frac{V}{R},\ \frac{V}{RR},\ \text{\&c.}\right. \\
 & \underline{VR-V} \\
 & +V \\
 & \underline{+\frac{V}{VR}} \\
 & \frac{V}{} \\
 & +\frac{V}{R} \\
 & \underline{+\frac{V}{R}\frac{V}{RR}} \\
 & \frac{V}{} \\
 & +\frac{V}{RR} \\
 & \text{\&c.}
\end{array}
$$

11. This infinite Progression is fitly expressed by an Ordinate in the Exterior Hyperbola, parallel to one of the Asymptotes; and the several Members of that, by the several Members of this, cut in continual Proportion. As is there demonstrated at *Prop.* 15. For let *S H*, (*vid.* Fig. 4. Tab. 5.) be an Hyperbola between the Asymptotes *A B*, *A F*: And let the Ordinate *D H* (in the Exterior Hyperbola, parallel to *A F*,) represent the impressed Force undiminished; or the Line to be described in such time, by a Celerity answerable to such undiminished Force. And let *B S* (a like Ordinate be $\frac{1}{m}$ thereof; which therefore, being less than *D H* (as being equal to a Part of it) will be farther

that

than it from AF. In AB (which I put $= 1$) let Bd be such a Part thereof, as is BS of DH. Now because (as is well known) all the inscribed Parallelograms, in the Exterior Hyperbola, AS, AH, &c. are equal; and therefore their sides reciprocal: Therefore as $Ad = 1 - \frac{1}{m}$ (supposing Bd to be taken, from B towards A,) to $AB = 1$, (or as $m - 1$ to m: so is $BS = \frac{1}{m} DH$, to $m-1)\,1\,(\frac{1}{m} + \frac{1}{mm} + \frac{1}{m^3} +$ &c. db, which is therefore equal to $\frac{1}{m-1}$ of DH; that is (as will appear by dividing 1, by $m - 1$,) to $\frac{1}{m} + \frac{1}{mm} + \frac{1}{m^3}$, &c. of DH.

$$\begin{array}{l} 1 - \frac{1}{m} \\ \hline +\frac{1}{m} \\ +\frac{1}{m} - \frac{1}{mm} \\ \hline +\frac{1}{mm} \\ +\frac{1}{mm} - \frac{1}{mmm} \\ \hline +\frac{1}{mmm} \\ \text{\&c.} \end{array}$$

Or if Bd be taken beyond B; then as $Ad = 1 + \frac{1}{m}$ to $AB = 1$, or as $m + 1$ to m, so is $\frac{1}{m} DH$ to db, which is therefore equal to $\frac{1}{m+1} DH$; that is (as will appear by like dividing of 1 by $m + 1$;) $=$ to $\frac{1}{m} - \frac{1}{mm} + \frac{1}{m^3} -$ &c. of DH.

12. Let

12. Let such ordinate dh, or (equal to it in the Asymptote) AF, be so divided in L, M, N, &c. (by Perpendiculars cutting the Hyperbola in l, m, n, &c.) as that FL, LM, MN, be as $\frac{1}{m}$, $\frac{1}{mm}$, $\frac{1}{m^3}$, &c. That is, so continually decreasing as that each Antecedent be to its Consequent, as 1 to $\frac{1}{m}$, or as m to 1. See *Fig.* 5. *Tab.* 5.

13. This is done by taking AF, AL, AN, &c. in such proportion. For, of continual Proportionals, the Differences are also continually proportional, and in the same proportion. For let A, B, C, D, &c. be such Proportionals, and their Differences a, b, c, &c. That is, $A-B=a$, $B-C=b$, $C-D$, $=c$, &c.

Then, because A, B, C, D, &c. are in continual proportion,
That is, A. B :: B. C :: C. D :: &c.
And dividing A—B.B :: B—C.C :: C—D D :: &c.
That is, *a*. B :: *b*. C :: *d*. D :: &c.
And alternly *a*. *b*. *c*. &c. :: B. C. D. &c. :: A. B. C. &c.
That is, in continual proportion as A to B, or as *m* to 1.

14. This being done; the Hyperbolick Spaces Fl, Lm, Mn, &c. are equal. As is demonstrated by *Gregory San-Vincent*; and as such is commonly admitted.

15. So that Fl, Lm, Mn, &c. may fitly represent equal Times, in which are dispatched unequal Lengths, represented by FL, LM, MN, &c.

16. And because they are in Number infinite (though equal to a finite Magnitude) the Duration is infinite: And consequently the impressed Force, and Motion thence arising, never to be wholly extinguished (without some further Impediment) but perpetually approaching to *A*, in the Nature of Asymptotes.

17. The Spaces *Fl*, *Fm*, *Fn*, &c. are therefore as Logarithms (in Arithmetical Progression increasing) answering to the Lines *AF*, *AL*, *AM*, &c. or to *FL*, *LM*, *MN*, &c. in Geometrical Progression decreasing.

18. Because *FL*, *LM*, *MN*, &c. are as $\frac{1}{m}$, $\frac{1}{mm}$, $\frac{1}{m^3}$, &c. (infinitely) terminated at *A*; therefore (by ¶ 10) their Aggregate *FA* or *dh*, is to *DH*, (so much Length as would have been dispatched, in the same time, by such impressed Force undiminished) as 1 to $m-1=n$.

19. If therefore we take, as 1 to *n*, so *AF* to *DH*; this will represent the Length to be dispatched, in the same time, by such undimished Force.

20. And if such *DH* be supposed to be divided into equal Parts innumerable (and therefore infinitely small;) these answer to those (as many) Parts unequal in *FA*, or *hd*.

21. But, what is the Proportion of *r* to 1, or (which depends on it) of $1-r$ to 1, or 1 to *m*; remains to be inquired by Experiment?

22. If the Progression be not infinitely continued; but end (suppose) at N, and its least Term be $A=MN$; then, out of $\frac{V}{R-1}=\frac{1}{m}+\frac{1}{mm}+\frac{1}{m^3}$, &c. is to be subducted $\frac{A}{R-1}$ (as at ¶ 10.) that is

(as

(as by Diviſion will appear) $\frac{A}{R} + \frac{A}{R^2} + \frac{A}{R^3}$ &c.

That is (in our preſent Caſe) $\frac{a}{m} + \frac{a}{mm} + \frac{a}{m^3}$ &c. And ſo the Aggregate will be $\frac{1-a}{m} + \frac{1-a}{mm} + \frac{1-a}{m^3}$ &c. $= \frac{1-a}{n}$.

And thus as to the Line of Projection, in which (ſecluding the Reſiſtance, the Motion is reputed uniform; diſpatching equal Lengths in equal Times. Conſider we next the Line of Deſcent.

23. In the Deſcent of Heavy Bodies, it is ſuppoſed that to each Moment of Time, there is ſuperadded a new Impulſe of Gravity to what was before: And each of theſe, ſecluding the Conſideration of the Air's Reſiſtance, to proceed equally (from their ſeveral beginnings) through the ſucceeding Moments. As (in the erect Lines) 1 1 1 1, *&c.* 1 1 1, *&c.* 1 1, *&c.* 1, *&c.* and ſo continually, as in the Line of Projection.

24. Hence ariſeth (in the tranſverſe Lines) for the firſt Moment 1, for the ſecond 1 + 1, for the third 1 + 1 + 1, and ſo forth, in Arithmetical Progreſſion: As are the Ordinates in a Triangle, at equal diſtance.

1
1 1
1 1 1
1 1 1 1
&c.

25. And ſuch are the continual Increments of the Diameter, or of the Ordinates in the exterior Parabola, anſwering to the interior Ordinates, or Segments of the Tangent, equally increaſing; as is known, and commonly admitted.

26. If we take in the Consideration of the Air's Resistance; we are then, for each of these equal Progressions, to substitute a decreasing Progression Geometrical; in like manner (and for the same Reasons) as in the Line of Projection.

27. Hence ariseth, for the first Moment $\frac{1}{m}$; for the second $\frac{1}{m} + \frac{1}{m^2}$; for the third $\frac{1}{m} + \frac{1}{m^2} + \frac{1}{m^3}$, &c. And such is therefore the Descent of a heavy Body falling by its own weight. The several Impulses of Gravity being supposed equal.

$$\frac{1}{m}$$
$$\frac{1}{m^2}\;\frac{1}{m}$$
$$\frac{1}{m^3}\;\frac{1}{m^2}\;\frac{1}{m}$$
$$\frac{1}{m^4}\;\frac{1}{m^3}\;\frac{1}{m^2}\;\frac{1}{m}$$

28. That is (in the Figure of ¶ 12) as *FL*, *FM*, *FN*, &c. in the Line of Descent, answering to *FL*, *LM*, *MN*, &c. in the Line of Projection.

29. But though the Progressions for the Line of Projection, are like to each of those many in the Line of Descent; it is not to be thence inferred, that therefore $\frac{1}{m}$ in the one, is equal to $\frac{1}{m}$ in the other: But in the Line of Projection (suppose) $\frac{1}{m}f$ (such a Part of the Force impressed, and a Celerity answerable:) in the Line of Descent, $\frac{1}{m}g$ such a Part of the Impulse of Gravity.

30. Those for the Line of Descent (of the same Body) are all equal, each to other: Because *g* (the

g (the new Impulſe of Gravity) in each Moment is ſuppoſed to be the ſame.

31. But what is the Proportion of f to g (that of the Force impreſſed, to the Impulſe of Gravity in each Body) remains to be inquired by Experiment.

32. This Proportion being found as to one known Force; the ſame is thence known as to any other Force (whoſe Proportion to this is given) in the ſame uniform *Medium*.

33. And this being known, as to one *Medium*; the ſame is thence known as to any other *Medium*, the Proportion of whoſe Reſiſtance to that of this is known.

34. If a heavy Body be projected downward in a perpendicular Line; it deſcends therefore at the Rate $\frac{1}{m}$, $\frac{1}{mm}$, $\frac{1}{m^3}$, &c. of f (the impreſſed Force) increaſed by $\frac{1}{m}$, $\frac{1}{m} + \frac{1}{m^2}$, $\frac{1}{m} + \frac{1}{m^2} + \frac{1}{m^3}$, &c. of g the Impulſe of Gravity, (by ¶ 7, and ¶ 27) Becauſe both Forces are here united.

35. If in a perpendicular Projection upwards; it aſcends in the rate of the former, abated by that of the latter. Becauſe here the Impulſe of Gravity is contrary to the Force impreſſed.

36. When therefore this latter (continually increaſing) becomes equal to that former (continually decreaſing) it then ceaſeth to aſcend; and doth thenceforth deſcend at the rate wherein the latter continually exceeds the former.

37. In an Horizontal, or Oblique Projection: If to a Tangent, whoſe Increments are as *F L*,

LM, *MN*, &c. that is as $\frac{1}{m}f$, &c. be fitted Ordinates (at a given Angle) whose Increments are as *FL*, *FM*, *FN*, &c. that is, as $\frac{1}{m}g$, &c. The Curve answering to the Compound of these Motions, is that wherein the Project is to move.

38. This Curve (being hitherto without a Name) may be call'd *Linea Projectorum*; the Line of Projects, or things projected; which resembles a Parabola deform'd.

39. The Celerity and Tendency, as to each Point of this Line, is determined by a Tangent at that Point.

40. And that against which it makes the greatest Stroke or Percussion, is that which (at that Point) is at right Angles to that Tangent.

41. If the Projection (at ¶ 27.) be not infinitely continued, but terminate (suppose) at *N*, so that the last Term in the first Column or Series erect be a; and consequently in the second, ma; in the third, mma, &c. (each Series having one Term fewer than that before it:) Then (for the same Reasons, as at ¶ 22.) the Aggregates of the several Columns (or erect Series) will be $\frac{1-a}{n}$, $\frac{1-ma}{n}$, $\frac{1-mma}{n}$, and so forth, till (the Multiple of a becoming $=1$) the Progression expire.

42 Now all the Abatements here, a, ma, mma, &c. are the same with the Terms of the first Column taken backward. For a is the last, ma the next before it; and so of the rest.

43. And

43. And the Aggregate of all the Numerators is so many times 1, as is the Number of Terms (suppose t,) wanting the first Column; that is $t - \frac{1-a}{n}$, or $\frac{nt-1+a}{n}$; and this again divided by the common Denominator n, becomes $\frac{nt-1+a}{nn}$. And therefore $\frac{nt-1+a}{nn}g$, is the Line of Descent by its own Gravity.

44. If therefore this be added to a projecting Force downward in a Perpendicular; or subducted from such projecting Force upward; that is, to or from $\frac{1-a}{n}f$: The Descent in the first Case will be $\frac{1-a}{n}f + \frac{nt-1+a}{nn}g$; and the Ascent in the other Case $\frac{1-a}{n}f - \frac{nt-1+a}{nn}g$. And in this latter Case, when the ablative Part becomes equal to the positive Part, the Ascent is at the highest; and thenceforth (the ablative Part exceeding the positive) will descend.

45. In an Horizontal or Oblique Projection, having taken $\frac{1-a}{n}f$, in the Line of Projection, and thence (at the Angle given) $\frac{nt-1+a}{nn}g$, in the Line of Descent; the Point in the Curve answering to these, is the Place of the Project answering to that Moment.

46. I am aware of ſome Objections to be made, whether to ſome Points of the Proceſs, or to ſome of the Suppoſitions. But I ſaw not well how to wave it, without making the Computation much more perplex'd. And in a Matter ſo nice, and which muſt depend upon Phyſical Obſervations, 'twill be hard to attain ſuch Accuracy, as not to ſtand in need of ſome Allowances.

47. Somewhat might have been farther added to direct the Experiments ſuggeſted at ¶ 21, and 31. But that may be done at leiſure, after deliberation had, which way to attempt the Experiment.

48. The like is to be ſaid of the different reſiſtance which different Bodies may meet with in the ſame *Medium*, according to their different Gravities (extenſively or intenſively conſider'd) and their different Figures and Poſitions in Motion. Whereof we have hitherto taken no account; but ſuppoſed them, as to all theſe, to be alike and equal.

POSTSCRIPT.

49. The Computation in ¶ 41, 42, 43, may (if that be alſo deſired) be thus repreſented by Lines and Spaces. The Ablatives *a*, *m a*, *m m a*, &c. (being the ſame with the firſt Column taken backward) are fitly repreſented by the Segments of *N F* (beginning at *N*) in Figure 5 and 6, and therefore by Parallelograms on theſe Baſes, aſſuming the common height of *F h*, or *N Q*; the Aggregate of which is *N h*, or *F Q*. And, ſo many times 1, by ſo many equal Spaces, on the ſame Baſes, between the ſame Parallels, terminated

terminated at the Hyperbola: The Aggregate of which is $hFNQn$. From whence if we subduct the Aggregate of Ablatives FY; the remaining Trilinear hQn, represents the Descent.

50. If to this of Gravity, be joined a projecting Force; which is to the Impulse of Gravity as as hK to hF (be it greater, less, or equal) taken in the same Line; the same Parallels determine proportional Parallelograms, whose Aggregate is KQ.

51. And therefore if this be a perpendicular Projection downwards; then $hKkn$ (the Sum of this with the former) represents the Descent.

52. If it be a Perpendicular upwards; then the difference of these two represents the Motion; which so long as KQ is the greater, is Ascendent; but Descendent, when hQn becomes greater; and it is then at the highest when they be equal.

53. If the Projection be not in the same Perpendicular, (but Horizontal, or Oblique) then KQ represents the Tangent of the Curve; and hQn the Ordinates to that Tangent, at the given Angle.

54. But the Computation before given, I take to be of better use than this Representation in Figure. Because in such Mathematical Enquiries, I choose to separate (as much as may be) what purely concerns Proportions; and consider it abstractly from Lines, or other Matter wherewith it is incumbred.

As to the Question proposed; whether the resistance of the *Medium* do not always take off such a proportional part of the Force moving through it, as is the specifick Gravity of the *Medium* to that of the Body moved in it: (For, if

so,

ſo, it will ſave us the trouble of Obſervation.)

I think this can by no means be admitted. For there be many other things of Conſideration herein, beſide the intenſive Gravity (or, as ſome call it, the ſpecifick Gravity) of the *Medium*.

A viſcous *Medium* ſhall more reſiſt, than one more fluid, though of like intenſive Gravity.

And a ſharp Arrow ſhall bore his way more eaſily through the *Medium*, than a blunt-headed Bolt, though of equal Weight, and like intenſive Gravity.

And the ſame Pyramid with the Point, than with the Baſe forward.

And many other like Varieties, intended in my ¶ 48.

But this I think may be admitted, namely, That different *Mediums*, equally liquid, (and other Circumſtances alike,) do in ſuch proportion reſiſt, as is their intenſive Gravity. Becauſe there is, in ſuch proportion, a heavier Object to be removed, by the ſame Force. Which is one of the things to which ¶ 33 refers.

And again: The heavier Project once in Motion, (being equally ſwift, and all other Circumſtances alike) moves through the ſame *Medium* in ſuch proportion more ſtrongly, as is its intenſive Gravity. For now the Force is in ſuch proportion greater, for the removal of the ſame reſiſtance. And this Part of what my ¶ 32 inſinuates.

But

But where there is a Complication of these Considerations one with another, and with many other Circumstances, whereof each is severally to be considered; there must be respect had to all of them.

A

An Instance of the Excellence of the Modern Algebra, *in the Resolution of the Problem of finding the* Foci *of Optick Glasses Universally.* *By* E. Halley, *S. R. S.*

THE Excellence of the *Modern Geometry* is in nothing more evident, than in those full and adequate Solutions it gives to Problems; representing all the possible Cases at one view, and in one general Theorem, many times comprehending whole Sciences; which deduced at length into Propositions, and demonstrated after the manner of the *Ancients*, might well become the Subjects of large Treatises: For whatsoever Theorem solves the most complicated Problem of the kind, does with a due Reduction reach all the subordinate Cases. Of this I now design to give a notable Instance in the Doctrine of *Dioptricks*.

This Dioptrick Problem is that of finding the *Focus* of any sort of *Lens*, exposed either to converging, diverging, or parallel Rays of Light, proceeding from, or tending to a given Point in the *Axis* of the *Lens*, be the *Ratio* of *Refraction* what it will, according to the Nature of the transparent Material whereof the *Lens* is formed, and also with allowance for the thickness of the *Lens* between the *Vertices*

tices of the two Spherical Segments. This Problem being ſolved in one Caſe, *mutatis mutandis*, will exhibit Theorems for all the poſſible Caſes, whether the *Lens* be *Double-Convex* or *Double-Concave*, *Plano-Convex*, or *Plano-Concave*, or *Convexo-Concave*, which ſort are uſually call'd *Meniſci*. But this only to be underſtood of thoſe Beams which are neareſt to the *Axis* of the *Lens*, ſo as to occaſion no ſenſible difference by their Inclination thereto; and the *Focus* here formed, is by *Dioptrick Writers* commonly call'd the principal *Focus*, being that of uſe in *Teleſcopes* and *Microſcopes*.

Let then (in *Fig.* 7. *Tab.* 5.) BEβ be a double Convex *Lens*, C the Center of the Segment EB, and K the Center of the Segment Eβ, Bβ the thickneſs of the *Lens*, D a Point in the *Axis* of the *Lens*; and it is required to find the Point F, at which the Beams proceeding from the Point D, are collected therein, the *Ratio* of Refraction being as m to n. Let the diſtance of the Object DB=DA=d (the Point A being ſuppoſed the ſame with B, but taken at a diſtance therefrom, to prevent the coincidence of ſo many Lines) the *Radius* of the Segment towards the Object CB or CA=r, and the *Radius* of the Segment from the Object Kβ or K=ρ; and let Bβ the thickneſs of the *Lens* be =t, and then let the Sine of the Angle of Incidence DAG be to the Sine of the refracted Angle HAG or CAφ as m to n: And in very ſmall Angles, the Angles themſelves will be in the ſame proportion; whence it will follow that,

As

As d to r, so the Angle at C to the Angle at D, and $d+r$ will be as the Angle of Incidence G A D; and again as m to n, so $d+r$ to $\frac{dn+rn}{m}$, which will be as the Angle G A H = C A φ; This being taken from A C D which is as d, will leave $\frac{m-n\,d-n\,r}{m}$ analogous to the Angle A φ D; and the Sides being in this Case proportional to the Angles they subtend, it will follow, that as the Angle A φ D is to the Angle A D φ, so is the Side A D or B D to A φ or B φ: That is, B φ will be = $\frac{m\,d\,r}{m-n\,d-n\,r}$, which shews in what Point the Beams proceeding from D, would be collected by means of the first Refraction; but if $n\,r$ cannot be substracted from $m-n\,d$, it follows that the Beams after Refraction do still pass on diverging, and the Point φ is on the same side of the *Lens* beyond D. But if $n\,r$ be equal to $m-nd$, then they proceed parallel to the *Axis*, and the Point φ is infinitely distant.

The Point φ being found as before, and Bφ—Bβ being given, which we will call δ, it follows by a Process like the former, that βF, or the focal Distance sought, is equal to $\frac{\delta\,\varrho\,n}{m-\delta+m\,\varrho}=f$. And in the room of δ substituting Bφ—Bβ $=\frac{m\,d\,r}{m-n\,d-n\,r}-t$, putting p for $\frac{n}{m-n}$, after due Reduction this fol-

lowing

lowing Equation will ariſe,

$$\frac{mpdr\varrho - nd\varrho t + npr\varrho t}{mdr + md\varrho - mpr\varrho - m - ndt + nrt} = f.$$

Which Theorem, however it may ſeem operoſe, is not ſo, conſidering the great Number of *Data* that enter the Queſtion; and that one half of the Terms ariſe from our taking in the thickneſs of the *Lens*, which in moſt Caſes can produce no great Effect; however it was neceſſary to conſider it, to make our Rule perfect. If therefore the *Lens* conſiſt of *Glaſs*, whoſe Refraction is as 3 to 2 'twill be $\frac{6dr\varrho - 2d\varrho t + 4r\varrho t}{3dr + 3d\varrho - 6r\varrho - dt + 2rt} = f$. If of *Water*, whoſe Refraction is as 4 to 3, the Theorem will ſtand thus $\frac{12dr\varrho - 3d\varrho t + 9r\varrho t}{4dr + 4d\varrho - 12r\varrho - dt + 3rt} = f$. If it could be made of *Diamant*, whoſe Refraction is as 5 to 2, it would be $\frac{\frac{10}{3}dr\varrho - 2d\varrho t + \frac{4}{3}r\varrho t}{5dr + 5d\varrho - \frac{10}{3}r\varrho - 3dt + 2rt} = f$. And this is the univerſal Rule for the *Foci* of double Convex Glaſſes expoſed to diverging Rays. But if the thickneſs of the *Lens* be rejected, as not ſenſible, the Rule will be much ſhorter, *viz.* $\frac{pdr\varrho}{dr + d\varrho - prt} = f$, or in Glaſs $\frac{2dr\varrho}{dr + d\varrho - 2r\varrho} = f$, all the Terms wherein t is found being omitted, as equal to nothing. In this Caſe, if d be ſo ſmall, as that $2r\varrho$ exceed $dr + d\varrho$, then will it be $-f$, or the *Focus* will be Negative, which ſhews that the Beams after both Refractions ſtill proceed diverging.

To bring this to the other Cases, as of converging Beams, or of Concave Glasses, the Rule is ever composed of the same Terms, only changing the Signs of + and —; for the distance of the Point of Concourse of converging Beams, from the Point B, or the first Surface of the *Lens*, I call a negative Distance or $-d$; and the Radius of a Concave *Lens* I call a negative Radius, or $-r$ if it be the first Surface, and $-\rho$, if it be the second Surface. Let then converging Beams fall on a double Convex of Glass, and the Theorem will stand thus $\frac{-2dr\rho}{-dr-d\rho-2rt} = +f$, which shews that in this Case the *Focus* is always affirmative.

If the *Lens* were a *Meniscus* of Glass, exposed to diverging Beams, the Rule is $\frac{-2dr\rho}{-dr+d\rho+2r\rho} = f$, which is affirmative when $2r\rho$ is less than $dr-d\rho$, otherwise negative: But in the Case of converging Beams falling on the same *Meniscus*, 'twill be $\frac{+2dr\rho}{+dr-d\rho+2rp} = f$, and it will be $+f$, whilst $d\rho - dr$ is less than $2r\rho$; but if it be greater than $2r\rho$, it will always be found negative or $-f$. If the *Lens* be double Concave, the *Focus* of converging Beams is negative, where it was affirmative in the the Case of diverging Beams on a double Convex, *viz.* $\frac{-2dr\rho}{+dr+d\rho-2r\rho} = f$, which is affirmative only when $2r\rho$ exceeds $dr+d\rho$: But diverging Beams passing a double Concave, have always a negative *Focus*, *viz.* $\frac{-2dr\rho}{+dr+d\rho+2r\rho} = -f$.

The

The Theorems for converging Beams, are principally of uſe to determine the *Focus* reſulting from any ſort of *Lens* placed in a Teleſcope, between the *Focus* of the Object-Glaſs and the Glaſs it ſelf; the diſtance between the ſaid *Focus* of the Object-Glaſs, and the interpoſed *Lens* being made $= -d$.

I here ſuppoſe my Reader acquainted with the Rules of Analytical Multiplication and Diſion, as that + multiplied by + makes the Product +, + by — makes —, and — by — makes +; ſo dividing + by + makes the Quote +, + by — makes —, and — by — makes +; which will be neceſſary to be underſtood in the preceding Examples.

In caſe the Beams are parallel, as coming from an infinite diſtance, (which is ſuppoſed in the Caſe of Teleſcopes) then will d be ſuppoſed Infinite, and in the Theorem $\frac{p\,d\,\varrho\,r}{d\,r + d\,\varrho - p\,r\,\varrho}$ the Term $p\ r\ \varrho$ vaniſhes, as being finite, which is no part of the other infinite Terms; and dividing the Remainder by the infinite Part d, the Theorem will ſtand thus $\frac{p\ \varrho\ r}{r + \varrho} = f$, or in Glaſs, $\frac{2\ r\ \varrho}{r + \varrho} = f$.

In caſe the *Lens* were *Plano-Convex* expoſed to diverging Beams, inſtead of $\frac{p\,d\,\varrho\,r}{d\,r + d\,\varrho - p\,r\,\varrho}$, r being infinite, it will be $\frac{p\ d\ \varrho}{d - p\varrho} = f$, or $\frac{2\,d\,\varrho}{d - 2\,\varrho}$ if the *Lens* be Glaſs.

If the *Lens* be Double-Convex, and r be equal to ϱ, as being formed of Segments of equal Spheres, then will $\frac{p\,d\,\varrho\,r}{d\,r + d\,\varrho - p\,r\,\varrho}$ be reduced to $\frac{p\,d\,r}{2\,d - p\,r}$ f; and in case d be infinite, then it will yet be farther contracted to $\frac{1}{2}\,p\,r$, and p being $= \frac{n}{m - n}$, the focal distance in Glass will be $= r$, in Water $1\frac{1}{2}\,r$, but in Diamant $\frac{1}{3}\,r$.

I am sensible that these Examples are too much for the compleat Analyst, though I fear too little for the less Skilful; it being very hard, if possible, in such Matters, so to write, as to give satisfaction to both; or to please the one, and instruct the other. But this may suffice to shew the extent of our Theorem, and how easie a Reduction adapts any one case to all the rest.

Nor is this only useful to discover the *Focus* from the other proposed *data*, but from the *Focus* given, we may thereby determine the distance of the Object; or from the *Focus* and Distance given, we may find of what Sphere it is requisite to take another Segment, to make any given Segment of another Sphere cast the Beams from the distance d to the *Focus* f. As likewise from the *Lens*, *Focus*, and Distance given, to find the *Ratio* of Refraction, or of m to n, requisite to answer those *Data*. All which it is obvious, are fully determined from the Equation we have hitherto used, *viz.* $p\,d\,\varrho\,r = d\,r\,f + d\,\varrho\,f - p\,r\,\varrho\,f$, for to find d The Theorem is $\frac{p\,r\,\varrho\,f}{r\,f + \varrho\,f - p\,\varrho\,r} = d$, the distance of the Object.

For

For ϱ the Rule is $\frac{drf}{pdr + df + \varrho rf} = \varrho$.

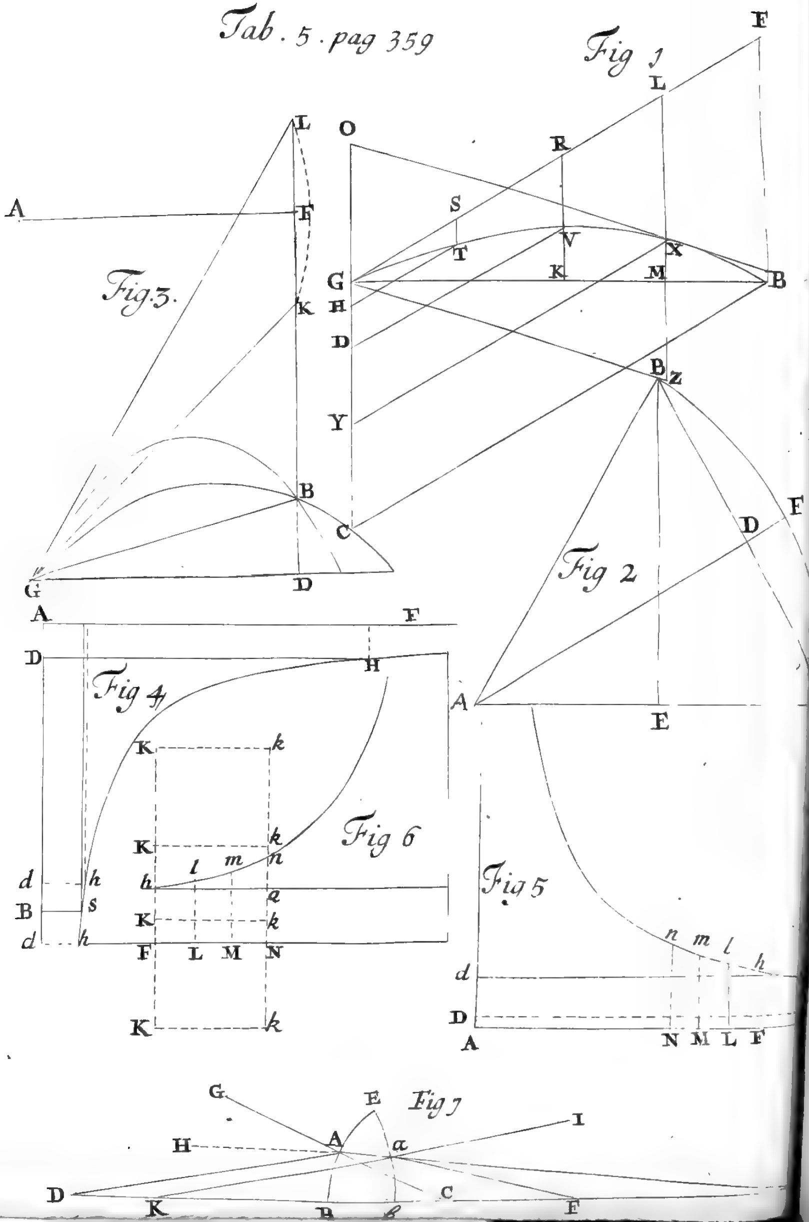
But for p will be $\frac{drf + d\varrho f}{d\varrho r + f\varrho r} = p$, which latter determines the *Ratio* of Refraction, m being to n, as $1 + p$ to p.

I shall not expatiate on these Particulars, but leave them for the Exercise of those that are desirous to be informed in Optical Matters, which I am bold to say are comprehended in these three Rules, as fully as the most Inquisitive can desire them, and in all possible Cases; regard being had to the Signs + and —, as in the former Cases of finding the *Focus*. I shall only shew two considerable Uses of them; the one to find the distance whereat an Object being plac'd, shall by a given *Lens* be represented in a *Species* as large as the Object it self, which may be of singular Use in drawing Faces and other things in their true Magnitude, by transmitting the *Species* by a Glass into a dark Room, which will not only give the true Figure and Shades, but even the Colours themselves, almost as vivid as the Life. In this Case d is equal to f, and substituting d for f in the Equation, we shall have $pdr\varrho = ddr + dd\varrho - dp\varrho r$, and dividing all by d $pr\varrho = dr + d\varrho - pr\varrho$, that is, $\frac{2pr\varrho}{r + \varrho} = d$; but if the two Convexities be of the same Sphere so as $r = \varrho$, then will the distance be $= pr$; that is, if the *Lens* be Glass $= 2r$, so that if an Object be placed at the Diameter of the Sphere distant, in this Case the *Focus* will be as far within as the Object is without, and the *Species* repreſented thereby will be as big as the Life; but if it were a *Plano-Convex*, the ſame diſtance will be $= 2pr$, or in Glaſs to four times the *Radius* of the Convexity; but of this Method I may entertain the Curious at ſome other Time, and ſhew how to magnifie or diminiſh an Object in any proportion aſſign'd, (which yet will be obvious enough from what is here deliver'd) as likewiſe how to erect the Object which in this Method is reprepreſented inverted.

A ſecond Uſe is to find what Convexity or Concavity is required, to make a vaſtly diſtant Object be repreſented at a given *Focus*, after the one Surface of the *Lens* is formed; which is but a Corollary of our Theorem for finding ϱ, having p, d, r and f given; for d being infinite, that Rule becomes $\frac{rf}{pr - f} = \varrho$, that is in Glaſs $\frac{rf}{2r - f} = \varrho$, whence if f be greater than $2r$, ϱ becomes Negative, and $\frac{rf}{f - 2r}$ is the *Radius* of the Concave ſought.

Thoſe that are wholly to begin with this Dioptrical Science, cannot do better than to read with Attention a late Treatiſe of Dioptricks, publiſhed by *W. Molineux*, Eſq, R. S. S. who has at large ſhewn the Nature of Optick Glaſſes, and the Conſtruction and Uſe of Microſcopes and Teleſcopes; and though ſome nicely Critical have endeavour'd to ſpy Faults, and to traduce the Book; yet having long ſince examin'd it with Care, I affirm, that if I can judge, it hath but two things that with any

Tab. 5. pag 359



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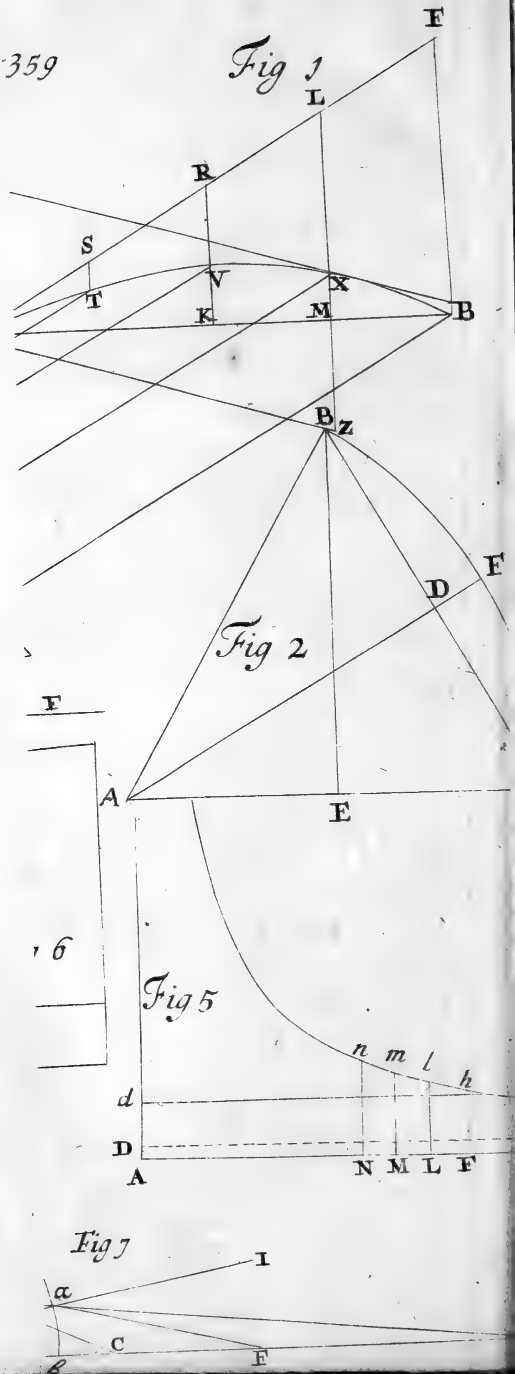
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any Colour may be call'd Faults; the one, an over-careful acknowledgment of every Trifle the Author had receiv'd from others; and the other that he labours to make eaſie this curious Subject, ſo little underſtood by moſt, in a manner perhaps too familiar for the *Learned Critick*, and which demonſtrates that it was writ *cum animo docendi*, both which require but very little Frienſhip or good Nature in the Reader, to paſs for Vertues in an Author.

But to return to our firſt Theorem, which accounting for the thickneſs of the *Lens*, we will here again reſume, *viz.*

$$\frac{mpdr\varrho - nd\varrho t + npr\varrho t}{mdr + md\varrho - mpr\varrho - m - ndt + nrt} = f.$$

And let it be required to find the *Focus* where a whole Sphere will collect the Beams proceeding from an Object at the diſtance d: Here t is equal to $2r$, and r equal to ϱ. And after due Reduction, the Theorem will ſtand thus, $\frac{mpdr - 2ndr + 2nprr}{2nd + 2nr - mpr} = f$; but if d be Infinite, it is contracted to $\frac{mpr}{2n} - r = \frac{2n - m}{2m - 2n} r = f$, wherefore a Sphere of Glaſs collects the Sun-Beams at half the Semi-diameter of the Sphere without it, and a Sphere of Water at a whole Semi-diameter. But if the *Ratio* of Refraction m to n be as 2 to 1, the *Focus* falls on the oppoſite Surface of the Sphere; but if it be of greater Inequality it falls within.

Another Example shall be when a Hemisphere is exposed to parallel Rays, that is, d and ϱ being infinite, and $t = r$, and after due Reduction the Theorem results $\frac{nn}{mm - mn} r = f$. That is, in Glass it is at $\frac{4}{3} r$, in Water at $\frac{9}{4} r$; but if the Hemisphere were Diamant, it would collect the Beams at $1 \frac{4}{15}$ of the *Radius* beyond the Center.

Lastly, As to the Effect of turning the two sides of a *Lens* towards an Object; it is evident, that if the thickness of the *Lens* be very small, so as that you neglect it, or account $t = 0$; then in all Cases the *Focus* of the same *Lens*, to whatsoever Beams, will be the same, without any difference upon the turning the *Lens*: But if you are so curious as to consider the thickness, (which is seldom worth accounting for) in the Case of parallel Rays falling on a *Plano-Convex* of Glass, if the plain side be towards the Object, t does occasion no difference, but the focal distance $f = 2r$. But when the Convex-side is towards the Object, it is contracted to $2r - \frac{2}{3}t$, so that the *Focus* is nearer by $\frac{2}{3}t$. If the *Lens* be double Convex, the difference is less; if a *Meniscus*, greater. If the Convexity on both sides be equal, the focal length is about $\frac{1}{6}t$ shorter than when $t = 0$. In a *Meniscus* the Concave-side towards the Cbject increases the focal Length, but the Convex towards the Object diminishes it. A General Rule for the difference arising on turning the *Lens*, where the *Focus* is Affirmative, is this $\frac{2rt - 2\varrho t}{3r + 3\varrho - t}$, for double Convexes of differing Spheres. But for *Menisci*

Menisci the same difference becomes $\frac{2rt + 2\varrho t}{3r - 3\varrho + t}$; of which I need give no other Demonstration, but that by a due Reduction it will so follow from what is premised, as will the Theorems for all sorts of Problems relating to the *Foci* of Optick-Glasses

APPENDIX.

An Analytical Resolution of certain Equations of the Third, Fifth, Seventh, Ninth Powers, and so on ad Infinitum, *in finite Terms, after the manner of* Cardan's *Rules for Cubicks. By Mr. A.* Moivre, *Transact.* N°. 309.

LET (n) be any Number, (y) an unknown Quantity, or Root of the Equation, (a) a Quantity altogether known, or what they call *Homogeneum Comparationis:* And let the Relation of these Quantities to each other be exprest by the Equation.

$$ny + \frac{nn-1}{2\times 3}ny^3 + \frac{nn-1}{2\times 3}\times\frac{nn-9}{4\times 5}ny^5 + \frac{nn-1}{2\times 3}\times\frac{nn-9}{4\times 5}\times\frac{nn-25}{6\times 7}ny^7, \text{ \&c.} = a.$$

Its plain from the Nature of this Series, that if n be any odd Number (that is an Integer, it matters not whether Affirmative or Negative) then the Series will Terminate, and the Equation arising will be one of the above defin'd, whose Root is

(1) $y=$

$$(1)\ y = \tfrac{1}{2}\sqrt[n]{\sqrt{1+aa}+a} - \frac{\tfrac{1}{2}}{\sqrt[n]{\sqrt{1+aa}+a}} \text{ or,}$$

$$(2)\ y = \tfrac{1}{2}\sqrt[n]{\sqrt{1+aa}+a} - \tfrac{1}{2}\sqrt[n]{\sqrt{1+aa}-a} \text{ or,}$$

$$(3)\ y = \frac{\tfrac{1}{2}}{\sqrt[n]{\sqrt{1+aa}-a}} - \tfrac{1}{2}\sqrt[n]{\sqrt{1+aa}-a} \text{ or,}$$

$$(4)\ y = \frac{\tfrac{1}{2}}{\sqrt[n]{\sqrt{1+aa}-a}} - \frac{\tfrac{1}{2}}{\sqrt[a]{\sqrt{1+aa}+a}}$$

For Example, Let the Root of this Equation of the Fifth Power be required $5y + 20y^3 + 16y^5 = 4$. in which case n is $= 5$, and $a = 4$, and the Root, according to the first Form, is

$$y = \tfrac{1}{2}\sqrt[5]{\sqrt{17}+4} - \frac{\tfrac{1}{2}}{\sqrt[5]{\sqrt{17}+4}}$$ which is Expeditiously resolved into Numbers after this manner.

$\sqrt{17}+4$ is equal to 8.1231, whose Logarithm is 0,9097164, and the fifth part of it is is 0,1819433, the Number answering it $1.5203 = \sqrt[5]{\sqrt{17}+4}$. But the Arithmetical Complement of 0.6577 is 9.8180567, the Number answering is $0.1819433 = \dfrac{1}{\sqrt[5]{\sqrt{17}+4}}$ and the half difference of these Numbers is $0{,}4313 = y$.

Here

Here we may obſerve, that in the Room of the general Root, we may advantageouſly take $y = \frac{1}{2}\sqrt[n]{2a} - \frac{\frac{1}{2}}{\sqrt[n]{2a}}$ if the quantity a be pretty large in reſpect of Unity. As if the Equation were $5y + 20y^3 + 16y^5 = 682$, the Logarithm of $2a = 3.1348143$ whoſe Fifth part is 0.6269628, the Number anſwering is 4.236, and the Number anſwering the Arithmetical Complement 9.3730372 is 0.236, the half difference of theſe Numbers is $2 = y$.

But if in the aforegoing Equation the Signs are alternately Affirmative and Negative; or which is the ſame thing if the Series be after this manner,

$$ny + \frac{1-nn}{2\times3}ny^3 + \frac{1-nn}{2\times3}\times\frac{9-nn}{4\times5}ny^5 + \frac{1-nn}{2\times3}\times\frac{9-nn}{4\times5}\times\frac{25-nn}{6\times7}ny^7 + \&c. = a.$$

The Root of it will be equal to

$$(1)\ y = \tfrac{1}{2}\sqrt[n]{a+\sqrt{aa-1}} + \frac{\frac{1}{2}}{\sqrt[n]{a+\sqrt{aa-1}}}, \text{ or}$$

$$(2)\ y = \tfrac{1}{2}\sqrt[n]{a+\sqrt{aa-1}} + \tfrac{1}{2}\sqrt[n]{a-\sqrt{aa-1}}, \text{ or}$$

$$(3)\ y = \frac{\frac{1}{2}}{\sqrt[n]{a-\sqrt{aa-1}}} + \tfrac{1}{2}\sqrt[n]{a-\sqrt{aa-1}}, \text{ or}$$

$$(4)\ y = \frac{\frac{1}{2}}{\sqrt[n]{a-\sqrt{aa-1}}} + \frac{\frac{1}{2}}{\sqrt[n]{a+\sqrt{aa-1}}}$$

Here

Here it is to be noted, that if $\frac{n-1}{2}$ be an odd Number, the Sign of the Root found must be contrary to it.

Let an Equation be propos'd $5y - 20y^3 + 16y^5 = 6$, whence $n = 5$, and $a = 6$, and the Root will be $= \frac{1}{2}\sqrt[5]{6+\sqrt{35}} + \frac{\frac{1}{2}}{\sqrt[5]{6+\sqrt{35}}}$ or because $6 + \sqrt{35} = 11.916$ whose Logarithm is 1.0761304, and its Fifth part is 0.2152261, whose Arithmetical Complement is 9.7847439. The Numbers belonging to these Logarithms are 1.6415 and 0.6091, whose half Sum is 1.1253 $= y$.

But if it happen that a is less than Unity then the Second Form, as being more convenient, ought to be pitch'd on. So if the Equation had been $5y - 20y^3 + 16y^5 = \frac{61}{64}$, then y will be $= \frac{1}{2}\sqrt[5]{\frac{61}{64} + \sqrt{\frac{-375}{4096}}} + \frac{1}{2}\sqrt[5]{\frac{61}{64} - \sqrt{\frac{-375}{4096}}}$ and if the Root of the Fifth Power can by any means be Extracted the true and possible Root of the Equation, will thence Emerge, tho' the Expression seems to insinuate an Impossibility. But the Root of the Fifth Power of the Binomial $\frac{61}{64} + \sqrt{\frac{-375}{4096}}$ is $\frac{1}{4} + \frac{1}{4}\sqrt{-15}$ and so the same Root of the Binomial.

$\frac{61}{64} + \sqrt{\frac{-375}{4096}}$ is $\frac{1}{4} - \frac{1}{4}\sqrt{-15}$ the half Sum of which Roots is $= \frac{1}{4} = y$. But

But if that Extraction can not be perform'd, or may seem too difficult, the thing may be solv'd by the help of a Table of Natural Sines, after the following manner;

To the Radius 1 let $a = \frac{61}{64} = 0{,}95112$ the Sine of some Arch which is therefore $72^\circ\ 23'$, whose Fifth part (because n is equal to 5) is $14^\circ\ 28'$ the Sine of it is $0.24981 = \frac{1}{4}$ nearly.

The same is the Method of proceeding in Equations of higher Dimensions.

A Diſcourſe concerning the Action of the Sun and Moon on Animal Bodies; and the Influence which This may have in many Diſeaſes. By Richard Mead, M. D. *F. R. S.*

PART I.

THAT ſome Diſeaſes are properly the Effects of the Influence of the Heavenly Bodies, and that others do vary their Periods and Symptoms according to the different Poſitions of one or other of thoſe Luminous Globes, is a very ancient and certain Obſervation. Upon this ſcore *Hippocrates* (a) adviſes his Son *Theſſalus* to the ſtudy of Geometry and Numbers, becauſe *the Knowledge of the Stars is of very great uſe in Phyſick* (b). And the earlieſt Hiſtories of Epidemic Diſtempers, particularly do all turn upon the alterations made in our Bodies by the Heavens.

But when in later Times Medicine came to be accommodated to the Reaſonings of Philoſophers; no body being able to account for the manner of this Celeſtial Action, It was allowed no farther ſhare in affecting our Health, than what might be imputed to the changes in the manifeſt Conſtitution of the Air, excepting perhaps ſome-

 thing

(a) *Epiſt. ad Theſſalum Filium.*
(b) Οὐκ ἐλάχιστον μέρος συμβάλλεται Ἀστρονομίη εἰς Ἰητρικήν. De Aere Aquis & Locis.

thing of Truth which still remains disguised and blended with the Jargon of Judiciary Astrology.

In order therefore to set this Matter in a little clearer light, I shall in the first place shew, That the Sun and Moon regarding their Nearness and Direction to the Earth only, besides the Effects of Heat, Moisture, *&c.* thereby caused in our Atmosphere, must at certain times make some Alterations in all Animal Bodies; then enumerate some Histories and Observations of such Changes, and enquire of what Use such Thoughts as these may be in the Practice of Physick.

It is a constant Observation of those who write the History of the *Winds*, That the most Windy Seasons of the Year, are the Time about the Vernal and Autumnal Equinox; for be the Air never so calm before or after, we never fail of having Winds at that Juncture. Every body likewise knows, that in the most quiet Weather we are sure of some Breeze at Mid-day and Midnight, as also at Full Sea, *i. e.* always about the time the Sun or Moon arrive at the Meridian. Seamen and Country People reckon upon This, and order their Affairs accordingly. And the changes of the Weather as to Winds or Calms especially about the New and Full Moon, are too well known to require any Authority to confirm such Remarks. Those who desire a fuller account of these Observations, may see it in *De Chales*'s Navigation, *Gassendus*'s Natural Philosophy, and *J. Goad*, his *Astro-Meteoro-Logica.*

These things being Matters of Fact, and in a manner Regular and Universal, it may very well seem strange that Philosophers have not been more accurate in their Enquiries into the Reason of such Appearances. True indeed it is, that the Origin of Winds is various and uncertain, but however

however, ſo conſtant and uniform an Effect muſt undoubtedly be owing to one neceſſary Cauſe.

It has bin, now a conſiderable time ſince, ſufficiently made out, that our Atmoſphere is a thin Elaſtic Fluid, one part of which gravitates upon another, and whoſe Preſſure is communicated every way in a Sphere to any given Part thereof. From hence it follows, That if by any external Cauſe the Gravity of any one part ſhou'd be taken off or diminiſhed, that from all ſides around this part, the more heavy Air would ruſh in to reſtore the Equilibrium which muſt of neceſſity be preſerved in all Fluids. Now this violent running in of the heavier Air would certainly produce a Wind, which is no more than a ſtrong Motion of the Air in ſome determined Direction. If therefore we can find any outward Cauſe that would at theſe ſtated Seaſons we have mentioned, diminiſh the Weight or Preſſure of the Atmoſphere; we ſhall have the genuine Reaſon of theſe Periodical Winds, and the neceſſary Conſequences thereof.

The Flux and Reflux of the Sea was a Phænomenon too viſible, and too much conducing to the Subſiſtance of Mankind, and all other Animals, to be neglected by thoſe who applyed themſelves to the Study of Nature; however all their Attempts to explain this Admirable Contrivance of infinite Wiſdom were unſucceſsfull, till Sir *Iſaac Newton* reveal'd to the World juſter Principles, and by a truer Philoſophy than was formerly known, ſhew'd us how by the United or Divided Forces of the Sun and Moon, which are encreaſed and leſſened by ſeveral Circumſtances, all the Varieties of the Tides are to be accounted for. And ſince all the Changes we have enumerated in the Atmoſphere do fall out at the ſame times when thoſe happen in the Ocean; and likewiſe whereas both the Waters of the Sea and the Air of our Earth, are Fluids ſubject, in a great Meaſure, to the ſame Laws of Motion; it is plain, that the Rule of our great Philoſopher takes place here, *viz. That Natural Effects of the ſame kind are owing to the ſame Cauſes.* (a)

What difference that known Property of the Air, which is not in Water, makes in the Caſe, I ſhall ſhew anon; ſetting aſide the Conſideration of that for the preſent; It is certain, That as the Sea is, ſo muſt our Air, twice every 25 Hours, be rais'd upwards to a conſiderable height, by the Attraction of the Moon coming to the Meridian; ſo that inſtead of a *Spherical*, it muſt form it ſelf into a *Spheroidal*, or *Oval* Figure, whoſe longeſt Diameter being produced, would paſs thro' the Moon. That the like Raiſing muſt follow as often as the Sun is in the Meridian of any Place, either above or below the Horizon. Moreover, That this Elevation is *greateſt* upon the New and Full Moons, becauſe both Sun and Moon do then conſpire in their Attraction; *leaſt* on the Quarters, in that they then drawing different ways, 'tis only the Difference of their Actions produces the Effect. Laſtly, That this Intumeſcence will be of a *middle degree*, at the time between the Quarters, and New and Full Moon.

From the ſame Principles, The Motion upwards of the Air will be ſtrongeſt of all about the Equinoxes; the Equinoctial Line being over that Circle of the Globe, which has the greateſt Diameter, either of the Luminaries when in that are

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(*a*) Newton, *Princip.* p. 402.

are nearer, and the Agitation of the Fluid Spheroid revolving about a greater Circle, is greater; beſides, the Centrifugal Force (ariſing from the Diurnal Rotation) is there greateſt of all. This will ſtill be more conſiderable about the New and Full Moons happening at theſe times, for the Reaſons juſt now mentioned. And the leaſt Attraction will be about the Quadratures of theſe Lunar Months, becauſe the Declination of the Moon from the Equator is then greateſt. The different diſtances of the Moon in her Perigæum and Apogæum, are the Reaſon that theſe full changes fall out a little before the Vernal, and after the Autumnal Equinox. Now the Inverſe of all this happens when the Luminaries are in the Solſtitial Circles. Laſtly, In the ſame Parallel, when the Moon's Declination is towards the Elevated Pole, the Attraction is ſtrongeſt when the Moon is in that Places Meridian, and weakeſt when ſhe is in the Oppoſite Places Meridian: The contrary happens in the Oppoſite Parallel; by reaſon of the Spheroidal Figure of the Earth and its Atmoſphere.

Whatever has been ſaid on this Head, is no more that applying what Sir *Iſaac Newton* has Demonſtrated of the Sea to our Atmoſphere; and it is needleſs to ſhew how neceſſarily thoſe Appearances, juſt now mentioned, of *Winds*, at the Stated Times, *&c.* muſt happen hereupon. It will be of more uſe to conſider the Proportion of the Forces of the two Luminaries upon the *Air*, to that which they have upon the Water of our Globe; that it may the more plainly appear what Influence the Alterations hereby made, muſt have upon the Animal Body.

Sir *Isaac Newton* has demonstrated (*a*) That the Force of the Sun to move the Sea, is to the Force of Gravity, as 1 to 12868200. Let that be

$$S.G :: 1.n. \text{ Hence, } S = \frac{G}{n}.$$

And that the Force of the Moon to raise the Sea is to Gravity, as 1 to 2031821. Let this be

$$L.G :: 1.s. \text{ Hence, } L = \frac{G}{s}.$$

And since the Centrifugal force of the Parts of the Earth arising from its Diurnal Motion is to Gravity, as 1 to 291. Let this be

$$C.G :: 1.C. \text{ Then } C = \frac{G}{e}. \quad \text{Hence,}$$

$$S + L.C :: \frac{G}{n} + \frac{G}{s}.\frac{G}{e} :: \frac{1}{n} + \frac{1}{s}.\frac{1}{e} ::$$

$$1.\frac{sn}{\overline{s+n} \times e} :: 1.\ 6031.$$

The same Philosopher has taught us (*b*) that the Centrifugal force raises the Water at the Equator above the Water at the Poles, to the height of 85200 Feet. Wherefore if that Force which is as 6031, raise the Ocean to 85200 Feet, the United forces of the Sun and Moon, which are as 1. will raise the same to 14 Feet, for $\frac{85200}{6031} = 14$. *Proximé.*

Now

(a) *Princip. Lib.* 3. *Prop.* 36.
(b) *Ibid. Lib.* 3. *Prop.* 37.

Now we know that the more eaſily the Waters can obey the Attraction, with the more Force are the Tides moved; but ſince, as Mr. *Halley* has determin'd it, (*a*) our Atmoſphere is extended to 45 Miles, whereas the middle depth of the Ocean is but about half a Mile; it is plain, that the Air revolving in a Sphere about 100 times larger than that of the Ocean, will have a proportionably greater Agitation.

Beſides, Rocks, Shelves, and the inequality of Shoars are a great ſtop to the Acceſs and Receſs of the Sea: But nothing repels the riſing Air, which is alſo of ſuch thinneſs and fluidity, that it is eaſily driven, and runs every way.

Nor ought we to omit, that it is the univerſal Law of Bodies Attracted, that the Force of Attraction is reciprocally as the Squares of their Diſtances; ſo that the Action of the Sun and Moon will be greater upon the Air than upon the Water, upon the Account of its Nearneſs.

But the Conſideration of the Elaſticity is ſtill of greater Moment here, of which this is the nature, that it is reciprocally as the Preſſure, ſo that the incumbent Weight being diminiſhed by the Attraction, the Air underneath will upon this ſcore be mightily expanded.

Theſe and ſuch like Cauſes will make the Tides in the Air to be much greater that thoſe of the Ocean; nor is it neceſſary to our purpoſe to determine, by nice Calculations, their particular Forces; it is ſufficient to have proved that theſe Motions muſt both be Univerſal, and alſo return at certain Intervals.

(a) *Philoſ. Tranſ.* N° 181.

Now since the raising of the Water of the Ocean 14 Feet, produces Torrents of such a prodigious Force, we may easily conceive what Tempests of Winds (if not otherwise check'd) the Elevation of the Air much higher (perhaps above a Mile) will necessarily cause. And there is no doubt to be made, but that the same infinitely Wise Being, who contrived the Flux and Reflux of the Sea, to secure that vast Collection of Waters from Stagnation and Corruption (which would inevitably destroy all the Animals and Vegetables on this Globe) has ordered this Ebb and Flood of the Air of our Atmosphere, with the like good design, that is to preserve (in Case all other Causes should fail, as they may, and at times do in some Countries) the sweet Freshness, and brisk Temper of this Fluid, so necessary to Life, and keep it, by a kind of continual Circulation, from Deadness and Stinking.

This Reasoning is liable to only one Objection that I know of, and that is this: That the Appearances we have mention'd cannot be owing to the Causes now assigned; since by Calculation from them, the Mercury must at New and Full Moon subside in the Barometer to a certain degree, which yet we do not observe to happen.

In answer to which, (besides that there have been some Observations made of the sinking of the Mercury at those times; and it may perhaps be the fault of the Observers that these have not been reduced to any Rule) We are to Consider, That altho' Winds and Alterations in the Pressure of the Atmosphere, are the necessary consequents of the Lunar Attraction, and true Cases of the different Rise of the Mercury in the Barometer; yet these may be produced many others ways too,

and

and therefore tho' regularly the Mercury would always fall at the New and Full Moon, thoſe other Cauſes may be ſtrong enough, even to raiſe it at thoſe Seaſons; in as much as two contrary Winds, for inſtance, blowing towards the Place of Obſervation, may accumulate the Air there, ſo as to increaſe both the height and weight of the incumbent Cylinder; in like manner, the Direction of two Winds may be ſuch, as meeting at certain Angle they may keep the Gravity of the Air in the middle place unaltered; and a Thouſand ſuch Varieties there may be, by which the Regularity of Appearances of this nature may be hindered. Now the other Springs, from which ſuch Changes in the Air may ariſe, are theſe.

1. Elaſtic Vapours forc'd from the Bowels of the Earth, by Subterraneous Heats, and condenſed by whatever cauſe in the Atmoſphere.

2. A mixture of Effluvia of different qualities in the Air, may by Rarefactions, Fermentations, *&c.* produce Winds and other Effects like thoſe reſulting from the Combination of ſome Chymical Liquors; and that ſuch things happen, we are aſſured from the Nature of Thunder, Lightning, and Meteors.

3. From the Eruptions of Vulcanoes and Earthquakes in diſtant Places, Winds may be propagated to remoter Countries.

4. The divided or United Forces of the other Planets and of Comets, may variouſly diſturb the influence of the Sun and Moon, *&c.* We know that there happen violent Tempeſts in the upper Regions of the Air, while we below enjoy a Calm; and how many Ridges of Mountains there are on our Globe, which interrupt and check the Propagation of the Winds; ſo that it is no won-

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der that the Phænomena we have ascribed to the Action of the Sun and Moon, are not always constant and uniform, and that every Effect does not hereupon follow; which, were there no other Powers in Nature able to alter the influence of this, might in a very regular and uniform manner be expected from it.

These things being premised, it will not be difficult to shew (as was proposed in the first Place) that these Changes in our Atmosphere at High Water, New and Full Moon, the Æquinoxes, &c. must occasion some Alterations in all Animal Bodies; and that from the following Considerations.

1. All living Creatures require Air of a determined Gravity to perform Respiration easily, and with Advantage; for it is by its weight that this Fluid insinuates it self into the Cavity of the Breast and Lungs. Now the Gravity, as we have proved, being lessened at these Seasons, a smaller quantity only will insinuate it self, and this must be of smaller force to comminute the Blood, and forward its Passage into the left Ventricle of the Heart, whence a slower Circulation insues, and the Secretion of Spirits is diminished.

2. This Effect will be the more sure, in that the Elasticity of the Atmosphere is likewise diminished. Animals want Air as heavy so Elastic to a certain degree; For as this is by its weight forced into the Cavity of the *Thorax* in Inspiration, so the Muscles of the *Abdomen* press it into the *Bronchi* in Expiration, where the bending force being somewhat taken off, and Springy Bodies when unbended, exerting their Power e-

very

very way, in Proportion to their Pressures, the Parts of the Air push against all the sides of the *Vesiculæ*, and promote the Passage of the Blood.

We have a convincing Instance of all this, in those who go to the top of high Mountains, for the Air is there so pure (as they call it) that is, wants so much of its Gravity and Elasticity, that they Breath with very great difficulty.

3. All the Fluids in Animals have in them a mixture of Elastic *Aura*, which when set at liberty, shews its Energy, and causes those Fermentations we observe in the Blood and Spirits: Now when the Pressure of the Atmosphere, upon the Surface of our Body is diminished, the inward Air in the Vessels must necessarity be inabled to exert its Force, in Proportion to the lessening the Gravity and Elasticity of the outward; hereupon the Juices begin to ferment, change the Union and Cohæsion of their Parts, break their Canals, *&c.*

This is very plain in living Creatures put into the Receiver, exhausted by the Air-Pump, which always swell as the Air is more and more drawn out; their Lungs at the same time contracting themselves, and falling so together as to be hardly discernible. (*a*)

E're we proceed to Matters of Fact, it may be worth the while to take Notice, That Effects depending on such Causes as these, must of necessity be most visible in Weak Bodies and Morbid Constitutions, when other Circumstances concur to their taking Place. For this reason, whatever Mischiefs do hence follow, cannot in the least

(a) *Esperienze dell' Academia del Cimento*, p. m. 113.

least disparage the Wise Contrivance of Infinite Power in ordering these Tides of our Atmosphere. The Author of Nature, we know, has made all things to the greatest Advantage that could be, for the whole System of Animals on our Globe, but it was impossible that such a disposition shou'd not in some Cases be prejudicial to a Few. The Position and Distance of the Sun are so adjusted, as to give in the most beneficial manner possible, Heat and Light to the Earth; yet this notwithstanding, some Places may be too hot for some weakly Bodies; some Autumns too sultry to agree with some Animals, and some Winters too cold to be endured by some tender Creatures: The whole however we must own, is most carefully provided for. Besides, as most of these last mentioned Inconveniencies are by easy shifts to be avoided; so there are such Powerful Checks put to this Aereal Flux and Reflux, so many ways of abating the Damages accruing from it now and then; that these are of no account in comparison of the mighty Benefits hence arising, in which the Race of Mankind does universally share.

PART II.

THERE are no Hiſtorys in Phyſick which we may more ſafely take upon the Credit of the Authors who relate 'em, than ſuch as we are now going to mention. In ſome Caſes a Point may perhaps be ſtrained to ſerve a darling Hypotheſis which the Writer has taken up, but here we are much more likely to have pure Matter of Fact, becauſe hitherto no one has pretended the Appearances of this kind to be within the Reach of any Scheme of Philoſophy.

Epileptical Diſeaſes beſides the other Difficultys with which they are attended, have this alſo ſurprizing, that in ſome the Fits do conſtantly return every New and Full Moon; *the Moon* (ſays Galen (a) *governs the Periods of Epileptic Caſes*. Upon this ſcore, They who were thus affected were called Σεληνιακοὶ *(b)* and in the Hiſtorys of the Goſpel Σεληνιαζόμενοι (*c*) by ſome of the Latins afterwards, *Lunatici* (*d*). *Bartholin* (*e*) tells a Story of one Epileptic who had apparent Spots in her Face, which according to the Time of the Moon, varyed both their Colour and Magnitude.

But

(a) Τὰς τῶν ἐπιληπτικῶν τηρεῖ περιόδους. *De Dieb. Critic. lib.* 3.
(b) *Alexand. Trallian.* lib. 1. c. 15.
(c) Matth. c. 17. v. 15.
(d) *Apuleius de Virtutib. Herbar.* cap. 6. & 95.
(e) *Anatom. Centur.* 2. H. 72.

But no greater Conſent in ſuch Caſes was perhaps ever Obſerved than what I ſaw ſome time ſince in a Child about 5 years old, in which the Convulſions were ſo ſtrong and frequent, that life was almoſt deſpair'd of, and by Evacuations and other Medicines very difficultly ſaved. The Girl, who was of a luſty full habit of Body, continued well for a few days, but was at Full Moon again ſeized with a moſt violent Fit, after which, the Diſeaſe kept its Periods conſtant and regular with the Tides; She lay always Speechleſs during the whole time of Flood, and Recovered upon the Ebb. The Father who lives by the *Thames* ſide, and does buſineſs upon the River, obſerved theſe Returns to be ſo punctual, that not only coming home He knew how the Child was before he ſaw it, but in the night has riſen to his Employ, being warned by Cries when coming out of her Fit, of the turning of the Water. This continued 14 days, that is, to the next great Change of the Moon, and then a dry Scab on the Crown of the Head, (the effect of an Epiſpaſtic Plaiſter, with which I had covered the whole *Occiput* in the beginning of the Illneſs) broke, and from the Sore, tho' there had been no ſenſible Diſcharge this way for above a Fortnight, ran a conſiderable quantity of limpid Serum; upon which, the Fits returning no more, I took great care to promote this new Evacuation by proper Applications, with deſired Succeſs, for ſome time; and when it ceaſed, beſides two or three Purges with *Mercurius Dulcis*, &c. ordered an Iſſue in the Neck, which being thought troubleſome, was made in the Arm; the Patient however has never ſince felt any Attacks of thoſe frightful Symptoms.

Whether or no it be thro' want of due Heed and Enquiry that we have not in all the Collections of Hiſtories and Caſes, any Inſtance of the like Nature ſo particular as this is, I know not; this is certain, that as the *Vertigo* is a Diſeaſe nearly related to the *Epilepſy*, and the *Hyſterical Symptoms* do partake of the ſame Nature; ſo both one and the other are frequently obſerved to obey the Lunar Influence. In like manner, the raving Fits of Mad People, which keep Lunar Periods, are generally in ſome degree Epileptic too.

Tulpius (*a*) and *Piſo* (*b*) afford us remarkable Inſtances of Periodical *Palſeys*.

Every one knows how great a ſhare the Moon has in forwarding thoſe Evacuations of the weaker Sex, which have their Name from the conſtant Regularity they keep in their Returns; and there is no queſtion to be made, but the Correſpondency we here obſerve, would be greater ſtill, and even Univerſal, did not many Accidents, and the infinite Varieties in particular Conſtitutions one way or other concur to make a difference. It is very obſervable that in Countries neareſt to the Æquator, where we have proved the Lunar Action to be ſtrongeſt; theſe Monthly Secretions are in much greater quantity than in thoſe near the Poles, where this force is weakeſt. This *Hippocrates* (*c*) takes notice of, and gives it as one Reaſon why the Women in *Scythia* are not very fruitful.

The Caſe being thus with Females, it is no wonder if we ſometimes meet with Periodical Hæmorrhages anſwering

(a) *Obſerv. Med.* lib. 1. cap. 12.
(b) *De Morb. à feroſâ Colluvie*, Obſ. 28.
(c) *De Aere Aquis & Locis.*

anſwering to the times of the Moon in Males alſo. For as a greater quantity of Blood in proportion to the bulk in *one* Sex, is the reaſon of its diſcharging it ſelf thro' proper Ducts, at certain Intervals, when the preſſure of the external Air being diminiſh'd, the internal *Aura* can exert its Elaſticity; ſo in the *other*, if at any time there happens to be a Superabundancy of the ſame Fluid, together with a weak Tone of the Fibres; it is plain that the Veſſels will be moſt eaſily burſt, when the Reſiſtance of the Atmoſphere is leaſt. And this more eſpecially, if any accidental hurt, or rarefying Force has firſt given occaſion to the other Cauſes to take effect.

I know a Gentleman of a tender frame of Body, who having once, by over reaching, ſtrained the parts about the Breaſt; fell thereupon into a ſpitting of Blood, which for a Year and half conſtantly return'd every New Moon, and decreaſing gradually, continued always 4 or 5 days. The Fits being more or leſs conſiderable, according as his management about that time, contributed to a greater or leſſer fullneſs of the Veſſels.

We have two notable Inſtances of the like nature in our Philoſophical Tranſactions; the one *(a)* of a Perſon, who from his Infancy to the 24th Year of his Age, had every full Moon an Eruption of Blood on the right ſide of the Nail of his left Thumb, at firſt to 3 or 4 Ounces, and after his ſixteenth Year, to half a Pound each time; which when by ſearing the part with a hot Iron, he ſtopp'd, he fell into a *Sputum Sanguinis*, and by frequent Bleeding, *&c.* was very difficultly

(a) N° 272.

difficultly ſaved from a Conſumption. The other (*b*) is a Story of an *Inn-Keeper* in *Ireland*, who from the 43 Year of his Life, to the 55th (in which it killed him) ſuffered a Periodical Evacuation at the point of the Fore-Finger of his Right-hand; and altho the Fits here kept not their returns ſo certain as in the forementioned Caſe, (it may be either from the irregular way of living of the Patient, or the mighty change every Effuſion made in his habit of Body, the quantity ſeldom amounting to leſs than four Pounds at a time) yet there is this remarkable Circumſtance in the Relation, that the firſt beginning of this *Hæmorrhage* was at *Eaſter*, that is, the next Full Moon after the Vernal Equinox, which is one of the two Seaſons of the Year, at which we have proved the attraction of the Air, or leſſening of its Preſſure, to be greater than at any other time whatſoever.

But we are beſides this to conſider, That the Static Chair, and nice Obſervation taught *Sanctorius*, (*b*) That *Men do increaſe a Pound or two in their weight every Month, which overplus is diſcharged at the Months end, by a Criſis of copious, or thick turbid Urine.*

It is not therefore at all ſtrange that we ſhou'd once a Month be liable to the returns of ſuch Diſtempers as depend upon a Fullneſs of the Veſſels, that theſe ſhould take place at thoſe times eſpecially, when the ambient Air is leaſt able to repreſs the Turgency; and that tho' New and Full Moon are both of equal Force, yet that ſometimes one, and ſometimes the other only ſhould Influence the Periods, according

(a) *Philoſ. Tranſ.* N° 171.
(b) *Medicin. Static.* Sect. 1. Aph. 65.

ing as this or that happens to fall in with the inward Repletion.

The Afflux of Humours to Ulcers is ſometimes manifeſtly altered by this Power ; (*a*) *Baglivi* was acquainted with a Learned Young Man at *Rome*, who labour'd under a *Fiſtula* in the *Abdomen*, penetrating to the *Colon*, which diſcharged ſo plentifully in the Increaſe, and ſo ſparingly in the Decreaſe of the Moon, that he could make a very true judgment of the Periods and Quadratures of the Planet, from the different quantity of the *Matter* that came from Him.

Nephritic Paroxyſms have frequently been obſerved to obey the Lunar Attraction : *Tulpius* (*b*) relates the Caſe of Mr. *Ainſworth*, an *Engliſh* Miniſter at *Amſterdam*, who had a Fit of the Gravel and ſuppreſſion of Urine every Full Moon, of which he found no relief till the Moon decreaſed, unleſs by Bleeding at the Arm. After his death two large Stones were taken out of his Bladder, and the *Pelvis* of the left Kidney was enlarged to that degree by the quantity of Urine ſo often ſtopt there, as to contain almoſt as much as the Bladder it ſelf.

I was preſent, not long ſince, at the Diſſection of a Child about 5 or 6 Year old, who dyed of the frequent returns of *Nephritic* Fits, attended with Vomitings and a *Diarrhæa.* The Kidneys and Ureters were quite ſtuffed with a ſlimy calculous Matter, and it was very inſtructive to ſee the different degrees of Concretion in the ſeveral parts of it, from a clear limpid Water, to a hard friable Subſtance. Dr. *Groenvelt*, who had tended

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(a) *De Experiment. circa Sanguin.* p. m. 341.

(b) *Obſervat.* Lib. 2. c. 43. *vid. etiam Obſerv.* 52.

ed the Boy in his Illness, observed him to be seized with his Pains at every Full Moon for several Months together, which generally ended with the voiding of a Stone.

What Influence the Moon has in *Asthma's*, (a) *van Helmont* takes Notice, *Exacerbatur Paroxysmus* (says he) *Lunæ Stationibus, & ævi tempestatibus quas ideo præsentit & præsagit* (b) And Sir *John Floyer*, who has given us a more particular History of this Disease than any Author, observes, that *The Fits usually return once in a Fortnight, and frequently happen near the Change of the Moon.*

'Tis a more uncommon Effect of this Attractive Power that is related by the Learned *Kerckringius.* (c) He knew a Young Gentlewoman, whose Beauty depended upon the Lunar Force, insomuch that at Full Moon she was Plump and very Handsome, but in the decrease of the Planet so Wan and ill Favoured, that she was asham'd to go abroad till the return of the New Moon gave *Fullness* to her Face, and *Attraction* to her Charms.

Tho' this is indeed no more than an Influence of the same kind, with that the Moon has always been observed to have upon Shell-Fish, and some other living Creatures. For as the old *Latin* Poet *Lucilius* says, (d)

Luna alit Ostrea & implet Echinos, Muribu' fibras
Et Pecui addit ———————

(a) *Asthma & Tuss.* § 22.
(b) *Treatise of the Asthma*, p. 17.
(c) *Observat. Anatomic.* 92.
(d) *Apud* A. Gellium, lib. 20. c. 8.

And after him *Manilius* (*a*)

Sic submersa fretris concharum & Carcere clausa,
Ad Lunæ motum variant animalia corpus.

It is very well worth the pains to enquire what share such an Alteration in the Weight and Pressure of the Atmosphere may have in the *Crises* or Changes of Acute Diseases. The Ancients made great Account of *Critical* Days, and regulated their Practice according to the Expectation they had from them; This Part of Physick is grown now into disuse, quite slighted, and even ridiculed; and that I suppose chiefly for these two reasons. In the first place, because the earliest Observations of this kind, which were drawn into Rules being made in *Eastern* Countries, when these came to be applied to the Distempers of *Northern* Regions, without allowance given for the difference of the Climate, they were oftentimes found not to answer. And secondly, Fevers of old were treated with few or no Medicines, the Motions of Nature were carefully watched, and no Violence offer'd to interrupt her Work. The Histories therefore of *Crises*, tho' of great Use, and certainty under such Management as this, were at length unavoidably set aside and lost; when Acute Cases came to be Cured, according to this or that Hypothesis, not only by Evacuations, but hot or cold Alteratives too; there being no longer any room for those Laws of Practice which supposed a regular and uniform Progress of the Distemper.

Where-

(a) *Astronomic.* lib. 2.

Wherefore, in order to underſtand a little both what might Induce the firſt Maſters of our Profeſſion to ſo nice and ſtrict an Obſervance in this point; and what grounds there may be now, for a more due regard to their Precepts, even upon the ſcore of the Lunar Attraction only, I propoſe the following Remarks.

1. All Epidemic Diſeaſes do in their regular courſe require a ſtated time, in which they come to their height, decline, and leave the Body free.

This is ſo conſtant and certain, that when a Fever of any *Conſtitution* which is *continual* in one Subject, happens from ſome other cauſe, in another to be *intermitting*, the Paroxyſms do always return ſo often as all together to make up juſt as many days of Illneſs as he ſuffers, whoſe Diſtemper goes on from beginning to end, without any abatement.

Dr. *Sydenham*, a ſworn Enemy to all Theories, learn'd thus much from downright Obſervation; and gives this reaſon why Autumnal Quartans hold ſix Months, becauſe by computation the Fits of ſo long a time amount to 336 hours, or 14 days, the period of a continual Fever of the ſame Seaſon. (*a*)

So *Galen* takes notice that when an Exquiſite Tertian is terminated in ſeven Paroxyſms, a true Continual at the ſame time has its Criſis in ſeven days; that is, the Fever laſts as long in one as in the other, in as much (ſays he) as *a Fit in an Intermitting Feaver anſwers to a day in a Continual* (*b*). Now this ſo comes to paſs, becauſe

(a) *De Feber. Intermit.* Ann. 1661. pag. *m.* 65.
(b) *Comment. in Aphor.* 59. lib. 4. & *de Criſib.* lib. 2. c. 6.

2. In these Cases there is always a Fermentation in the Blood, which goes not off till the active Particles are thrown out by those Organs of Secretion, which, according to the Laws of Motion, are most fitted to separate 'em. And

3 As different Liquors put upon a Ferment, are depurated in different times, so the Arterial Fluid takes up a determined Period, of which it is discharged of an induced Effervescence.

4. The Symptoms, during this Ebullition, do not proceed all along in the same Tenour; but on some days particularly, they give such evident Marks of their good or bad Quality, that the nature of the ensuing *Solution* may very well be guess'd at, and foretold by 'em.

Things being thus, Those days on which the Disease was so evidently terminated one way or other, might very justly be call'd the days of *Crisis*; and those upon which the tendency of Illness was discovered by most visible Tokens, the *Indices* of the *Critical Days*.

And thus far the Foundation was good, but when a false Theory happen'd unluckily to be joined to true Observations, this did a little puzzle the Cause. *Hippocrates*, it is plain, knew not to what to ascribe that remarkable regularity with which he saw the Periods of Feavers were ended on the *Seventh*, *Fourteenth*, *One and Twentieth* day, *&c.* *Pythagoras* his Philosophy was in those Ages very Famous, of which *Harmony* and the *Mysteries of Numbers* made a considerable part, *Odd* were more Powerful than *Even*, and *Seven* was the most perfect of all. Our great Physician espoused these Notions, (*a*) and confined the Stages

(a) *Epidem.* lib. 1. Sect. 3.

Stages of acute Distempers to a *Septenary* Progression (*a*), upon which this Inconvenience follow'd, that when a Crisis fell out a day sooner or later than this Computation required, his Measures were quite broken; and that this must necessarily oftentimes happen, will appear by and by.

Upon this score *Asclepiades* rejected this whole Doctrine as vain, (*b*) and *Celsus* finding it to be too nice and scrupulous, observes that the *Pythagorean Numbers led the Ancients into the Error.* (*c*)

Galen being aware of this, succeeded much better in his reasoning upon the Matter, and very happily imputed the Critical Changes not to the Power of Numbers, but to the Influence of the Moon; which he observes, *has a mighty Action upon our Earth, exceeding the other Planets, not in Energy, but in Nearness* (*d*) So that according to him, the Septenary Periods in Diseases are owing to the *Quarterly Lunar Phases, which are the times of the greatest Force, and which return in about seven days.* (*e*)

The result of the whole Affair, in short is this, A *Crisis* is no more than the Expulsion of the Morbific Matter out of the Body, thro' some or other of the Secretory Organs; in order to which, it is necessary that this should be prepar'd

 and

(a) *αἱ μὲν ἐν ἡμέρῃσι ἐπισημόταταί εἰσιν ἐν τοῖς πλείστοις αἵτε πρῶται καὶ ἑβδομαῖαι, πολλαὶ μὲν περὶ νόσων, πολλαὶ δὲ καὶ τοῖς ἐμβρύοις. de Septimestri Partu.*
(b) *Vid. Celsum* lib. 3. c. 4.
(c) *Ibid.*
(d) *De diebus Decretor.* lib. 3.
(e) *Ibid.*

and comminuted to ſuch a degree, as is requi-red to make it paſs into the Orifices of the reſpe-ctive Glands; and therefore *as* the moſt *perfect Criſis* is by *Sweat*, (both by reaſon that the Sub-cutaneous Glands do naturally diſcharge more than all the other put together, and alſo that their Ducts being the ſmalleſt of any, whatſoe-ver comes this way is certainly wery well divi-ded and broken) *ſo* the moſt *imperfect* is an *Hæmorrhage*, becauſe This is an Argument that what Offends is not fit to be caſt off in any Part, and conſequently breaks the Veſſels by the Efferve-ſcence of the Blood. An *Abſceſs* in thoſe Organs which ſeparate thick, ſlimy Juices is of a middle nature betwixt theſe two.

Now it is very plain, That if the time, in which either the Peccant Humour is prepar'd for Secre-tion, or the Fermentation of the Blood is come to its height, falls in with thoſe Changes in the Atmoſphere which diminiſh its preſſure; the *Criſis* will then be more compleat and large. And alſo, that this Work may be forwarded or de-lay'd a day, upon the account of ſuch an Altera-tion in the Air; the Diſtention of the Veſſels up-on which it depends, being hereby made more eaſie, and a weak Habit of Body in ſome Caſes ſtanding in need of this outward Aſſiſtance. Thus a Fever which requires about a Week to its Pe-riod, may ſometimes, as *Hippocrates* obſerved, have a good Criſis on the ſixth, and ſometimes not till the eighth day.

In Order therefore to make true Obſervations of this kind, the time of Invaſion is to be conſi-dered, The genuine courſe of the Diſtemper muſt firſt be watched, which is not to be interrupted by any violent Methods: The ſtrength of Na-ture in the Patient is to be conſidered, and by

what

what Secretions the Criſis is moſt likely to be performed; and it will then be found, that not only the *New* and *Full* Moons, but even the *Southings*, whether viſible or latent, of the Planet, are here of conſiderable Moment.

For Confirmation of which, we need only to reflect on what Mr. *Paſchal* has remark'd, *concerning the Motions of Diſeaſes and Births and Deaths* (*a*). Dividing the Νυχθήμερον into Four Senaries of Hours, the firſt conſiſts of three hours before the Southing of the Moon, and three after; the ſecond of the ſix hours following, and the third and fourth of the remaining Quarters of the natural day; He takes notice that none are born, or die a natural Death in the firſt and third Senaries, which he calls firſt and ſecond Tides, but all either inthe ſecond or fourth Senaries, which he calls firſt and ſecond Ebbs. In like manner, that in Agues, the tumult of the Fits generally laſts all the Tiding time, and then goes off in kindly Sweats in the Ebbs. From whence he very rationally concludes, that Motion, Vigour, Action, Strength, &c. appear moſt, and do beſt in the *Tiding Senaries*; and that Reſt, Relaxation, Decay, Diſſolution, &c. belong to the *Ebbing Senaries*.

(a) *Philoſ. Tranſact.* N° 202.

A

COROLLARY.

IT having bin explained in the Beginning of this Discourse, how those Influences of the Heavens, which favour the *Returns* of *Diseases*, may likewise raise *Winds* at the same times; and that We feel the different Effects of *These* according as other Causes do concurr to the Motion of the Air; it will not be amiss, to shew in one Instance or two, how much Natural History confirms this Reasoning.

There happened on the 26th of *November*, 1703. a little before Midnight, a most terrible *Storm* of *Wind*, the Fury of it is still fresh in every ones Mind, which lasted above six Hours.

It is not to the present purpose to relate its History and Causes; What we observe is, That the Moon was at that time *in Perigæo*, and just upon the change to *New*. Upon both which accounts its Action in raising the Atmosphere must be great; And hence indeed the *Tides* which followed were also very great,

great, and the *Mercury* in the *Barometer*, at least, in most places, fell very low.

This Influence was, without all doubt, assisted by some such other Causes of *Winds*, as we have mentioned; These we can't know, but may however take notice how much the manifest State of the Air contributed to this Calamity.

After a greater quantity of Rains than ordinary had fallen in the Summer and Autumn, in those places where the Storm was felt, the Winter came on much warmer than usual; so that the Liquor in a Thermometer, of which the 84th Degree notes Frost, never fell below the 100th. *(a)*

Hence we may very well believe, that the Atmosphere was at that time fill'd with Atoms of *Salts* and *Sulphur*, out of the Vapours raised by the Heat from the moist Earth, which being variously combined and agitated, gave that deadly force to the Motion of the Air.

A Proof of this we have not only from the frequent *Flashes* of *Lightning*, observed a little before the Storm, but also from what the Country People took notice of the next day, that the Grass and

(a) *Vid.* Philos. Transact. N 289.

and Twiggs of the Trees, in Fields remote from the Sea, tasted very salt, so that the Cattle wou'd not feed on them.

Our Histories mention another Storm, which if not equal to this last in Violence, is however thought the greatest that had then ever been known and memorable from the time at which it happened, *viz.* on the 3d of *September*, 1658. the day on which the Usurper O. *Cromwel* died.

No *Ephemerides* that I know of relate the Condition of the Air that Year, but it is sufficient to remark, That whatever other Causes concurr'd, their force was accompanied with a *Full Moon*, just before the time of the *Atumnal Equinox*.

Upon the same score it comes to pass, That in those Countries which are Subject to frequent *Inundations*, these Calamities are observed to happen at the times of the *Moon*'s greatest Influence, so that the Learned *Baccius* (*a*) has rightly enough laid the Cause of such Mischiefs upon immoderate *Tides of the Ocean*, being unhappily accompanied with

(a) *Del* Tevere, lib. 3. p. 228.

with the *attractive Force* of some or other *Stars.*

Dr. *Childrey* in his *Britannia Baconica* (*a*) has from several Instances shewn the *Lunar* Action in Damages of this kind.

Such and the like *Natural* Causes have *Storms* and *Tempests*; for as to the Question of Divine Power, whether or no Calamities of this kind do not sometimes, by the Anger of Heaven, happen out of the Course of Nature, it is not my Business to Dispute, nor would I by any means indeavour to absolve Mens Minds from the Bands of Religion. For although we must allow all the Parts of the Machine of this World to be framed and moved by Established Laws, and that the same Disposition of its Fabrick, which is most beneficial to the Whole, must of necessity, in some few Places now and then occasion Hurts and Mischiefs; it is however most highly reasonable, that we should yield to the Supreme Creator an absolute Power over all his Works; Concluding withal, that it was perhaps agreeable to Divine Wisdom, to order the Make of

(a) Pag. 97.

of the World after such a manner as might sometimes bring Mischiefs and Calamities upon Mankind, whom it was necessary by the Frights of *Storms*, *Thunder* and *Lightning* to keep in a continual Sence of their Duty.

The End.

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