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The Posthumous

WORKS

OF

Dr. Robert Hooke.

The Posthumous

WORKS

OF

ROBERT HOOKE, *M.D. S.R.S.*

Geom. Prof. Gresh. *&c.*

Containing his

Cutlerian Lectures,

AND OTHER

DISCOURSES,

Read at the MEETINGS of the Illustrious

ROYAL SOCIETY.

IN WHICH

I. The present Deficiency of NATURAL PHILOSOPHY is discoursed of, with the Methods of rendering it more certain and beneficial.

II. The Nature, Motion and Effects of LIGHT are treated of, particularly that of the *Sun* and *Comets*.

III. An Hypothetical Explication of MEMORY; how the Organs made use of by the Mind in its Operation may be Mechanically understood.

IV. An Hypothesis and Explication of the cause of GRAVITY, or GRAVITATION, MAGNETISM, *&c.*

V. Discourses of EARTHQUAKES, their *Causes* and *Effects*, and Histories of several; to which are annext, *Physical Explications* of several of the Fables in *Ovid*'s *Metamorphoses*, very different from other Mythologick Interpreters.

VI. Lectures for improving NAVIGATION and ASTRONOMY, with the Descriptions of several new and useful *Instruments* and *Contrivances*; the whole full of curious Disquisitions and Experiments.

Illustrated with SCULPTURES.

To these DISCOURSES is prefixt the AUTHOR'S LIFE, giving an Account of his Studies and Employments, with an Enumeration of the many Experiments, Instruments, Contrivances and Inventions, by him made and produc'd as Curator of Experiments to the *Royal Society*.

PUBLISH'D

By *RICHARD WALLER*, R. S. Secr.

LONDON:

Printed by SAM. SMITH and BENJ. WALFORD, (Printers to the Royal Society) at the *Princes Arms* in St. *Paul*'s Church-yard. 1705.

TO

Sir *ISAAC NEWTON*, Kt.

PRESIDENT,

And to the

Council and Fellows

OF THE

ROYAL SOCIETY

OF

LONDON,

FOR THE

Advancement of *Natural Knowledge.*

THESE

POSTHUMOUS WORKS

OF

Dr. Robert Hooke

Are humbly Dedicated

By *Richard Waller*, S. R. Secr.

THE PUBLISHER TO THE READER.

Custom having made a Preface or Epistle to the Reader almost necessary, I shall so far comply as to give some short Account of the following Treatises. The Reputation of the Author is so well establish'd, that I shall wave all that might be said upon that Head, and only desire the Reader to observe, that soon after his Decease, his Papers were, by his Relations, committed to my care to Publish what I thought might prove acceptable to the Learned, which I have endeavour'd in this Volume.

The Tracts here Publish'd are for the most part Lectures, made and read by him at several distant times upon different Subjects, which the Reader is here presented with as the Author left them; for I was unwilling to Model or Methodize them a new, by reducing the Subjects and Discourses of many Lectures into one continu'd Discourse, as his method has been in the Treatises formerly Publish'd by him in Quarto; much less have I ventur'd upon any Epitome, Abridgments too often distorting and curtailing the Author's true Sense, and disguising it so, that his own Sentiments are hard to be distinguish'd and always dubious, which Errors I have desir'd as much as possible to shun. I am sensible, by publishing his Discourses thus at large, some Recapitulations have been unavoidable, especially in Discourses of this Nature, which it is possible may disgust some nice Criticks; nevertheless I hope the Canded Reader will not find these Repetitions so many or large, as to be dissatisfy'd thereat, most, if not all of them, containing some new Matter added to what was said before.

The Subjects here handl'd are some of the most difficult in Natural Philosophy, *and the Discourses were all well accepted and approv'd of when read before competent Judges of the* Royal Society, *at their usual Meetings.*

The first contains a general Scheme or Draught of a method of advancing and promoting Natural Philosophy, *shewing its present deficiency, with the several Queries to be made, and how they may be answer'd to render it more instructive and beneficial. It must be granted the last and chief Part of this* Physical Algebra, *or* New Organ, *viz. The method of ranging the Experiments and Observations in order, so as to frame and raise* Axioms *from them is wanting (which I believe was never wrote by the Author) however I make no doubt but what is here offer'd will prove acceptable for the many curious Informations and Experiments therein contain'd.*

What follows is a Collection of several Lectures concerning the Nature of Light, *in which its Cause, Motion, Action, Velocity and Properties are largely treated of, with many new, useful and entertaining Subjects, either more copiously handled or hinted* in Transitu. *Tho' the Author has not in these Discourses treated of the several alterations and affections of the Rays of* Light *from* Reflection, Inflection, *and* Refraction, *&c.*

as his intention was to do (which is evident from several Passages in his Writings) yet the Learned will here meet with several no less difficult than curious Matters explain'd, among the rest that great Problem of Memory, *which is here at least intelligibly explicated with the Organs, necessary to perform that action of the Mind, or* Reflection, *which Organs possibly are not immaterial or incorporeal*

From this Contemplation he comes to treat of Time and Duration, shewing whence we gain the Notion of it, which he supposes from the formation of, and impressions upon sensible and coporeal Ideas, *or Images stored up in the Repository of the Brain, tho' he positively asserts the recipient and directing Power or* Soul to be a self-moving immaterial Being.

Next to this is a Physical Treatise of Comets, *proving from many Observations, that they are actually burning Bodies, with an account of the unconceivable Velocity of the motion of the Flashes or Accension of the Steames in the Blaze or Taile far surpassing those of Light'ning: To this is join'd the Author's* Hypothesis *of the cause of* Gravity, *a Subject that has hitherto puzzl'd, as well as exercis'd the most ingenious Heads. This* Hypothesis *is deduc'd from Mechanick Principles, and back'd with Experiments; to which is added a short Account of his* Hypothesis of Magnetism.

After these are many Lectures concerning the external Shell or Superfices of the Earth, *of the Cause and Original of Mountains, Vallies and Lakes. Of Fossile Shells, and other marine Remains found on the highest Hills over most part of the known World, with Historical Accounts of* Earthquakes, *fiery Eruptions, Deluges,* &c. *and a Physical Interpretation of the most antient* Mythologick Representations of Natural History. *In these Lectures the figure of the Terraqueous Globe and encompassing Air is prov'd from the diurnal Motion and Gravitation.*

Lastly, I have added some Lectures relating to the Improvement of Astronomy *and* Navigation, *wherein, tho' I cannot promise the Reader the Invention of the* Longitude, *or the like great Matters, yet I hope they will prove agreeable for the several new and useful Suggestions and Instruments therein mention'd and describ'd, with some new methods of making Observations at Land and Sea, to determine the true Meridian Latitude of the Place,* &c.

In all these Discourses I have fairly and truly given the Author's own Opinions and Reasonings in his own words, with the several times when they were read before the ROYAL SOCIETY, *when I could any way discover them.*

I could wish the Author had himself fitted these Papers for the Press in his Life time, or at least stich'd the several agreeing Subjects together, which would have prevented some Errors that possibly have happen'd in the Order and Disposition of them, for which I desire the Reader to accept this Excuse, that several of his Papers came to my Sight and Hands, when others that might better have follow'd them, were Printed off.

R. W.

THE

THE LIFE OF Dr. Robert Hooke.

UNnderſtanding that it would be acceptable to ſeveral Learned and Ingenious Perſons to have ſome publick Account given of the Life, Studies and Employments of ſo knowing and diligent an Inquirer into Nature, as Dr. *Robert Hooke* is generally allow'd to have been, and who was one of the greateſt Promoters of Experimental Natural Knowledge, as well as Ornaments of the laſt Century (ſo fruitful of great *Genii*) I could not well refuſe that Task, which (knowing my own inſufficiency for ſuch an Attempt) I could hardly undertake, being conſcious it requir'd a Perſon much better qualify'd with natural and acquir'd Abilities to perform it with Satisfaction; eſpecially in ſo judicious and nice an Age, more ready to find Faults than pardon Miſtakes: Beſides my deſire has always been not to expoſe my ſelf to Cenſure, when I might live quietly, *Studiis ignobilis otii.* But the following Papers of Dr. *Hooke* having been put into my Hands to be Publiſh'd, I was, in ſome manner, oblig'd to appear in Print. What Miſtakes the Candid Reader may obſerve, in the following Relation of his Life, I hope he will obligingly pardon. In which I profeſs the utmoſt Sincerity, the greateſt part of my Vouchers being either taken out his own Memorials, or from the Journals of the Royal Society.

Had Dr. *Hooke* proſecuted a Deſign which I find he once propoſed to himſelf, my preſent Undertaking had been as vain as needleſs, for in a ſmall Pocket-Diary of his I found theſe Words written.

'*Saturday April* the 10*th* 1697. I began this Day to write the 'Hiſtory of my own Life, wherein I will comprize as many re-'markable Paſſages, as I can now remember or collect out of ſuch 'Memorials as I have kept in Writing, or are in the Regiſters of 'the ROYAL SOCIETY; together with all my Inventions, Ex-'periments, Diſcoveries, Diſcourſes, *&c.* which I have made, the 'time when, the manner how, and means by which, with the ſuc-'ceſs and effect of them, together with the ſtate of my Health, 'my Employments and Studies, my good or bad Fortune, my 'Friends and Enemies, *&c.* all which ſhall be the truth of Matter 'of Fact, ſo far as I can be inform'd by my Memorials or my own 'Memory, which Rule I reſolve not to tranſgreſs.

Accordingly I found a beginning of his Life, which tho' it affords but little ſatisfaction, being only concerning his Childhood, yet I have here given an Abſtract of what is contained in it.

Dr. *Robert Hooke* was Born at *Freſhwater*, a Peninſula on the Weſt ſide of the Iſle of *Wight*, on the eighteenth of *July*, being *Saturday*, 1635, at twelve a Clock at Noon, and Chriſtened the twenty ſixth following by his own Father Miniſter of that Pariſh.

He was very infirm and weakly, and therefore Nurſt at Home, tho' his Brothers and Siſters were Nurſt Abroad; and for at leaſt ſeven Years his Parents had very little hopes of his Life, being often ſick; all which time his chief Food was Milk, or things made thereof, and Fruits, no Fleſh in the leaſt agreeing with his weak Conſtitution.

For his Age he was very ſprightly and active in Running, Leaping, *&c.* tho' very weak as to any robuſt Exerciſe: Was very apt to learn any thing, and after his Engliſh ſoon learnt his Grammar by Heart; but, as he ſays, with but little underſtanding, till his Father deſigning him for the Miniſtry, took ſome pains to inſtruct him. But he ſtill being often ſubject to the Head-ach which hindered his Learning, his Father laid aſide all Thoughts of breeding him a Scholar, and finding himſelf alſo grow very infirm through Age and Sickneſs, wholly neglected his farther Education, who being thus left to himſelf ſpent his time in making little mechanical 'Toys, (as he ſays) in which he was very intent, and for the Tools 'he had ſucceſsful; ſo that there was nothing he ſaw done by any 'Mechanick, but he endeavoured to imitate, and in ſome parti-'culars could exceed (which are his own words.) His Father obſerving by theſe Indications, his great inclination to Mechanicks, thought to put him Apprentice to ſome eaſy Trade (as a Watchmakers or Limners) he ſhewing moſt inclinations to thoſe or the like curious Mechanical Performances; for making uſe of ſuch Tools as he could procure, 'ſeeing an old Braſs Clock taken to pieces, 'he attemted to imitate it, and made a wooden one that would go: 'Much about the ſame time he made a ſmall Ship about a Yard 'long, fitly ſhaping it, adding its Rigging of Ropes, Pullies, Maſts, '*&c.* with a contrivance to make it fire off ſome ſmall Guns, as it 'was Sailing croſs a Haven of a pretty breadth: He had alſo a 'great fancy for drawing, having much about the ſame Age Cop-'pied ſeveral Prints with a Pen, that Mr. *Hoskins* (Son to the fa-'mous *Hoskins Cowpers* Maſter) much admired one not inſtructed 'could ſo well imitate them.

Theſe Indications of a Mechanick Genius appeared in him when very young; for by the ſame Paper I find that his Father died in *October* 1648, having for three or four Years before his Death been much afflicted with a Cough, a Palſy, Jaundice and Dropſy.

This is the ſum of what he has left of his own Writing, by which we find him at the time of his Fathers Death, to be thirteen Years and about three Months Old.

This early Propenſity of his to Mechanicks was a ſign of his future Excellency in ſuch Contrivances, and admirable Facility he afterwards manifeſted in applying Mechanical Principles to the explication of the moſt difficult *Phænomena* of Nature, and I remember it has been often obſerved by ſeveral Perſons, that whatever *apparatus* he contrived for the exhibiting any Experiment before the

ROYAL

ROYAL SOCIETY, it was performed with the leaſt Embarraſſment clearly and evidently, to explain the preſent Subject, which was a ſufficient proof of his true knowledge of the Mechanical Powers, and of a method of applying them to the Explication of Nature.

How he ſpent the next ſix or ſeven Years of his Life I have not been particularly informed; but I underſtand he was for ſome time with Sir *Peter Lely*, how long I am not certain: I ſuppoſe but a ſhort time; for I have heard that the ſmell of the Oil Colours did not agree with his Conſtitution, increaſing his Head-ach, to which he was ever too much ſubject.

It was after this that he lived with Dr. *Busby*, the late famous Maſter of *Weſtminſter-School*, as a Scholar in his own Houſe, where with more diligence he apply'd himſelf to *Latin* and *Greek*, in which he made a ſufficient proficiency for the time, and had a competent Knowledge, and at the ſame time got ſome inſight into the *Hebrew* and ſome other Oriental Languages. While he liv'd with Dr. *Buſby*, he fell ſeriouſly upon the ſtudy of the Mathematicks, the Dr. encouraging him therein, and allowing him particular times for that purpoſe. In this he took the moſt regular Method, and firſt made himſelf Maſter of *Euclide*'s Elements, and thence proceeded orderly from that ſure Baſis to the other parts of the Mathematicks, and after to the application thereof to Mechanicks, his firſt and laſt Miſtreſs.

From *Weſtminſter-School* he went to the Univerſity of *Oxford*, in 1653. but as 'tis often the Fate of Perſons great in Learning to be ſmall in other Circumſtances, his were but mean. I find that he was a Student of *Chriſt-Church*, tho' not of the Foundation, but was, as I have heard, a Servitor to one Mr. *Goodman*, and took his Degree of *Maſter of Arts* ſeveral Years after, about 1662, or 1663.

About the Year 1655, he began to ſhew himſelf to the World, and that he had not ſpent his Juvenile Years in vain; for there being a Concourſe at that time of extraordinary Perſons at *Oxford*, each of which afterwards were particularly diſtinguiſh'd for the great Light they gave the Learned World by their juſtly admired Labours; he was ſoon taken notice of, and for his Facility in Mechanick Inventions much priz'd by them.

For the proof of his being at this time brought into the acquaintance of theſe great Men, I ſhall tranſcribe ſome Paſſages which I met with among his Manuſcripts; and firſt ſpeaking of their Philoſophical Meetings at *Oxford*, he ſays,

'At theſe Meetings, which were about the Year 1655 (before 'which time I knew little of them) divers Experiments were ſug-'geſted, diſcours'd and try'd with various ſucceſſes, tho' no other 'account was taken of them but what particular Perſons perhaps 'did for the help of their own Memories; ſo that many excellent 'things have been loſt, ſome few only by the kindneſs of the Au-'thors have been ſince made publick; among theſe may be reckon'd 'the Honourable Mr. *Boyle*'s *Pneumatick Engine* and Experiments, 'firſt Printed in the Year 1660. for in 1658, or 9, I contriv'd and 'perfected the Air-pump for Mr *Boyle*, having firſt ſeen a Contri-'vance for that purpoſe made for the ſame honourable Perſon by 'Mr. *Gratorix*, which was too groſs to perform any great matter.

The

The Draught of this Air-pump and all its parts, as it was after Publiſh'd by Mr. *Boyle*, I have now by me deſign'd by Mr. *Hooke*, and I have heard him ſay, he was then ſent to *London* by Mr. *Boyle* to get the Barrel and other parts for that Engine which could not be made at *Oxford*. But to return to ſome other Notes.

'The ſame Year I contriv'd and made many trials about the Art 'of flying in the Air, and moving very ſwift on the Land and Wa-'ter, of which I ſhew'd ſeveral Deſigns to Dr. *Wilkins* then *War-'den* of *Wadham College*, and at the ſame time made a Module, 'which, by the help of Springs and Wings, rais'd and ſuſtain'd it 'ſelf in the Air; but finding by my own trials, and afterwards by 'Calculation, that the Muſcles of a Mans Body were not ſuffici-'ent to do any thing conſiderable of that kind, I apply'd my Mind 'to contrive a way to make artificial Muſcles; divers deſigns where-'of I ſhew'd alſo at the ſame time to Dr. *Wilkins*, but was in ma-'ny of my Trials fruſtrated of my expectations.

What is mention'd here of his attempts about flying, is confirm'd by ſeveral Draughts and Schemes upon Paper, of the Methods that might be attempted for that purpoſe, and of ſome contrivances for faſtening ſuccedaneous Wings, not unlike thoſe of Bats, to the Arms and Legs of a Man, as likewiſe of a Contrivance to raiſe him up by means of Horizontal Vanes plac'd a little aſlope to the Wind, which being blown round, turn'd an endleſs Screw in the Center, which help'd to move the Wings, to be manag'd by the Perſon by this means rais'd aloft: Theſe Schemes I have now by me, with ſome few Fragments relating thereto, but ſo imperfect, that I do not judge them fit for the Publick. But to return to his own Notes.

'About this time having an opportunity of acquainting my ſelf 'with Aſtronomy by the kindneſs of Dr. *Ward*, I apply'd my ſelf 'to the improving of the *Pendulum* for ſuch Obſervations, and in the 'Year 1656, or 57, I contriv'd a way to continue the motion of 'the *Pendulum*, ſo much commended by *Ricciolus* in his *Almageſtum*, 'which Dr. *Ward* had recommended to me to peruſe; I made ſome 'trials for this end, which I found to ſucced to my wiſh.

Tom. 1. *Lib.*2. *Cap.*20. & 21.

'The ſucceſs of theſe made me farther think of improving it for 'finding the Longitude, and * *the Method I had made for my ſelf for 'Mechanick Inventions*, quickly led me to the uſe of Springs inſtead 'of Gravity for the making a Body vibrate in any Poſture, where-'upon I did firſt in great, and afterwards in ſmaller Modules, ſatiſ-'fy my ſelf of the Practicableneſs of ſuch an Invention, and hop-'ing to have made great advantage thereby, I acquainted divers 'of my Friends, and particularly Mr. *Boyle*, that I was poſſeſt of 'ſuch an Invention, and crav'd their Aſſiſtance for improving the 'uſe of it to my advantage.

**I never could meet with what is mentioned here, and in ſeveral other places of his Tracts already Printed, and of thoſe contained in this Volume, of a method for Mechanick Inventions, which he ſomewhere calls a* Mechanick Algebra *for ſolving any Probleme in Mechanicks, as eaſily and certainly as any Geometrick by* Algebra, *and ſays, that by this his method he could readily determine whether any ſuch Probleme was poſſible, and if ſo, which was the neareſt and eaſieſt way of ſolving it.*

'Immediately after his *Majeſty*'s Reſtoration, Mr. *Boyle* was plea-'ſed to acquaint the Lord *Brouncher* and Sir *Robert Moray* with it, 'who advis'd me to get a Patent for the Invention, and propoun-'ded very probable ways of making conſiderable advantage by it. 'To induce them to a belief of my performance, I ſhew'd a Pocket-

'watch,

‘ watch, accommodated with a Spring, apply'd to the Arbor of ‘ the Ballance to regulate the motion thereof; concealing the way ‘ I had for finding the Longitude; this was so well approv'd of, ‘ that Sir *Robert Moray* drew me up the form of a Patent, the prin- ‘ cipal part whereof, *viz.* the description of the Watch, so regulat- ‘ ed, is his own hand Writing, which I have yet by me, the dis- ‘ couragement I met with in the management of this Affair, made ‘ me desist for that time.

So far this Paper. In confirmation of what is abovesaid, I met with a Draught of an Agreement between the Lord *Brouncher*, Mr. *Boyle*, and Sir *Robert Moray*, with *Robert Hooke* Master of Arts to this purpose, that *Robert Hooke* should discover to them the whole of his Invention to measure the parts of Time at Sea as exactly and truly as they are at Land by the *Pendulum* Clocks invented by Monsieur *Huygens*; That of the Profits to be made thereby not exceeding 6000 *l. Robert Hooke* was to have $\frac{3}{4}$ of whatever was made more of it, not exceeding 4000 *l. Robert Hooke* was to have $\frac{2}{3}$ of the rest, if more could be made of it, he was to have the $\frac{1}{2}$, and *Robert Hooke* to be publickly owned the Author and Inventor thereof. This is the sum of one Draught; there are indeed some others which differ only in the division of the Profits, which it is needless here to trouble the Reader with. In pursuance of this Design there were several Papers drawn up, *viz.* The Draught of an Act of Parliament to oblige all Masters of Ships to pay so much *per* Tun for the use of this Invention, as also of a Warrant to be granted by the *King* to *Robert Hooke*, *M. A.* &c. for a Patent for the sole use of the said Invention for fourteen Years, and sign'd by His Majesty's Command, *William Morrice*. I have some other Papers which are unnecessary to be here mention'd.

Thus far the Matter then proceeded, and how it came to stop here may be justly wondred; but to give the Reader the best satisfaction I can in this matter, I shall transcribe a Paragraph out of the Postcript to *Hooke*'s Treatise of *Helioscopes* Printed 1676. *Pag.* 27.

‘ This Treaty with me had been finally concluded for several ‘ Thousand Pounds, had not the inserting of one Clause broke it ‘ off, which was, *That if after I had discover'd my Invention about ‘ the finding the Longitude by Watches (tho' in themselves sufficient) they, ‘ or any other Person should find a way of improving my Principles, he or ‘ they should have the benefit thereof during the term of the Patent, and ‘ not I.* To which Clause I could no ways agree, knowing 'twas ‘ easy to vary my Principles an hundred ways; and 'twas not im- ‘ probable, but there might be some addition of conveniency to ‘ what I should at first discover, it being *facile inventis addere*; and ‘ judging it unreasonable to be depriv'd of the benefit of my In- ‘ ventions, in themselves sufficient, because others might vary ‘ them, or any other ways improve them, of which it was very ‘ probable they would have no thought if they had not the advan- ‘ tage of being instructed by my Discovery, it having been hid ‘ some Thousands of Years already; as indeed the effect hath made ‘ evident and certain, there having been nothing done by any Bo- ‘ dy else upon that matter ever since.

There is more in the same place worth the perusal, which, for brevity, I omit.

Dr. *Hooke* ſuffering this Invention to lie undiſcover'd to the laſt, gave ſomePerſons cauſe to queſtion whether he was ever Poſſeſſor of it, and to doubt whether what in Theory ſeem'd very promiſing, wou'd anſwer when put to the Teſt of Practice; others indeed more ſeverely judged, that it was only a kind of boaſting in him, to aſſert he knew that which had not yet been perform'd, tho' attempted by many. However the matter is, it is certain he perſiſted in the affirmation to the laſt, and not many Weeks before his Death, told me and other Perſons, that he knew a certain and infallible method to deſcover the true place of a Veſſel at Sea, as to its Eaſt and Weſt diſtance from the Port departed from: Whether by Watches, or other Time-keepers, or by any other ways, I know not, tho' indeed by what is before mention'd, it ſhould ſeem to be by Watches, for the improvement of which he made many Trials, and read ſeveral Diſcourſes.

However this matter produc'd the diſcovery of that moſt uſeful and practicable method of regulating Pocket-watches by a ſpiral Spring, apply'd to the Arbor of the Ballance as they are now made without any conſiderable addition ſince; the Hiſtory of which, as I have heard it from himſelf and find publiſh'd, is thus.

In Diſcourſe once he told me, that aboutthe Year 1660. he having ſhewn a Movement ſo regulated to the Lord *Brouncher*, &c. as is above related, Monſieur *Huygens* having for ſome time apply'd himſelf to invent ſeveral ways to regulate Time-keepers by the correſpondence he held with Mr. *Oldenburgh*, among other matters had notice of this, for which there was afterwards an application made to procure a Patent. This indeed is poſſible, but whether it were ſo or not I cannot determine. That Mr. *Hooke* had many Years before (*Huygens* mention'd it) diſcover'd the Invention is certain, by what is related in the Hiſtory of the ROYAL SOCIETY among ſeveral new Inventions, in theſe words, *There have been invented ſeveral*
Pag. 247. *kinds of Pendulum Watches for the Pocket, wherein the motion is regulated by Springs*, &c.

Now tho' this does not mention the Springs being ſpiral or faſtened to the Arbor of the Ballance, yet it appears it was ſo by what is related above, and a Paſſage I have ſeen in a Leter from Sir *Robert Moray* to Mr. *Oldenburgh*, dated *Oxon Sept.* 30. 1665. clears it, in which are theſe words. ' You (meaning *Oldenburgh*) will be ' the firſt that knows when his (that is *Hugyens*'s) Watches will be ' ready, and I will therefore expect from you an account of them, ' and if he imparts to you what he does, let me know it; to that ' purpoſe you may ask him if he doth not *apply a Spring to the Arbor* ' *of the Ballance*, and that will give him occaſion to ſay ſomewhat ' to you; if it be that, you may tell him what *Hooke has done in* ' *that matter, and what he intends more.* Altho' I cannot be aſſur'd what *Oldenburgh* wrote to Monſieur *Huygens*, yet it is probable their intimacy procur'd what he knew; and it is evident that *Huygens*'s diſcovery of this was firſt publiſh'd in the *Journal des Scavans*, and from thence in the Philoſ. Tranſact. for *March* 25th. 1675, about ten Years after that Letter of Sir *Robert Morays*, and near fifteen after *Hooke*'s firſt diſcovery of it.

To this I ſhall add what Mr. *Oldenburgh* has Printed, *Philoſ. Tranſact.* N°. 118. ' 'Tis certain the deſcriber of Helioſcopes (mean- ' ing *Hooke*) ſome Years ago caus'd to be actually made ſome

' Watches

' Watches of this kind; which (indeed he there ſays) were unſucceſsful. Which whether ſo or not, I cannot learn, ſo many Years after; tho' I am inclin'd to think that Expreſſion proceeded from Paſſion, the Invention and Principle of *Hooke*'s and *Huygens*'s being both the very ſame as are now us'd.

To this of Mr. *Oldenburgh*, Mr. *Hooke* made his Reply in a Poſtſcript to his *Lampas*: In rejoinder to which *Oldenburg* Printed a Declaration of the Council of the ROYAL SOCIETY, to teſtify his faithfulneſs in managing the Correſpondence of the Society; but it is obſervable that in this place there is no contradiction to *Hooke*'s being the firſt in that Invention. *Philoſ. Tranſ. N°. 129. p. 749.*

It cannot be deny'd but that Mr. *Hooke* was frequently deſir'd to perfect his Inventions about Watches and Time-keepers, which, when urg'd, he as often promis'd, and when any new Contrivance was by any Perſon produc'd, he then ſhew'd ſomething of his own, either the ſame, or excelling it, a Proof he had try'd the ſame before. ' Particularly when on the *9th* of *Auguſt* 1666. Mr. *Mercator* ſhew'd to the Society a Watch of his Invention, repreſenting the Æquation of Time to the approbation of the Company. ' Mr. *Hooke* at the ſame time produc'd a new piece of Watchwork of his own Contrivance to meaſure Time exactly both at Sea and Land, of which he was deſir'd to bring in the Deſcription, which, tho' promis'd, was, as I think, never done. *Journal R. Soc.*

It muſt be confeſs'd that very many of his Inventions were never brought to the perfection they were capable of, nor put in practice till ſome other Perſon either Foreigner or of our own Nation cultivated the Invention, which, when *Hooke* found, it put him upon the finiſhing that which otherwiſe poſſibly might have lain 'till this time in its firſt Defects: Whether this miſtake aroſe from the multiplicity of his Buſineſs which did not allow him a ſufficient time, or from the fertility of his Invention which hurry'd him on, in the queſt of new Entertainments, neglecting the former Diſcoveries when he was once ſatisfied of the feazableneſs and certainty of them, tho' there wanted ſome ſmall matter to render their uſe more practicable and general, I know not, and whether this was the Caſe in the preſent Subject: But this I ſuppoſe may be an undoubted Truth, the ſpiral Springs were not apply'd generally to regulate Watches, 'till after this Diſpute with *Huygens*.

I have been the more particular in this matter, that I Might, as far as I was able, aſſert the Invention to the true Author, and ſuppoſe I have wrong'd no Perſon. They that require more of this Subject may conſult the Philoſophical Tranſactions, and *Hooke*'s Tracts in the places before quoted: I have in this brought all that relates to this Queſtion together, that the Reader may the better underſtand the whole matter, tho' thereby I have diſorder'd the ſeries of his Life, and order of Time.

But to return (from this Digreſſion, which, to make it more plain, I have enlarg'd upon) to *Oxford*, I find that 1655, or 6 there were many curious Experiments, Obſervations and Inquiries made, and Inſtruments for thoſe purpoſes contriv'd, as particularly the *Barometer*, of which he ſays, the firſt occaſion of the Invention was a Suggeſtion of Sir *Ch. Wren* in order to find whether the Hypotheſis of *Des Cartes* for giving the Reaſon of the Tides from the preſſure of the

the Moon upon the Air in its passage by the Meridian, were true or not. At this time I have heard Mr. *Hooke* say, it was first observ'd, that the height of the *Mercury* in the *Barometer* did not conform itself to the Moon's motion, but to that of the different Gravitation of the Air, as has been since sufficiently verified. Yet in a *French* Treatise Printed at *Paris*, several Years after this Observation at *Oxford*, the discovery of the Gravitation of the Air is attributed to Monsieur *Pascal* deduced from several Experiments, made about the Year 1650. at *Clermont* in *Auvergne* by Monsieur *Perier*, at *Paris* by others: And at *Stockholm* by Messeures *Des Cartes* and *Chanute*; which if it be, as is there related, and the Inferences from that Experiment such as are in the same Tract mentioned, 'tis strange they should not have been apply'd to the use of so beneficial an Instrument sooner, which I do not find it was till after this Observation at *Oxford*.

Traitez de l' Equilibre de-liqueurs, &c. 1664.

By the persuasion of Dr. *Seth Ward*, afterwards Bishop of *Salisbury*, about 1656, he apply'd himself more particularly to the Study of Astronomy, and about 58, or 59, he says thus, ' I contriv'd several Astronomical Instruments for making Observations both at ' Sea and Land, which I afterwards produc'd before the ROYAL ' SOCIETY.

Some of these, I suppose, are the Instruments hereafter mention'd in his Astronomical Lectures, where I have endeavour'd to retrieve as many as I could, partly from some rough Draughts, partly from old Modules, and some from the verbal Descriptions where both those helps were wanting; in which how I have succeeded, is left to the candid Readers Judgment.

Vide p. 500. &c. *infra.*

' Much about this time (as he says) he contriv'd the *Circular Pen-* ' *dulum*, and the use of it for continuing the motion of another *Pendulum*, which he afterwards shew'd to the ROYAL SOCIETY in 1663; about which time, and afterwards, there are several particulars relating to the *Circular Pendulum* enter'd in the Journals as his: A Movement to this purpose; is describ'd in his *Animadversions* on *Machina Cælestis*, pag. 68. Printed 1674.

In the Year 1660. the most Illustrious ROYAL SOCIETY was founded, for a full account of which, and its Institution, the Reader is referred to the Right Reverend and Learned, Dr. *Sprat*'s History thereof, Publish'd 1667. I shall only observe the Occasion and Time when Mr. *Hooke* was introduc'd into their Service as *Curator*. Soon after the beginning of the ROYAL SOCIETY, *viz.* about *April* 1661. a Debate arose in the Society, occasion'd by a small Tract Printed in 1660. about the cause of the rising of Water in slender Glass Pipes, higher than in larger, and that in a certain proportion to their Bores; this Discourse was wrote and Publish'd by *Hooke*; the Explication of which difficult *Phænomenon* made him the more regarded. The sum of his Reasonings upon this Subject he Publish'd afterward, *Micrography Observ.* the 6th. in which there are several very curious and then new Remarks and Hints; as to the Nature of Fluidity and Gravity, which last is farther prosecuted in his Treatise of Springs, with other excellent Subjects, to which the Inquisitive are referr'd for a more ample satisfaction.

This,

This, together with his former Performances, made him much respected by the *R. Society*, and on the fifth of *November* 1662. ‘ Sir ‘ *Robert Moray* propos'd a Person that was willing to be entertain'd ‘ as a *Curator* by the *Society*, offering to furnish them every day ‘ when they met, with three or four considerable Experiments; ‘ which Proposition was unanimously receiv'd, Mr. *Hooke* being ‘ nam'd to be the Person; and accordingly the next Day of their ‘ meeting on the twelfth of *November* he was unanimously accep- ‘ ted and taken as *Curator*, with the Thanks of the *Society* order'd ‘ to Mr. *Boyle* for dispensing with him for their use, and order'd ‘ that Mr. *Hooke* should come and sit among them, and both bring ‘ in every Day three or four of his own Experiments, and take care ‘ of such others as should be recommended to him by the *So-* ‘ *ciety*.

From this time the *Societies* Journals gave sufficient Testimonials of his Performances, all which would be too many to particularize here, therefore I shall only touch upon some of the chief, as the Experiment of breaking Glass-Bubbles inward, the Air contain'd in them being rarify'd by heat in their blowing, and so hermetically sealing them whilst hot; which Bubbles were observ'd at a certain degree of Tension, both in the distending them whilst blowing, and in their contracting as they cool'd, to yield a smart sound, several of these in cooling would break inwards with a brisk noise, tho' others broak without any noise, upon which the Experimenter made several Remarks.

Many Experiments were made to explicate the Nature and Quality of the Air, *viz.* as to its Gravitation, its different Effects when Rarify'd, Condens'd and Natural, with its use as to the Life of Animals, and maintaining a lucid Flame, or cause the Dissolution of Bodies by Fire, a live Animal and Lamp being inclosed together in a Receiver, shew'd the *Pabulum vitæ* and *flammæ* to be much the same: At which time also he try'd how long the same Air would serve for breathing. This leads me to remember that noble Experiment made by him of keeping a Dog alive, his *Thorax* being laid open, by blowing fresh Air into his Lungs, of which a particular Account is given in the History of the Royal Society, pag. 232. which plainly shews the use of the Air, and difference between venal and arterial Blood.

He shew'd what addition of weight is given to Fluids, by ascending and descending Bodies in them. The different Specifick weight of Hot and Cold Water, with the uses to be made thereof in heating large quantities of Water. Of the difference of Ice and Water, with the Refraction of other Fluids, by an Instrument describ'd in the Preface to his Micrography.

Experiments and a Contrivance to shew the Force and Velocity of Bodies falling from several heights, weighing Bodies at several heights. *Pendulums* of two hundred Foot long. The difference of the *Barometer* at several heights. Experiments to improve Land Carriage. Methods of conveying secret and quick Intelligence.

Instruments to measure time exactly. To observe a second Minute by the Sun or Stars. To try the strength of Gun-power, and several others, particularly an Engine to cut down the Teeth of Watch Wheels more exactly than can be done by the most expert Hand, an Invention now of constant use.

About this time he fix'd the Standard for the *Thermometer* from the Point of Freezing; and contriv'd a way to make the motions of the *Barometer* more ſenſible, which is ſince with farther Improvements, Publiſh'd in the *Philoſoph. Tranſact.* N°. 185. p. 241.

In *Feb.* 166¾. he contriv'd a way to ſupply freſh Air to the Urinator under the Diving Bell by a Chain of Buckets and a Leaden Box for his Head, when he went out of the Bell to be ſupply'd with freſh Air from the Bell, *&c.*

At this time he ſhew'd Experiments of the dilating of Glaſs and other Bodies by Heat.

In *July* 1664. he produc'd an Experement to ſhew the number of Vibrations of an extended String, made in a determinate time, requiſite to give a certain Tone or Note, by which it was found that a Wire making two hundred ſeventy two vibrations in one Second of Time, ſounded *G Sol Re Ut* in the Scale of all Muſick. Other Experiments were made of the diviſion of a Monochord, which I omit.

Philoſ. Tranſ. N°. 9. p. 147. & N°. 24. p. 439.

About this time many Experiments were made of the Velocity of Bodies ſinking and riſing in Water, in order to aſcertain that Contrivance, which was after made publick, of ſounding the Seas depth with the ſounding Ball, which is too well known to inſiſt on it.

At ſeveral Meetings of the *Society* in 1663, and 4. he produc'd his Microſcopial Obſervations, and read the Explications and Diſcourſes made upon them, which were after publiſh'd in his *Micrographia*, at the beginning of the Year 1665. In which Book, I ſuppoſe, it will hardly be deny'd, that there are more excellent Philoſophical Diſcoveries and Hints, that in moſt extant of its bulk: The Book itſelf being well known, I ſhall only obſerve that there are deſcrib'd in it ſeveral ſorts of Microſcopes, with the ways of uſing them. The Baroſcope, Hygroſcope, an Inſtrument to graduate Thermometers, an Engine to grind Optick-glaſſes, an Inſtrument to meaſure the Refraction of Liquors, *&c.* I remember Mr. *Marſhal* when he deſir'd the *Societies* Approbation of his new Method of grinding Spectacles and other Optick-glaſſes, own'd he had the firſt intimation of it from a hint of Mr. *Hooke*'s in this Book about the Poliſhing many very ſmall Microſcope Object-glaſſes at once.

A more particular Account of this Book is extant in the *Philoſoph. Tranſact.* N° 2. p. 29. and to ſhew the Eſteem Foreigners had of it, I ſhall refer the Reader to the account given of it in the *Journal des Scavans* for the Month of *December* 1666. In this the Journaliſt ſpeaks with great Reſpect of the Author, and Eſteem for the Work itſelf, obſerving the vaſt number of curious Remarks made therein concerning the improvement of the other Senſes, as well as that of ſeeing: Obſervations of Colours and Light, the Moon, Stars, Reflexion, Inflection, *&c.* concluding after (having mention'd ſeveral) that the Book contains more than can be taken notice of in an Extract.

In the beginning of *June* 1664. Sir *John Cutler* having intimated his Deſign to ſome Members of the *Society* of founding a Mechanick Lecture, with a Yearly Gratuity of fifty Pounds, on the twenty ſecond of the ſame Month ſeveral Members met to confer about the manner of ſetling that Lecture, and on the ninth of *November* following, it is enter'd in the Journals to this purpoſe; 'Sir

'*John*

'*John Cutler* having founded a Lecture, and settl'd an Annual Sti-
'pend upon *Robert Hooke*, M. A. of fifty Pounds during Life (en-
'trusting the President, Council and Fellows of the said *Society* to
'direct and appoint the said Mr. *Hooke* as to the Subject and Number
'of his Lectures) the *Society* order'd several of their Members to
'wait upon Sir *John Cutler*, with their Thanks for his particular
'Favour to a worthy Member, and for that Respect and Confidence
'he hath hereby exprest towards their whole Body, *&c.*

'On the twenty seventh of *June* 1664. it was voted that at the
'first Opportunity Mr. *Hooke* should be put to the Scrutiny for
'the *Curators* place by Office; on the twenty third of *November*
'following he was propos'd as a *Setled Curator* of Experiments;
'and on the eleventh of *Jan.* 1664. elected and made *Curator by Of-*
'*fice* for Life, with an additional Salary to Sir *John Cutler*'s Annu-
'ity.

At this time he read several Astronomical Lectures, some of which are publish'd in this Volume, and invented many Instruments, particularly his Quadrant with a Roler on the Limb; an Instrument to measure the Velocity of the Wind, and repeated the Experiment of the Vibrations of a Pendule two hundred Foot long. The first proposal for the Weather-Clock was then offer'd upon the Description of one made by Sir *Christopher Wren*. The Experiment was made and account given of the suspension of the Mercury to seventy five Inches in the Tube, which, with some additions, is Printed in this Volume. From this time he brought in almost at every Meeting Experiments, Observations, Schemes of new Instruments and Inventions, or something considerable to the advancement of Knowledge, and very frequently read his *Cutlerian* Lectures, of many whereof he publish'd, the most material parts in his Tracts Printed at different times, in Quarto, call'd *Lectures and Collections*, &c. comprizing compendiously in one continu'd Discourse, the chief Matters and Subjects handled in several Lectures.

Thus the generous Ardor with which the ROYAL SOCIETY was inspir'd, continu'd 'till the Year 1665. when, by reason of the great Mortaity then reigning, they were oblig'd to desist and break up their Weekly Meetings till the fourteenth of *March* 166⅚. when, upon Summons, they met again. In this Interim the Members retir'd to several Places in the Country, and Mr. *Hooke* attended Dr. *Wilkins*, and some other ingenious Gentlemen into *Surry*, near *Banstead Downs*, where several Experiments were made during this Recess, an account of which was after brought into the *Society*.

At some of the first Meetings, after they came together again,
'Mr. *Hooke* produc'd a very small Quadrant for observing accu-
'rately to Minutes and Seconds, it had an Arm moving on it by
'means of a Screw lying on the Limb of the Quadrant; this is
all the account I find of it. Possibly this was the first ever made after that manner, tho' it is now sufficiently known and practis'd: A large one of this sort, and of all its parts, with the rest of the *apparatus* and manner of using it, is at large publish'd by the Inventor, *Anno* 1674. in his Animadversions on *Hevelius*'s *Machina Cælestis*, pag. 54. in which Book also several other ingenious Contrivances, Instruments and Inventions are mention'd.

'*May*

Journal R. S. ‘ *May* 23d. 1666. There was read a Paper of Mr. *Hooke*'s explicating the Inflexion of a direct motion into a Curve, by a supervening, attractive Principle, which was order'd to be Register'd. The Discourse contain'd therein is an Introduction to an Experiment to shew that Circular Motion, is compounded of an indeavour by a direct motion by the Tangent, and of another indeavour tending to the Center: To which purpose there was a *Pendulum* fastened to the Roof of the Room with a large wooden Ball of *Lignum Vitæ* on the end of it; and it was found, that if the *Impetus* of the indeavour by the Tangent, at the first setting out, was stronger than the indeavour to the Center, there was generated such an Elliptical Motion, whose longest Diameter was parallel to the direct indeavour of the Body at the first Impulse: But if that *Impetus* were weaker than that indeavour to the Center, there was generated such an Elliptical Motion, whose shorter Diameter was parallel to the direct indeavour of the Body in the first point of the Impulse; if both were equal there was made a perfect Circular Motion. There was also made another Experiment, by fastening another Pendulous Body by a short String on the lower part of the Wire, by which the greater weight was suspended, that it might freely make a Circular or Elliptical Motion round the bigger, whilst the bigger mov'd Circularly or Elliptically about the first Center. The intention whereof was to explicate the manner of the Moons motion about the Earth, it appearing evidently thereby, that neither the bigger Ball, which represented the Earth, nor the less which represented the Moon, were mov'd in so perfect a Circle or Ellipsis, as otherwise they would have been, if either of them had been suspended and mov'd singly: But that a certain Point which seem'd to be the Center of Gravity of the two Bodies (howsoever posited and consider'd as one) seem'd to be regularly mov'd, in such a Circle or Ellipsis, the two Balls having other perculiar motions in small Epicicles about the said Point.

‘ *Aug.* 1st. 1666. he read his Observations of the Comet in 1664. after Printed among his Tracts, and call'd *Cometa.* The same produc'd a certain Contrivance to shew that the Circular Pendulum was made of two strait Lines crossing each other, *&c.* and about the same time his Instrument to take the distance of the Stars from the Moon, the one Object seen direct, the other by Reflexion, this is publish'd in his Book, pag. 503.

The dreadful Conflagration of a great part of the City of *London* happening in the beginning of *September* 1666. brought another great hindrance to the *Societies* Proceedings; so that they were oblig'd to remove their usual place of Meeting from *Gresham College* to *Arundel* House in the *Strand*, where, by the favour of the then Duke of *Norfolk*, they prosecuted their former Inquiries, their first Meeting at *Arundel* House being on the ninth of *Jan.* 166⁷.

‘ On the nineteenth of *Sep.* 1666. he produc'd a Module he had design'd for the Rebuilding of the City, with which the *Society* were very well pleas'd, and Sir *John Laurence* the then late *Lord Major*, address'd himself to the *Society*, expressing the present *Lord Majors and Aldermens* liking thereof, as also their desire that it might be shewn to his *Majesty*, they preferring it far before the Model drawn up by the City Surveyor.

What

What this Model was, I cannot ſo well determine, but I have heard that it was deſign'd in it to have all the chief Streets as from *Leaden-Hall* corner to *Newgate*, and the like, to lie in an exact ſtrait Line, and all the other croſs Streets turning out of them at right Angles, all the Churches, publick Buildings, Market-places, and the like, in proper and convenient places, which, no doubt, would have added much to the Beauty and Symmetry of the whole. How this came not to be accepted of I know not, but it is probable this might contribute not a little to his being taken notice off by the Magiſtrates of the City, and ſoon after made Surveyor.

The Rebuilding of the City, according to the Act of Parliament, requiring an able Perſon to ſet out the Ground to the ſeveral Proprietors, Mr. *Hooke* was pitch'd upon, and appointed *City-Surveyor* for that difficult Work, which being very great, took up a large proportion of his Time, to the no ſmall hindrance of his Philoſophical Diſquiſitions.

In this Employment he got the moſt part of that Eſtate he died poſſeſſed of, as was evident by a large Iron Cheſt of Money found after his Death, which had been lock'd down with the Key in it, with a date of the Time, by which it appear'd to have been ſo ſhut up for above thirty Years: In this was contain'd the greateſt part of what he left behind him, which was to the value of many thouſands in Gold and Silver. That he might by this place juſtly acquire a conſiderable Eſtate, I think cannot be deny'd, every particular Perſon after the Fire being in haſte to have his concerns expedited; ſo that as I have been inform'd he had no Reſt early and late from Perſons ſoliciting to have their Grounds ſet out, which, without any Fraud or Injuſtice, deſerv'd a due recompence in ſo fatiguing an Employ.

Oct. 31. 1666. He ſhew'd his inclineing *Pendulum*, with the uſes thereof, to regulate the motions of a Clock as exactly as a long one.

On the 9th of *Jan.* 1669. he was order'd to proſecute his Obſervations of the Earth's *Paralax* formerly by him propos'd: A large Account of the Reſult of his Obſervations therein were after Printed in his *Attempt to prove the motion of the Earth* 1674, being the firſt of his *Cutlerian* Lectures Publiſh'd.

On the 6th of *Feb.* following, he produc'd his new *Lamp* contriv'd ſo as to ſupply the Oil in equal quantity as it waſtes, that it may never riſe too much or too little, the farther Deſcription and Explication of which, with many curious Remarks, were Publiſh'd 1677. and intitl'd *Lampas*, or *Deſcriptions of ſome Improvements of Lamps and Water-poiſes*, &c.

Feb. the 28th. He firſt produc'd his *Reflecting Teleſcope*, which is deſcrib'd with the Reaſon of the Principle, with ſome other Inſtruments in his Treatiſe of *Helioſcopes*, Printed 1676.

On the 17th of *June* 1667. and afterwards he read large Diſcourſes of the Cauſes, Powers and Effects of *Earthquakes*, affirming the great Hills and Mountains in the World to have been raiſed by them, of which Subject he at ſeveral times afterwards made very many Diſcourſes and Lectures, the moſt part of which are collected together in this Volume, beginning at Page 279.

In *July* 1667. he try'd ſeveral Experiments upon himſelf in an *exhauſted Receiver*, big enough to contain a Man, I think the only Experiment of that kind ever try'd.

At this time he contriv'd a *Micrometer* of leſs Charge and Difficuly than that invented by Mr. *Gaſcoin* with Screws; this, I ſuppoſe, is Publiſh'd in this Volume, Page 498.

Dec. 26. 1667. He brought in a farther Deſcription of a *Sea Barometer.*

Jan. the 16th 166$^{7}_{8}$. he produc'd 'his new Contrivance of promoting the Vibrations of Pendules, ſo as to prevent all Checks, which 'he affirmed had not been provided againſt by any Contrivance to 'that time.

Apr. 9. 1668. He produc'd two Inſtruments to promote the ſenſe of Hearing.

May the 14th He ſhew'd an Experiment of the penetration of Liquors in Oil of Vitriol and fair Water.

About this time he produc'd many other Experiments and Inventions, which I omit, and ſhall only obſerve, that there being ſeveral Diſcourſes about the meaſuring a of Degree of the Earth, he propos'd divers Methods of performing it, and invented ſeveral Inſtruments; and as is enter'd in the Journal, *Oct.* 28. 1669. Mr. *Hooke* was of Opinion, *That one of the exacteſt ways of meaſuring, was by making accurate Obſervations of the Heavens to a ſecond, by a Perpendicular Tube, and then to take exact diſtances by Angles to a ſecond alſo*, which I take to be the Method obſerv'd by the *French* not long after, as may be ſeen by a particular Treatiſe of it Publiſh'd by Monſieur *Picart*, as likewiſe by what *Duhamel* ſays in his Hiſtory of that Society, p. 98. to which the curious are refer'd. I find alſo by ſome Notices and looſe Papers of our Curator, that he invented a ſort of travelling Caleſh for this purpoſe, which ſhould deſcribe upon a Paper, not only the Menſuration of the way gone over, but the ſeveral Aſcents and Deſcents, together with the turnings and windings of the Caleſh, or the Points of the Compaſs upon which the Perſon travell'd with other Contrivances, which I know not by what misfortune, were never put in practiſe. There were alſo other Methods for meaſuring a Degree propos'd to be made in St. *James*'s Park on the Canal, which alſo had the like fate of not being proſecuted.

In *Jan* 166$^{7}_{0}$. He firſt propos'd a drop of Mercury for an univerſal Standard, which is more at large deſcrib'd, Page 472. of the following Volume. And in *April* ſhew'd an Experiment with a ſolution of Copper to repreſent the appearance of Clouds and other aerial Meteors, by dropping into it ſeveral Salts, *&c.* and at the ſame time ſhew'd the uſe of introducing the Species into a dark Room for Painting, and contriv'd a Box for that purpoſe, which is here Printed.

In *March* 1671. 'he ſhew'd ſeveral Experiments to explain the 'Nature and Cauſe of *Gravity*: Particularly on the 9th an Ex'periment was made, in which ſome Flower put into a void ſhal'low Glaſs with a large ſloping brim, and a pretty tall Foot was 'made to riſe and run over like a fluid, by the knocking on the 'edge of the Glaſs, and alſo by the forceably moving of ones Fin'ger round the edge of the ſame. Leaden Bullets alſo being put 'into this Glaſs, did, by knocking, move it like a fluid.----This

'was

'was propos'd to consider what might be the cause of Gravity, 'and suggest an Hypothesis to explicate the motion of Gravity 'by, *&c.*

These, and several other Experiments, he shew'd to explain Natural Bodies and Actions, in some of which I have been the more particular out of a hope these hints may excite some inquisitive Person to proceed farther in such Inquiries.

This same Year several Discourses and Papers past between the Learned Mr. *Newton* and Mr. *Hooke* concerning a new Theory of Light and Colours, which being now so generally known, I shall not farther insist on.

About this time he made a Proposition for perfecting all sorts of Optick-glasses, the secret of which was deliver'd in an Anagram to the President my Lord *Brouncher.*

Not long after this time began that unhappy Dispute between Monsieur *Hevelius* and *Hooke* concerning the preference of Plain and Telescopical Sights for Astronomical Instruments, which, as I can collect, was thus occasion'd. Mr. *Hooke*, by means of Mr. *Oldenburgh*, had recommended to Monsieur *Hevelius* the Application of Telescopick Sights to his exquisitely contriv'd and elobrated Instruments, affirming that by them an Angle might be taken to a much greater niceness than with plain Sights, and gave them a short, but as he thought a sufficient information of the manner of applying them to the Instrument, and intimated that if any thing requir'd a farther Explication, he was ready to give it. Nevertheless *Hevelius* could not be prevail'd with to make use of them, whether he thought himself too experienc'd to be inform'd by a young Astronomer, as he reckon'd *Hooke*, or whether having made so many Observations with plain Sights, he was unwilling to alter his Method, least he might bring their exactness into Question, or whether being by long practice accustom'd to the use of them, and not thoroughly apprehending the use of the other, nor well understanding the difference, as Mr. *Molineux* has observ'd in his Opticks, is indeed uncertain. *The Dispute with* Hevelius.

Not long after came out his curious and pompous Book of the first part of his *Machina Cælestis*; and *Hooke* took occasion in his *Cutlerian Lectures*, to read several Discourses upon that Book, and the Instruments therein describ'd, which were Printed *Anno* 1674. under the Title of *Animadversions upon Hevelius's Machina Cælestis.*

In which Treatise vindicating somewhat warmely the benefit of Telescopick Sights and their preference, he chanc'd to let slip some Expressions, which, tho' possibly strictly true, could yet never be digested by *Hevelius.*

Several Years after *Hevelius* Publish'd his *Annus Climactericus*, which again reviv'd the Dispute, and caus'd several Learned Men to interest themselves in the Controversy. This, I think, is the true History of the Matter. I shall here subjoin what *Hooke* wrote himself in Answer to what some Persons thought fit to write upon this Subject, as I found them drawn up by himself in a Paper or two among his Manuscripts; for the better understanding of which, I shall observe, First, That *Hevelius* having sent his *Annus Climactericus* to the ROYAL SOCIETY, Dr. *Wallis* was desir'd to give an account of it, which is Printed in the *Philosophical Transactions* N°. 175. p. 1162. in which the Dr. having used some Expressions which

Hooke

Hooke thought reflected too severely upon him; and Mr. *Molineux* not long after sending a Letter to the same purpose, he wrote his own Vindication almost verbatim, as I have here Printed it, at least nothing material is omitted or added.

'There having been lately read in a Meeting of this Honour-
'able *Society* a Letter from Mr. *Molineux* containing several Re-
'flections that concern'd me, which, without some satisfactory an-
'swer, must needs make me suffer in the Opinion of those who
'have not truly understood the Matter in Controversy, and the
'high Esteem I have of the Justice and Judgment of this Illustri-
'ous Company, persuades me the rather to make my Defence
'here.

'The Objections in the Letter were these.

'That if it be true which has been asserted, not only by some
'celebrated Astronomers, but chiefly by Mr. *Hooke* in his *Animad-*
'*versions*, &c. the Indeavours of *Hevelius* will be frustrated and his
'vast Charges to no more purpose than *Ticho*'s and all his splendid
'*apparatus* but meer Lumber; for upon this Question as to plain
'Sights, the price of his Astronomical Labours of his whole Life
'depends; but surely this were an Event highly deplorable, not
'only to the party himself immediately concern'd, but the whole
'*Respublica Literaria*.

Secondly, Mention is made of the slightness and smallness of
'what I had publish'd, which was only a Pamphlet, that asserted,
'that notwithstanding all this, yet meerly for want of Telescopick
'Sights and some new kind of invented Divisions on Mr. *Hevelius*'s
'Instruments, I went so far as to doubt whether his Observations
'could be true, and always the same to two or three Minutes, and
'that the whole import of it besides this, was nothing but the De-
'scription of an Instrument which he never heard was put in
'practice.

'The Third Objection against me is that, tho' Monsieur *Heve-*
'*lius* had earnestly requested from me, or any one else that had Te-
'lescopick Instruments, to send him some distances of fixt Stars
'observ'd by them, yet he could never be so happy as to obtain a-
'ny from me, tho' afterwards he did from some others, *&c.*

'These, and some other Discourses, spread abroad tacitely insi-
'nuate, that the Publishing those *Animadversions* was a very ill
'Action, and that the Learned in general have receiv'd a great pre-
'judice thereby, it concerns me therefore to clear my self of this
'Imputation: For Answer then I say,

'First, If what I have Publish'd in those *Animadversions* be true
'and certain, then I desire to know whether it were better for the
'*Respublica Literaria* to be acquainted with it, or to remain possest
'with the belief of some Assertions of Monsieur *Hevelius*, which
'are really Mistakes (not to say worse) tho' possibly till that time,
'wherein I publish'd them, they were generally believ'd to be Truths,
'as he has taken a great deal of pains to induce a belief of, in the first
'part of his *Machina Cælestis*, from Page 293, to Page 300, which I
'the

‘ the rather mention, becauſe ſome Perſons have thought and aſ-
‘ ſerted, that I was the firſt Aggreſſor in Print, the contrary of
‘ which thoſe ſix Pages evince.

Secondly, ‘ Whether thoſe deplorable Events of leſſening the
‘ price of Monſieur *Hevelius*'s Works, if that were true, when
‘ put into the Ballance, will out-weigh the detecting a Miſtake, or
‘ diſcovery of a Truth in a matter of ſo great Moment in Natu-
‘ ral Philoſophy, as concerns the moſt conſiderable parts of Know-
‘ ledge in the Theory of the Univerſe, eſpecially of Celeſtial Bo-
‘ dies; for if Truth be that which is moſt prevalent with all Phi-
‘ loſophical Spirits againſt any particular Intereſt, then I hope I ſhall
‘ prove I have not offended in that particular in my publication of
‘ thoſe *Animadverſions*. And *Hevelius* himſelf was of the ſame
‘ Mind, when at the ſixty firſt Page of his Preface he writes
‘ (ſpeaking of his diſparaging ſome things of *Ticho Brahe*) *in hoc ne-*
‘ *gotio ſemper in cujuſuis animo hærere debet. Amicus Plato, Amicus*
‘ *Ariſtoteles, ſed magis tamen amica veritas.* Nor do I find him ſo
‘ ſhy in proclaiming the Miſtakes of *Ticho*'s Obſervations, when it
‘ made for his own Reputation; for in the thirty fourth Page of his
‘ Preface he ſays, that the greateſt part of *Ticho*'s Obſervations dif-
‘ fer'd from his own four, five, ſix, and even ten Min. At the
‘ thirty ninth Page he ſays, That of 780 in *Ticho*'s Catalogue there
‘ are but 260 which differ, not leſs than two Minutes; but all the
‘ reſt differ 3′. 5′. 10′. 20′. 30′. 40′. 45′. 1°. nay a whole Degree from
‘ the truth, and that fifteen differ above a Degree, and ſome many
‘ more, even to eight Degrees in Longitude, and in Latitude to
‘ thirteen whole Degrees, ſometimes in defect, ſometimes in ex-
‘ ceſs, yet for all this *Hevelius* would be thought highly to value
‘ *Ticho Brahe*, and not to have made any Reflections upon him.

‘ Nor has the detecting Miſtakes even in Perſons of as great
‘ Fame been look'd upon ſo ill a thing, but rather a meritorious
‘ Action, as might be inſtanc'd in Dr. *Pell*'s ſhort Anſwer in a ¼ of
‘ a Sheet of Paper to *Longomontanus* his Work, which had been the
‘ buſineſs of thirty Years. Another inſtance may be of *Phocilides*
‘ upon *Lansbergius*, the learned *Savilian Aſtronomick Profeſſor* againſt
‘ *Bulialdus*, &c. all which Authors were well eſteem'd for their de-
‘ tecting Miſtakes, and diſcovering Truth. And as for any diſre-
‘ ſpectful or undervaluing Sentiments I had of *Hevelius* or his Per-
‘ formances, I hope what I have printed in my *Admadverſions* will
‘ prevail with the unprejudiced to believe the contrary; where I P. 43. & 44.
‘ ſay, *That I would not be underſtood by theſe Animadverſions to under-*
‘ *value the Works and Performances of a Perſon ſo highly meriting the*
‘ *Thanks of the Learned World for his great Expence and vaſt Pains, in*
‘ *performing a Work ſo highly uſeful to Aſtronomy and Navigation, that*
‘ *I did not in the leaſt doubt but that it would be a Work of perpetual*
‘ *Eſteem, and much preferrable to any thing of the like kind yet done in the*
‘ *World; and that he had gone as far as was poſſible for humane Induſtry*
‘ *to go with Inſtruments of that kind, which were as compleat and exact*
‘ *as Inſtruments with plain Sights could be made; and that he had calcu-*
‘ *lated with all imaginable care and skill, and deliver'd them with the like*
‘ *Candor and Integrity: But yet that it was my Opinion, that this ought*
‘ *not to diſcourage others from making uſe of Teleſcope-ſights, and to make*
‘ *better Obſervations with Inſtruments by that means more exact.*

'This I hope may Apologize for my writing those *Animadversions*. 'But in the next place I must make some defence for what is 'said in them. This Gentleman says I went so far as to doubt 'whether *Hevelius*'s Observations could be made true and always 'the same to two or three Minutes, I wish the place had been quo- 'ted where I said so, since I only said that I believ'd it impossible 'for any one to distinguish with common Sights any distance in 'the Heavens to less than half a Minute, and very few to a Mi- 'nute, and I am apt to believe there may be some instances even 'in *Hevelius*'s Catalogue that will verify this Assertion.

Animadversions, Pag. 7.

'And for any other Assertion, which is *really mine* in that Trea- 'tise, I do not doubt of satisfying any unprejudiced Person by ex- 'periment, if desir'd, which I say, is *really my Assertion*; for by 'mistake or otherwise, some things have been fathered upon me 'I never said, *viz.* that I should assert, *That an Instrument of a span 'Radius might be made, that should perform Observations sixty times more 'accurate than could be done with his best Instruments*: Which Asser- 'tion is none of mine, and whoever have spread these Falsities, 'might have found better Employment. I say indeed, that a very 'small Instrument, curiously made, exactly divided and instructed 'with Telescope-Sights will perform much better in all Observa- 'tions (except of the Sun) than the largest Instrument without 'such Sights, for the reason before alledged from the defect in our 'Eyes which cannot distinguish an Angle less than half a Minute, 'nor is this a defect in my own Eyes only (as *Hevelius* somewhere seems 'to hint) for the Experiment may easily be try'd with the best Eyes.

'Nor is it any disparagement to *Hevelius*'s Observations to com- 'pare them with *Ticho Brahe*'s, tho' I should have suppos'd them 'but of equal value, since the mere repeating of his Observations 'would be of great use in Astronomy, these being almost one hun- 'dred Years after his; for we must by such comparisons judge 'of many considerable inquiries concerning Celestial Bodies, which 'cannot by other means be so well detected, for which I refer to 'the seventy sixth Page of my *Animadversions*, viz. to know whe- 'ther those Celestial Bodies which are suppos'd so fixt, do not vary 'their Positions to each other, and also their Magnitudes, which I 'had good grounds to believe.

'As to the Objection that my Pamphlet contain'd *little besides the 'Description of an Instrument never put in practice.* I conceive there 'may be several Mistakes; for I am of Opinion, upon perusal there 'will be somewhat else in that Treatise worth consideration. Next 'that there has been Instruments made, perfected and used after 'that way, by Sir *Jonas More*, by Mr. *Gregory* in *Scotland*, by Mr. '*Halley*, and many others, and I believe very few Astronomical In- 'struments since have been made with plain Sights; and if the 'multiude of Authorities were necessary, I could produce *Auzout*, '*Ricart*, *Mariot*, *Romer*, *De la Hire*, *Montanari*, *Gotignies*, and o- 'thers, not to name those of our own Nation.

'As to my not returning the Observations of certain distances 'of Stars, which *Hevelius* desir'd, 'tis sufficiently known what in- 'conveniences we lay under in this place after the Fire of *London*, 'and had I found conveniences, yet the unkind Reception those 'things found, which I sent him, was enough to deter me from 'such a Compliance; tho' he was sensible how I had often been rea-

'dy

'dy to gratify his Curiosity in many other particulars. But when 'his *Machina Cælestis* was publish'd, I was oblig'd to write those *A*-'*nimadversions*, in which I hope all unprejudic'd Readers will justify 'my proceedure, at least I am ready to prove any thing I have 'therein asserted.

I have been the larger in the Account of this Controversy that the intelligent Reader may make the better judgment thereof, it being the most considerable he ever had with any Person, and shall wave the giving my Opinion of it.

In 1674. he shew'd an Engine or Instrument to perform any Arithmetical Operation, but the more particular account of this and other Instruments not describ'd in this Volume, I shall reserve for another opportunity.

About the latter end of the same Year the ROYAL SOCIETY kept their Weekly Meeting at *Gresham College* again, and on the fifteenth of *Jan.* following he shew'd a way to determine how small an Angle the unassisted Eye is able to discern, by which it was found, that none of the Persons Eyes present could observe a much less Angle than of a Minute; for a more ample account of which the Reader is referr'd to the eighth Page of his *Animadversions.*

From this time many Magnetical Experiments were made by him, and on the nineteenth of *March* he propos'd a Theory of the variation, the substance of which was this, 'That the Magnet 'hath its peculiar Poles distant ten Degrees from the Poles of the 'Earth, about which they move so as to make a Revolution in 'three hundred and seventy Years, whence the variation hath al-'tered of late about ten or eleven Minutes every Year, and will 'probably continue so to do for some time, till it begins to grow 'slower and slower, and will at length be Stationary and Retro-'grade, and in probability may return; but whether it will be so or 'not Time must shew. At the same time he propos'd the making 'of a very easy and nice Instrument to observe the variation of the 'variations of the Needle in different parts of the World.

What this Instrument was is not easy now to be determin'd, but the Reader will find the Figure of an Instrument something to this purpose at Page 486.

On the 4th of *Feb.* 167$\frac{4}{5}$. several Observations and Discourses having been made about the Structure of the Muscles of Animals, Mr. *Hooke* said, 'That his Observation was, that the fleshy part of 'a Muscle consisted of an infinite number of exceeding small round 'Pipes, extended between the two tendons of the Muscles, and 'seem'd to end in them. Which Tendons, in the Muscles of Beef 'boyl'd would be easily stript off from those Pipes, and so leave the 'round ends of those Pipes very distinct and visible: He said that 'the reason of the moving of a Muscle might be from the filling 'or emptying of those Pipes, whose sides seem'd to be flexible like 'those of a Gut. He intimated also, that he knew a way of mak-'ing succedaneous Muscles for a Man to supply the defect of his 'Muscles for flying, and give one Man the strength of ten or 'twenty, if required.

'*March* the 18th 167$\frac{4}{5}$. he made an Experiment of a new proper-'ty of Light, having before read some Discourses upon that Sub-'ject. This Experiment is to be seen Page 186 of this Book, to which the Reader is referr'd for a more full account.

Mr.

Mr. *Oldenburgh*, the then Secretary, dying in the time of the Societies Recess, 1677. Mr. *Hooke* was desir'd to take his place, and take the Minutes of what considerable Matters past, which he did on the twenty fifth of *October* 1677. and the same day produc'd his Water-poise and shew'd the nicety thereof. The Description of this is in the *Philos. Transact.* N°. 197. p. 623. There were afterwards some other Hydrostatical Instruments produc'd, as likewise many Improvements of the double and single Microscopes, with the use of small glass Canes and other Contrivances, by which he verify'd Monsieur *Leuenhook*'s Observations; these, with several others, I omit, they not being so intelligible without Schemes.

From that time he officiated in that Place, as well as his Curatorship, shewing several Experiments and Instruments in order to explain the Gravitation and Alterations in the Air by Vapours, *&c.* Contriving an Air-poise to shew the different specifick Gravity of the Air by a large thin ball of Glass counter-poised.

In *Feb.* 167$^{7}_{8}$. upon an account of Monsieur *Gallet*'s Observation of the Oval Figure of *Mercury* in the Sun, he gave several reasons for the prolated Oval Figure of the Planets, some of which are Printed in this Volume, Page 355. with a Demonstration thereof, ‘ and said, ‘ That all Fluids on the Surface would run into that ‘ Shape, and that 'twas not improbable but that the Water here ‘ about the Earth might do so by the influence of the diurnal Mo- ‘ tion of the Earth, which compounded with that of the Moon, he ‘ conceiv'd was the cause of the Tides.

From this time he made Microscopal Observations on *Animalcules* in Peper-water, and other Seeds steeped in Water, confirming Monsieur *Leuenhook*'s Assertions, and propos'd some Improvements of Microscopes.

Some proposals were made by him of Instruments more accurate than those formerly invented for sounding the Seas depth, bringing up Water, or other Substances from the bottom, or any assigned depth which were some Years after more perfected.

Apr. 25. 1678. he shew'd an Experiment farther to explain the action of a Muscle, ‘ which was by a Chain of small Bladders fa- ‘ stened together, so as by blowing into one Pipe, the whole might ‘ be successively fill'd, and by that means contracted, supposing the ‘ Fibres of the Muscles which seem'd like a Necklace of Pearl in ‘ the Microscope, might be fill'd with a very agill Matter, which ‘ he thought most likely to be Air, which being included in so thin ‘ Skins, was easily wrought upon by Heat, Cold, or the acting ‘ Properties of the Liquors that pass between them, and so perform ‘ the lengthening and contracting of the Muscles.

Aug. 1678. he read several Discourses, and shew'd Experiments in order to confirm his Theory of Springs and springy Bodies, which are publish'd in his Treatise *de Potentia restitutiva* the same Year, the sum of which Hypothesis is comprized in a Cypher at the end of his Description of Helioscopes, being the third of a Decimate of Inventions which he there mentions he was Master of, some of which he discover'd himself, affirming he had a Centry of the like useful Inventions: Others of them I have had the luck to find out, which I shall take this opportunity of mentioning. I shall first transcribe what he says of them, and then add the deciphering of them.

Pag. 31.

The

The ſecond Invention, which is the firſt Cypher, is thus worded.

'The true Mathematical and Mechanical Form of all manner of 'Arches for building with the true butment neceſſary to each of 'them, a Problem which no Architectonick Writer hath ever yet 'attempted, much leſs perform'd. ab, ccc, dd, eeeee, f, gg, iiiiiii, ll, 'mmmm, nnnnn, oo, p, rr, sss, tttttt, uuuuuuuu, x, which deci-'phered is theſe words, *Ut pendet continuum flexile, ſic ſtabit conti-'guum rigidum inverſum*, which is the *Linea Catenaria*.

The third is his Theory of Springineſs in theſe Letters, ce, iii, no, sss, tt, uu, which is *Ut Tenſio ſic vis*; this is the principle of his Theory of Springs.

'The ninth, which is the next Cypher, is concerning a new 'ſort of Philoſophical Scales of great uſe in Experimental Philo-'ſophy, cde, ii, nn, oo, p, sss, tt, uu, *Ut Pondus ſic Tenſio*.

The laſt is mention'd as a very extraordinary invention in Mechanicks above the Chimeras of perpetual motions for ſeveral uſes, aa, æ, b, cc, dd, eeeeee, g, iii, l, mmm, nn, oo, pp, q, rrrr, s, ttt, uuuuu. *Pondere premit aer vacuum quod ab igne relictum eſt.* This is one of the Principles upon which Mr. *Savery*'s late invented Engine for raiſing Water is founded. See *Lexicon Technicum* under Engine.

On the 29th of *Aug.* 1678. his Grace the Duke of *Norfolke* having given the *Arundelian* Library to the ROYAL SOCIETY, Mr. *Hooke* was order'd to be Aſſiſtant in making a Catalogue thereof, and removing it to *Greſham College*.

In the beginning of the Year 1679. and afterwards, ſeveral Experiments were repeated to examine the uſe of the Air in Reſpiration by including Animals in common rarify'd and condenſed Air, as likewiſe concerning the neceſſity of the Air to maintain Fire, to illuſtrate his Theory of Fire farther, *viz.* 'That Air is a *Menſtruum* 'that diſſolves all Sulphureous Bodies by burning, and that without 'Air no ſuch diſſolution will follow, tho' the heat apply'd be ne-'ver ſo great, which was try'd particularly by a Charcoal encloſ-'ed in an Iron Caſe with a Screw-ſtopper, which tho' violently 'heated yet the Cole was not burnt nor waſted when taken out.

Some Experiments were made to explain the different Gravitation of the Air, and to ſhew that Vapours preſs only according to their own Gravity, and not according to the ſpace they take up in the Atmoſphere.

Some Contrivances were ſhewn by him to be added to the Weather-Clock, as a Hygroſcope, a contrivance to meaſure the quantity of Rain, Snow, or Hail fallen in a certain time; which Engine was ſoon after perfected in all its parts, and ſet up in the Repoſitory.

In *July* 1679. he read a Diſcourſe concerning a way to help ſhorted Sighted Perſons, which he call'd *Myopibus Invamen*; this is Printed in his third Collection, p. 59. 'At the ſame time he gave his 'Thoughts of the reaſon of the different apparent Magnitude of 'the Sun and Moon in the Meridian and near the Horizon, which 'he ſuppos'd to be a deception of the Eye as judging them when near 'the Horizon, to be farther off than when nearer the Zenith, for 'that he ſaid the Diameters meaſur'd were really the ſame in both 'places, or rather ſomething leſs in the Horizon than in the Zenith, 'being remov'd a Semidiameter of the Earth farther off.

Experiments were made by him of the mixtures of Metals, particularly of Copper and Tin, in which there was observ'd a real Penetration, the *Compositum* being specifically heavier than either of the Metals before mixture; for whereas Copper is to Water as 8 $\frac{1}{2}$ to 1. and Tin to Water as $7\frac{17}{30}$ to 1. the compositum was to Water as 8 $\frac{3}{4}$ to 1.

'In *December*, the same Year, an Experiment being suggested to 'try whether the Earth mov'd with a diurnal motion or not, by the 'fall of a Body from a considerable height, alledging it would fall to 'the East of true Perpendicular: Mr. *Hooke* read a Discourse up- 'on that Subject, wherein he explain'd what the Line describ'd by 'a falling Body must be, suppos'd to be mov'd circularly by the di- 'urnal motion of the Earth, and perpendicularly by the power of 'Gravity, and shew'd it would not be a Spiral Line, but an Ex- 'centrical-Elliptoeid, supposing no resistance in the *medium*, but sup- 'posing a Resistance, it would be an Excentric-Ellipti-Spiral, 'which after many Revolutions, would rest in the Center at last; 'that the fall of the Body would not be directly East, but to the 'South-East, and more to the South than the East. This was try'd, 'in which the Ball was still found to fall to the South-East.

The remainder of this Year was spent in making Experiments of the mixture of several Metals, among the rest Mr. *Hooke* took notice in the mixture of Copper and Tin of several particulars, as First, 'That the colour of the Copper was quite destroy'd, it ap- 'pearing much of the colour of Iron Polish'd. Secondly, That 'the Composition, tho' made of two very malleable Metals, was 'yet very brittle and friable. Thirdly, That it bore a pretty good 'Polish and Reflection. Fourthly, That tho' Copper is exceeding 'hard to be melted, yet the mixture melted very easily. Fifthly, 'That viewing the Polish'd Surface with a Microscope, he found 'it very full of very small holes or blebs in the Metal.

In *April* 1680. he produc'd a new invented Level.

In *May* he read a Paper of Observations upon an unusual sort of Hail-stones that fell on the 18th. the sum of which was to this purpose. About ten a Clock in the Morning it grew very dark and Thundered much, and near to the S. E. when soon after the Hail fell from the size of Pistol-Bullets to the bigness of Pullets Eggs, the smaller were white like Chalk, and pretty round, the larger Conical or Oval, upon breaking them they were found to be made of several Orbs, encompassing one another; several had a white Center or Nucleus in the middle, which in others was more toward one side; they that exceeded in bigness were made by an additional accretion of transparent Icecles, radiating from the white Ball in the middle; some of these stood in distinct transparent Rays, in others the Interstices were fill'd up between the Rays with a white opaque Concretion: The lower part of these Stones were more flat and like a Turnip, the radiations appearing more towards the upper side; the sides and top were more rough, and the ends of the Stiriæ were prominent. Before they fell a great noise was heard in the Sky: From the manner of their Figure Mr. *Hooke* conceiv'd their accretion was made by a congelation of Water as they fell; that the Globe in the middle about the bigness of a Pea, was the first drop that concreted into Hail, the Coats being added to it as it past through the watry Clouds, of which some

were

were white, ſome pellucid, according to the different coldneſs of the Regions they paſt through.

July 8th 1680. upon a Debate concerning the Experiment of my Lord *Bacon*'s of the internal motion of Bodies, Mr. *Hooke* related, ‘ That he had obſerv'd that the motion of the Glaſs, fill'd with ‘ Water, was obſerv'd to be vibrative, perpendicular to the Sur- ‘ face of the Glaſs, and that the Circular Figure chang'd into an ‘ Oval one way, and that the Reciprocation preſently changed it ‘ into an Oval the other way, which he diſcover'd by the motion ‘ of the Undulation or riſing of the Water in the Glaſs, which was ‘ obſerv'd to be in four places of the Surface in a ſquare poſture, ‘ the ſame Glaſs being ſtruck on the edge with a Viol-bow, this ‘ ſquare Undulation was very plain, and there was alſo diſcover'd ‘ another Undulation, by which the Water was obſerv'd to riſe in ‘ ſix places like an Hexagon, and upon farther trials alſo in eight ‘ places like an Octagon; each of theſe gave their particular and ‘ diſtinct Sounds or Notes, the 4 and 8 were Octaves, and the 6 and ‘ 4 were Fifths, *&c.*

In *November* 1680. he read ſome Obſervations he had made of a *Comet* then appearing, which, with other Obſervations and Diſcourſes of other Comets are publiſh'd in this Volume under that Title, beginning at Page 194.

And about this time Mr. *Hooke* ſhew'd a Contrivance by a *Statera* to examine the attractive power of the Magnet at ſeveral diſtances, and made many Experiments therewith.

In *April* 1681. and afterwards, he read his Lectures of *Light* and *Luminous* Bodies, which are here collected together, and begin at Page 71.

In *July* the ſame Year he ſhew'd a way of making *Muſical and other Sounds*, by the ſtriking of the Teeth of ſeveral Braſs Wheels, proportionally cut as to their numbers, and turned very faſt round, in which it was obſervable, that the equal or proportional ſtroaks of the Teeth, that is, 2 to 1, 4 to 3, *&c.* made the Muſical Notes, but the unequal ſtroaks of the Teeth more anſwer'd the ſound of the Voice in ſpeaking.

November following he mention'd a new Sea-Quadrant for making Obſervations more accurate than could be done by any Inſtrument yet known; this is what the Reader will find towards the end of this Volume: At the ſame time he firſt mention'd his new Compaſſes for deſcribing all ſorts of Spirals, as likewiſe of the Rumb-lines, which Inſtrument I alſo have indeavour'd to retrieve from being loſt.

Soon after this he ſhew'd and demonſtrated a very expeditious way of drawing the Rumb-lines exactly true upon a Globe, by an Inſtrument grounded upon the ſame Principle with the other. He ſhew'd alſo a very eaſy way of finding all the poſſible *foci* of Rays refracted by a *Plano-Spherical Lens*, whereof the Convex ſide was turn'd toward the *focus*, as alſo the quantity of Rays that would paſs thro' ſuch a Glaſs, whoſe Convexity was of the full bigneſs of a Hemiſphere.

‘ In *Jan.* 168$\frac{1}{2}$. he ſhew'd an Inſtrument to deſcribe all ſorts of ‘ *Helixes* upon a Cone, by which he affirm'd to be able to divide any ‘ given length, tho' very ſhort, into almoſt any aſſignable number ‘ of given parts, as ſuppoſe an Inch into 100000 equal parts; this ‘ he

' he conceiv'd very uſeful for perfecting Aſtronomical and Geogra-
' phical Inſtruments. And at the next Meeting he produc'd ano-
' ther Inſtrument, by which he deſcrib'd a certain Curve Line,
' which may be call'd an *Invented Parabola*, or *Parabolical-Hyperbo-*
' *la*, having theſe Proprieties, that it is infinite both ways, and
' hath two *Aſymptotes* as an *Hyperbola*, &c. A third Inſtrument
' was alſo ſhew'd for exactly deſcribing the *Spiral* of *Archimedes* by
' a new Propriety thereof, and that as eaſily and truly as a Circle,
' whereby not only any given Arch might be divided into any
' number of equal parts, but a ſtrait Line given equal to the Cir-
' cumference of a Circle.

' *March* the firſt, he ſhew'd a way, by the ſame Inſtrument, of
' deſcribing all varieties of Ellipſes.

In the ſame Year he read the remainder of his Diſcourſes of *Light*, which are in the following Volume Printed, and particularly that Lecture explicating the Memory, and how we come by the notion of Time.

From this time, or rather ſomething before, he began to be more reſerv'd than he had been formerly, ſo that altho' he often made Experiments, and ſhew'd new Inſtruments and Inventions, and read his *Cutlerian* Lectures, yet he ſeldom left any full Account of them to be enter'd, deſigning, as he ſaid, to fit them himſelf for the Preſs, and then make them publick, which he never perform'd. This is the reaſon that I am oblig'd to be the ſhorter in the remaining part of his Life; and ſhall only touch upon ſome few of his Performances, ſince the bare nameing of them, or mentioning their Titles, will but create an uneaſy Curioſity in the Reader without any ſatisfaction.

Several of theſe Lectures and Diſcourſes I have indeavour'd to preſerve from being loſt, by Publiſhing them in this Book, and ſome Inſtruments are there deſcrib'd.

In the beginning of the Year 1687. his Brothers Daughter, Mrs. *Grace Hooke* dy'd, who had liv'd with him ſeveral Years, the concern for whoſe Death he hardly ever wore off, being obſerv'd from that time to grow leſs active, more Melancholly and Cynical.

On the fifth of *May* he read a Lecture of the unequal *diurnal* motion of the Earth, which the Reader may find in this Book

In *July* he ſhew'd an Experiment of the communication of Motion by a Packthread extended a very conſiderable length, and, after running over a Pulley, brought back to the place, near to which the other end was faſtened, and it was found that any addition of Weight or Motion given to the one end, would be immediately ſenſible at the other end of the String, tho' it muſt paſs in going and returning ſo great a length; there were other ways ſhewn of communicating motion, as by a long Cane ſuſpended by Strings, or by Wires diſtended a great length; in which it was obſervable, that the ſound was propagated inſtantaneouſly, even as quick as the motion of Light, the ſound convey'd by the Air coming a conſiderable time after that by the Wire.

A great part of the next Year he was very weak and ill, being often troubl'd with Head-achs, Giddineſs and Fainting, and with a general decay all over, which hinder'd his Philoſophical Studies, yet ſtill he read ſome Lectures whenever he was able. At the ſame time a Chancery-Suit, which he was forc'd to have with Sir *John*

Cutler

Cutler for his yearly Salary, made him very uneasy, the trouble of which increas'd his Illness.

But on the 20th of *June* he read a farther Description concerning several ways of making a portable *Sea-Barometer*, with the great uses thereof in foretelling changes of the Weather and Storms.

From this time, for some Years, I find but little done by him, except his reading the Lectures founded by Sir *John Cutler*, several of which are here Printed, to which the curious are referr'd: Of these he read in *Dec.* 1691. several relating to improvements of founding Instruments which he call'd *Nuntii inanimati ad fundum Abyssi emissarii.* Having receiv'd a warrant from Dr. *Tillotson* the Arch-bishop of *Canterbury*, for a *Degree of Dr. of Physick*, he went on the 7th of *Dec.* the same Year, and took the Oaths before Sir *Charles Hedges* in *Doctors Commons.*

About this time he was employ'd about the contriving and surveying the Hospital standing near *Hoxton*, given by the Will of Alderman *Ask*, a Building that few will judge any disreputation to the Contriver, for the due proportion of its Parts, and Beauty of the whole. I have heard indeed that Dr. *Hooke* has been blam'd for exceeding the Sum at first propos'd to be expended thereon; and once discoursing with him upon that Subject, he own'd to me that it had far exceeded the first Estimate he had given in of the Charges, but not by this Fault or Mistake, but partly by new additions and alterations of the first Design, and chiefly by his not procuring and agreeing with the Workmen himself, which if he had done, as he said, he would have ingag'd it should have come to little or no more than his first propos'd Sum. He also propos'd that there might be instituted in that place, a *Mathematical*-School for Boys to be instructed in the Principles of *Astronomy* and *Navigation*, which at first was well approv'd of by the Persons concern'd in the Management of that Affair.

On *Thursday* the 8th of *Sep.* 1692. he sets down an Earthquake to be observ'd by himself exactly 55 Min. past one a Clock p. m. he notes that there was no Wind but Rain all Day. It was remarkable that this Earthquake was felt at the same time not only in most parts of *England*, but also in several parts of *Germany.*

This Year he read a curious Discourse describing the Tower of *Babel* or *Belus.* The Year following he read several Lectures about Earthquakes, and an Explication of *Ovid's Metamorphosis*, of which it is needless to mention the Contents, or the Times, the Dates of most of them being affixt to them in the following Book, they begin at Page

On the 18th of *July* 1696. being his Birth Day, his Chancery-Suit for Sir *John Cutler*'s Salary, was determin'd for him, to his great satisfaction, which had made him very uneasy for several Years. In his Diary he shews his sense of it in these Terms DOMSHLGISS: A. which I read thus *Deo Opt. Max. summus Honor, Gloria in secula secularum, Amen. I was Born on this Day of* July 1635. *and* GOD *has given me a new Birth, may I never forget his Mercies to me; whilst he gives me Breath may I praise him.*

March the 5th 169$\frac{7}{8}$. he read a Lecture about the prolated Spheroedical Figure of the Sun, and other *Phænomena* thereof, of the *Maculæ* and *Faculæ*, &c. of making a Helioscope by four reflex Planes in a twenty four Foot Tube, or a Telescope for Planets and

fix'd Stars, by two Reflexions in a Tube of forty Foot with Monsieur *Huygens* 120 Foot Glass, which was well lik'd of.

June 27. 1698. he read a Lecture upon *Huygen's Cosmotheoros*, and shew'd a Module of *Saturn* and his Ring.

Thus I have mention'd some of his Performances, in the latter of which I have been the more succinct, having exceeded the bounds I at first intended in the Accounts of the former. It must be confessed that the later part of his Life was nothing near so fruitful of Inventions as the former; tho' it is certain he had a design to repeat the most part of his Experiments, and finish the Accounts, Observations and Deductions from them, and had an Order for the Societies bearing the Charge thereof, in *June* 1696. when he propos'd likewise to perfect the Description of all the Instruments he had at any time contriv'd; but by reason of his increasing Weakness and a general Decay, he was absolutely unable to perform it, had he desir'd it never so much.

He had for several Years been often taken with a giddiness in his Head, and sometimes great Pain, little Appetite, and great faintness, that he was soon very much tir'd with walking, or any Exercise. About *July* 1697. he began to complain of the swelling and soreness of his Legs, and was much over-run with the Scurvy, and about the same time being taken with a giddiness he fell down Stairs and cut his Head, bruis'd his Shoulder, and hurt his Ribbs, of which he complain'd often to the last. About *September* he thought himself (as indeed all others did that saw him) that he could not last out a Month. About which time his Legs swell'd more and more, and not long after broke, and for want of due care Mortify'd a little before his Death. From this time he grew blinder and blinder, that at last he could neither see to Read nor Write. Some of the last he wrote, I believe was on the 17th of *Dec.* 1702. when he sets down a Memorandum about an Instrument to take the Horizontal Diameter of the Sun to the tenth of a second Minute, but discovers not the way.

Thus he liv'd a dying Life for a considerable time, being more than a Year very infirm, and such as might be call'd Bed-rid for the greatest part, tho' indeed he seldom all the time went to Bed but kept in his Cloaths, and when over tir'd, lay down upon his Bed in them, which doubtless brought several Inconveniences upon him, so that at last his Distempers of shortness of Breath, Swelling, partly of his Body, but mostly of his Legs, increasing, and at last Mortifying, as was observ'd after his Death by their looking very black, being emaciated to the utmost, his Strength wholly worn out, he dy'd on the third of *March* 170$\frac{2}{3}$. being 67 Years, 7 Months, and 13 Days Old.

His Corps was decently and handsomely interr'd in the Church of St. *Hellen* in *London*, all the Members of the ROYAL SOCIETY then in Town attending his Body to the Grave, paying the Respect due to his extraordinary Merit.

His Character. As to his Person he was but despicable, being very crooked, tho' I have heard from himself, and others, that he was strait till about 16 Years of Age when he first grew awry, by frequent practicing, turning with a Turn-Lath, and the like incurvating Exercises, being but of a thin weak habit of Body, which increas'd as he grew older, so as to be very remarkable at last: This made him but low of Stature,

ture, tho' by his Limbs he ſhou'd have been moderately tall. He was always very pale and lean, and laterly nothing but Skin and Bone, with a meagre Aſpect, his Eyes grey and full, with a ſharp ingenious Look whilſt younger; his Noſe but thin, of a moderate height and length; his Mouth meanly wide, and upper Lip thin; his Chin ſharp, and Forehead large; his Head of a middle ſize. He wore his own Hair of a dark Brown colour, very long and hanging neglected over his Face uncut and lank, which about three Year before his Death he cut off, and wore a Periwig. He went ſtooping and very faſt (till his weakneſs a few Years before his Death hindred him) having but a light Body to carry, and a great deal of Spirits and Activity, eſpecially in his Youth.

He was of an active, reſtleſs, indefatigable Genius even almoſt to the laſt, and always ſlept little to his Death, ſeldom going to Sleep till two three, or four a Clock in the Morning, and ſeldomer to Bed, oftener continuing his Studies all Night, and taking a ſhort Nap in the Day. His Temper was Melancholy, Miſtruſtful and Jealous, which more increas'd upon him with his Years. He was in the beginning of his being made known to the Learned, very communicative of his Philoſophical Diſcoveries and Inventions, till ſome Accidents made him to a Crime cloſe and reſerv'd. He laid the cauſe upon ſome Perſons, challenging his Diſcoveries for their own, taking occaſion from his Hints to perfect what he had not; which made him ſay he would ſuggeſt nothing till he had time to perfect it himſelf, which has been the Reaſon that many things are loſt, which he affirm'd he knew. He had a piercing Judgment into the Diſpoſitions of others, and would ſometimes give ſhrewd Gueſſes and ſmart Characters.

From his Youth he had been us'd to a Collegiate, or rather Monaſtick Life, which might be ſome reaſon of his continuing to live ſo like an Hermit or Cynick too penuriouſly, when his Circumſtances, as to Eſtate, were very conſiderable, ſcarcely affording himſelf Neceſſaries.

I indeed, as well as others, have heard him declare ſometimes that he had a great Project in his Head as to the diſpoſal of the moſt part of his Eſtate for the advancement of Natural Knowledge, and to promote the Ends and Deſigns for which the ROYAL SOCIETY was inſtituted: To build an handſome Fabrick for the *Societies* uſe, with a Library, Reſpoſitary, Laboratory, and other Conveniencies for making Experiments, and to found and endow a perpetual *Phyſico-Mechanick Lecture* of the Nature of what himſelf read. But tho' he was often ſolicited by his Friends to put his Deſigns down in Writing, and make his Will as to the diſpoſal of his Eſtate to his own liking in the time of his Health; and after when himſelf, and all thought, his End drew near, yet he could never be prevail'd with to perfect it, ſtill procraſtinating it, till at laſt this great Deſign prov'd an airy Phantom and vaniſh'd into nothing. Thus he dy'd at laſt without any Will and Teſtament that could be found. It is indeed but a melancholy Reflexion, that while ſo many rich and great Men leave conſiderable Sums for founding Hoſpitals, and the the like pious Uſes, few ſince Sir *Thomas Greſham* ſhould do any thing of this kind for the promoting of Learning, which no doubt would be as much for the Good of the Nation, and Glory of God, as the other of releiving the Poor.

He

He always expreſt a great Veneration for the eternal and immenſe Cauſe of all Beings, as may be ſeen in very many Paſſages in his Writings, and ſeldom receiv'd any remarkable Benefit from God without thankfully ackowledging the Mercy; never made any conſiderable diſcovery in Nature, invented any uſeful Contrivance, or found out any difficult Problem, without ſetting down his Acknowledgement to the Omnipotent Providence, as many places in his Diary teſtify, frequently in theſe or the like words, abbreviated thus, D O M G M. and was a frequent ſtudier of the Holy Scripture in the Originals: If he was particular in ſome Matters, let us leave him to the ſearcher of Hearts.

To conclude, all his Errors and Blemiſhes were more than made amends for, by the Greatneſs and Extent of his natural and acquired Parts, and more than common, if not wonderful Sagacity, in diving into the moſt hidden Secrets of Nature, and in contriving proper Methods of forcing her to confeſs the Truth, by driving and purſuing the *Proteus* thro' all her Changes, to her laſt and utmoſt Receſſes; ſo that what *Ovid* ſaid of *Pythagoras* may not unfitly be apply'd to him.

Mente Deos adiit, & quæ Natura negavit
Viſibus humanis, oculis ea Pectoris hauſit.

Metamorph. Lib. 15.

There needs no other Proof for this than the great number of Experiments he made, with the Contrivances for them, amounting to ſome hundreds; his new and uſeful Inſtruments and Inventions, which were numerous, his admirable Facility and Clearneſs, in explaining the Phænomena of Nature, and demonſtrating his Aſſertions; his happy Talent in adapting Theories to the Phænomena obſerv'd, and contriving eaſy and plain, not pompous and amuſing Experiments to back and prove thoſe Theories; proceeding from Obſervations to Theories, and from Theories to farther trials, which he often aſſerted to be the moſt proper method to ſucceed in the interpretation of Nature. For theſe, his happy Qualifications, he was much reſpected by the moſt learned Philoſophers both at home and abroad: And as with all his Failures, he may be reckon'd among the great Men of the laſt Age, ſo had he been free from them, poſſibly, he might have ſtood in the Front. But *humanum eſt errare.*

A General

A

General Scheme, or Idea

Of the PRESENT STATE of

Natural Philosophy,

AND

How its DEFECTS may be Remedied

By a Methodical Proceeding in the making

EXPERIMENTS

AND COLLECTING

OBSERVATIONS.

WHEREBY

To Compile a NATURAL HISTORY, as the Solid Basis for the Superstructure of True

PHILOSOPHY.

THIS Treatise of Dr. Hook's *tho' it was never brought to its designed Perfection, yet I thought best to present the Learned with in the first place, since it treats of the Method he proposed to himself in his Inquiries into Nature; and which he has very much observed, I have here publisht it as he left it, not presuming to alter any thing in his Writings, lest it might be doubted what were his Genuine Thoughts. I have only added the Marginal Contents, believing they would not be unacceptable. The Discourse contains Two Principal Parts, or Generals. The First Treats of the State of Philosophy, as delivered to us by the Ancients, with its Defects. The Second, How these Defects may be Remedied, for the building up a solid Philosophical Structure.*

R. Waller.

FIRST GENERAL.

The Present State of Natural Philosophy, *and wherein it is deficient.*

THE Business of Philosophy is to find out a perfect Knowledge of the Nature and Proprieties of Bodies, and of the Causes of Natural Productions, and this Knowledge is not barely acquir'd for it self, but in order to the inabling a Man to understand how by the joyning of fit Agents to Patients according to the Orders, Laws, Times and Methods of Nature, he may be able to produce and bring to pass such Effects, as may very much conduce to his well being in this World, both for *satisfying his Desires*, and the relieving of his *Necessities*: And for advancing his State above the common Condition of Men, and make him able to excel them as much, almost, as they do Brutes or Ideots. *First General.*

Now though there have been many Men, in divers Ages of the World, which seem to have had some confus'd and imperfect Conception of this Idea of the Business of Philosophy, and accordingly seem to have had some Aims and Designs towards the attaining of their propos'd end; yet having not a right Understanding of the chief end, and failing much more in the Knowledge of the Means, or the manner of making use of them, they have generally left Philosophical Knowledge almost in the Condition they found it: Without making any considerable Increase or Addition to it. Whence this kind of Knowledge has been very little promoted ever since the very first times we have had any History of it. And though it has always made a fair shew of flourishing; yet upon Examination, it has been found to yield Leaves instead of solid Fruit, to be a Knowledge very confus'd and imperfect, and very insignificant as to the inabling a Man to practise or operate by it. *The Present State of* Natural Philosophy.

This seems to have proceeded from divers Causes, as

First, from the Unskilfulness of the Inventors and Founders of it, who seem to have many ways contributed thereto.

1. First in that they had not a true Idea of the Design and thing it self, their Aims were low and mean, and reacht but at small things, such as the giving the Explication of things in hard words, which might serve to amuse their Auditors, and to raise some Esteem of themselves amongst them, scarce ever thinking, much less indeavouring to find out the true Nature and Proprieties of Bodies; what the inward Texture and Constitution of them is, and what the Internal Motions, Powers and Energies are, and how they may be made use of for producing such Changes and Transformations of Bodies from one thing to another as is desired. *The Reasons of the Deficiency of* Natural Philosophy. 1. *From the first Inventors Ways.*

2. Next in that they were as ignorant of the true *means* of attaining it, as they were of the Knowledge of the End. Some esteem indeed we find them to have had of *Natural History*, and some Imagination they had that it was conducive to Natural Knowledge, but what History was requisite, they neither had, or indeed so much as knew, for what we find in *Aristotle*, *Pliny*, and others called by that Name is so uncertain and superficial, taking notice only of some slight and obvious things, and those so unaccurately, as makes them signify but little; but as for the more subtile Examinations of Natural Bodies, by Dissections, Experiments, or Mechanical Tryals, we find them not to mention them as needful, much less to have practised them. Nor can I perceive that they had any Affection or Industry for Experiments, much less for such as ought to be vigorously prosecuted with Care and Judgment: Nor do they seem to have had that Strictness and Accurateness as is requisite in setting down or registring those things which their Writings contain, but good and indifferent

and

and stark naught are without Distinction mixt together, true and probable and false are all alike dignified, nor are they so accurate in their Descriptions, even of not common things that they help us with; but a great part of them we find to be a needless insisting upon the outward Shape and Figure, or Beauty, and the like, or else of some Magical and Superstitious Effects Producible by it seeming to aim at creating Pleasure, and Divertisement or Admiration and Wonder, and not of such a Knowledge of Bodies as might tend to Practice.

3. *Thirdly*, In that, as they knew not the means; so neither did they the *manner* of making use of them, in which Particular we may find them to be much more to seek than in knowing what Materials were requisite. Their Method herein indeed was most prepotterous and very pernicious, for first we find them much inclin'd to a Belief of implanted Notions, at least in their Practice; though some of them affirm, *Nihil esse in intellectu quod non fuit prius in sensu*; yet upon the whole, we may find that in their manner of proceeding they did quite otherwise. From a very few uncertain Histories they usually rais'd the most general Deductions, and from them though never so imperfect, would needs prescribe Laws to the Universe and Nature it self. In this they were very supercilious, and very angry to be contradicted, and maintained their Opinions more because they had asserted them, than because they were true; they studied more to gain Applause and make themselves admired, or the Head of some Sect, or the Author of some strange Opinion, or the Opposer of some one already famous Doctrine, or the like, than to perfect their Knowledge, or to discern the Secrets of Nature, or advance the active Power of Man over the Creatures. Nor was this all; but we may find them even to wrest those few Experiments and Observations they had read, or collected, and to endeavour rather to adapt them to their Hypothesis, than to regulate their Thoughts by them, esteeming their own Understandings to be the Mine of all Science, and that by pertinacious ruminating, they could thence produce the true Image and Picture of the Universe.

II. *From the Sectators from several Causes.* Nor was this the only ill Fortune of true Science, but there is somewhat more behind. A Second Reason therefore why Philosophy has not increased is to be ascribed to the Sectators of these Theories, who at best have not improv'd it to a nearer Approach to Truth, but have rather made it worse than better, and more obscure by Interpretation. The Reason of which seems to be from these Particulars.

1. From their manner of Institution, being bred up with a Prejudice against the search of Truth elsewhere, than in Books thereby chained up by the imbib'd Principles and Dictates of their Teachers, and their Minds habituated to a loathing of any thing that offered it self as a Novelty or new Discovery, and upon that account whether true or false rejected. This proceeded partly in the 2d. Place.

2. From an Imagination they have that Arts are already come to their highest pitch of Perfection, and that therefore 'tis in vain to endeavour to find out that by the most difficult way, which might be obtained more easily and fully out of Books.

This Aversion also to Inquiries and New Discoveries proceeded partly also in the 3d. Place.

3. From a too great Reverence and Esteem for the Writings of the Ancients, as supposing those to be the greatest Men for Wisdom and Knowledge, and those Ages wherein they liv'd to be the elder Times of the World; and therefore they accounted it a great piece of Folly, and a kind of Impiety to contradict, or endeavour to be wiser than their Fore-fathers.

Hence proceeded a *Fourth* Impediment, namely,

4. From their following the same Way and Method in illustrating or endeavouring to understand their Writings, that the Authors themselves did in composing them: And therefore 'tis not to be expected that Water should rise higher than the Fountain Head from whence it came; or that greater and more notable Effects should be produced by any other than an extraordinary Method. For the Logick or way of Ratiocination they have made use of, hath been rather an Hindrance than a Furtherance. For neither is the way of *Syllogising* as it ought

nor

nor are their first *Notions* stated aright, and consequently their Axioms and Conclusions cannot be better than the Grounds and Principles from which they were rais'd; so that it does not only not promote real Knowledge, but is injurious to it, by begetting an Opinion of Science where there is no such thing.

5*ly*, From their mistaken Aim or Scope, which is an indeavour by Nice Distinctions to wrest over all the Observations they chance to stumble upon, and make them correspondent with their already believ'd Theory; instead of an indeavour to rectify and regulate those so receiv'd Theories by those Intimations, which careful and accurate Observations would afford. 5.

6*ly*, Such as have a little varied from the receiv'd Opinions, the Alteration has been rather for the bringing in some one New Hypothesis or Opinion of their own instead of the Old, and not for the renewing or Amending the whole. 6.

7*ly*, And some that have indeavoured to make use of Arguments rais'd from the Experiments, and Observations, have been so confounded with them, for want of a Method of proceeding; that it has been to little purpose, save the putting of Men upon new Tryals, whereby perhaps some useful Experiment has been light on, and thereby some latent Error in the former Theories detected. For neither having a true Idea of making Observations and Experiments, nor a convenient way of ordering, nor a right Method of using them, the greater number of them they have, the more are they confounded; for 'tis not the Multitude of Experiments nor the Excellency of them, nor is it indeed the subtile and curious Ratiocinations of an accomplisht Mind, nor the Endeavours of a Multitude of such joyned together, that will be able to do any great matter in this Design; for such Endeavours do at best but raise new Probabilities, and consequently augment Disputes on the one hand, and new Tryals on the other, and all to as little purpose as 'twould be to attempt to find some extreamly difficult Geometrical Problem by the Ruler and Compass, without the Knowledge or Help of Geometrical Algebra. 7.

For where the Examination and Comparison of so great a Number of Particulars is requisite, and where the Process is long, and the Informations but thinly scatter'd, and those also in the Dark, 'tis not to be expected from the most subtile Wit, that the whole Operation should be only performed by the Strength of its Memory, and the Activity of its Ratiocination, though each of them in the greatest pitch of Perfection; much less can it be hoped from Endeavours, that want either of these Accomplishments. And how usual 'tis for one of these to be defective where the other prevails, may be sufficiently evident from the almost Proverbial Saying, that good Wits have ill Memories. Some things indeed have been by lucky Inquirers light on by chance, but those so few and seldom, that 'twas not absurd in *Pythagoras* to offer up a *Hecatomb* for a single Invention in Geometry. I do not here with the Scepticks affirm, that nothing is or can be known, my Design is quite another thing; their end only in denying any thing to be knowable, seems to be Dispute, and tends to Ignorance and Lazinesse, mine on the other side supposes all things as possible to be known, and accordingly studies and considers of the Means that seem to tend to that end, and rouses up the deceiv'd Faculties to seek a Means of recovering themselves out of their Thraldom, and of improving, rectifying and inlarging their Powers. They affirm positively nothing can be known any way, I only that many more things may be discover'd by this Method I here propound, than are already known.

III. *Philosophy hitherto not much improved by the Moderns, and the Reasons why.*

Nor is the State of Philosophy as yet very much improved by our Modern Writers, who have endeavour'd to illustrate or piece up the old, by adding some Placits of their own: There are yet many Impediments to be removed, and many Helps to be supplied before any very great Increase in Knowledge is to be expected. It may be questioned whether piecing or mending will serve the turn, or whether there must not be a new Foundation laid on the Informations of our Senses, and more strictly examined and surveyed by accurate and judicious Experiments and Observations. That which hath had the Cultivation of many Hundreds of Years, and by divers very acute Men in all Ages, and yet as to the Inquiry after the Causes of Natural Efficients, has made so little, if any Progress at all, cannot with any Probability be imagined to afford a Method sufficient for this Inquiry. I do not here altogether reject *Logick*, or the

way of Ratiocination already known; as a thing of no use. It has its peculiar Excellencies and Uses, in ordinary Discourse and Conversation: And affords some Helps to some kinds of Invention, especially of Arguments, as well as to the Memory, by its Method: It affords copious Matter for Disputes as well for, as against the Truth, and teaches how to solve, as well as how to make a fallacious Assertion. It shews how the Modes of speaking and arguing may be reduced to certain Rules, and how each compleat Sentence may be trisected into its constituent Parts, and how those may be various ways shuffl'd and chang'd, and likewise on occasion also how each of these bigger may be divided into three less. But as to the Inquiry into Natural Operations, what are the Kinds of secret and subtile Actors, and what the abstruse and hidden Instruments and Engines there made use of, may be; It seems not, to me, as yet at all adapted and wholly deficient. For 'tis not to be expected from the Accomplishments the Creator has endowed Man withal, that he should be able to leap, from a few particular Informations of his Senses, and those very superficial at best, and for the most part fallacious, to the general Knowledge of Universals or abstracted Natures, and thence be able, as out of an inexhaustable Fountain, to draw out a perfect Knowledge of all Particulars, to deduce the Causes of all Effects and Actions from this or that Axiome or Sentence, and as it were intuitively, to know what Nature does or is capable of effecting: And after what manner and Method she works; and yet that Method supposes little less: Man's Memory seems very shallow and infirm, and so is very prone to forget many Circumstances, besides it cannot so well propound all it does remember, to be examin'd at once by the Judgment; but prefers some things first in order, before others, and some things with more Vehemence and greater concern, and accordingly the Understanding is more apt to be sway'd to this or that hand, according as it is more affected or prest by this or that Instance, and is very liable to oversee some considerable Passages, or to neglect them; and thence very apt to be seduc'd, in pronouncing positively for this or that Opinion, especially being very prone to run into the affirmative way of judging, and wanting Patience to follow and prosecute the negative way of Inquiry, by Rejection of Disagreeing Natures.

Farther, a great Cause why Philosophy has not formerly or of late increased, is because the greatest part of Learned Men have applied themselves to other Studies, Divinity, Law, Physick, *&c.* as being those standing Professions whereby Men of the most liberal and ingenuous Education and Spirit might provide for themselves, and promote their Fortune in the World: Taking only a transient View of Natural Philosophy, in their Passage to other things, thinking it sufficient to be able to talk of it in the Phrase of the School. Nor is it only so now, but it has been so almost in all Ages, so that for about two Thousand Years, of which we have some account in History, there is not above one quarter of that space wherein Men have been Philosophically given, and among such as have been so, several of them have been so far disjoined by Time, Language, and Climate, by manner of Education, Manners, Opinions, and divers other Prejudices, that it could not be expected it should make any considerable Progress: For either because it seemed to promise little, Men for the most part have neglected it, or in those short spaces of time in which it was somewhat more minded and look'd after, what from the want of Dowry belonging to other liberal Professions, what from the Contests of several Theorists, and the Defect of applying of it to such things as might be useful to Humane Life; Men have been either discouraged from the Study, or tired out in it.

Some other Course therefore must be taken to promote the Search of Knowledge. Some other kind of Art for Inquiry than what hath been hitherto made use of, must be discovered; the Intellect is not to be suffer'd to act without its Helps, but is continually to be assisted by some Method or Engine, which shall be as a Guide to regulate its Actions, so as that it shall not be able to act amiss: Of this Engine, no Man except the incomparable *Verulam*, hath had any Thoughts, and he indeed hath promoted it to a very good pitch; but there is yet somewhat more to be added, which he seem'd to want time to compleat. By this, as by that Art of *Algebra* in Geometry, 'twill be very easy to proceed in any Natural Inquiry, regularly and certainly: And indeed it may not

improperly

improperly be call'd a Philosophical Algebra, or an Art of directing the Mind in the search after Philosophical Truths, for as 'tis very hard for the most acute Wit to find out any difficult Problem in Geometry, without the help of *Algebra* to direct and regulate the Acts of the Reason in the Process from the Question to the *quæsitum*, and altogether as easy for the meanest Capacity acting by that Method to compleat and perfect it, so will it be in the Inquiry after Natural Knowledge.

The greatest and most accomplisht Wits for these many Ages have labour'd and sweat in these Inquiries, and yet they have not been able to bring forth any greater Effects than Probabilities: Whereas I cannot doubt but that if this Art be well prosecuted and made use of, an ordinary Capacity with Industry, will be able to do very much more than has yet been done, and to shew that even Physical and Natural Enquiries as well as Mathematical and Geometrical, will be capable also of Demonstration; so that henceforward the business of Invention will not be so much the Effect of acute Wit, as of a serious and industrious Prosecution: And therefore, I hope as I shall not seem to detract from the Parts and Excellency of the Ancients, but rather to admire and magnify their Wit and Industry that they were able to proceed so far as they did, without the Help of this Method, so I hope I shall not be look'd on as vain or boasting, or extolling of the present Abilities of this Age, if by the Prosecution of this Method I expect and assert a much greater Proficiency. And this Art we owe first and chiefly to that excellent Person I now mention'd, who was able to overcome all the Difficulties of Prejudice, with which Mens Minds are usually beset, and to consider and weigh the Nature of things so far, as not only to discover the Impediments of Learning, but to contrive a Method how to free the Mind from them; and likewise to fortify and inrich it with such a Method, as shall be a constant Guide and Assistant to regulate all its Motions, so that by the use of it, it may be able to go through with its Undertaking, and as with an Engine to perform incomparably much more than 'tis possible to do without that Assistance.

SECOND GENERAL.

Of the True Method of Building a Solid Philosophy, or of a Philosophical Algebra.

THIS Method of a Philosophical Algebra, I shall divide into two main Branches. *Philosophical Algebra consists of two Parts.*

The First shall contain the manner of Preparing the Mind, and Furnishing it with fit Materials to work on.

The Second shall contain the Rules and Methods of proceeding or operating with this so collected and qualify'd Supellex.

Of the former only I shall speak at present, reserving the Explication of the later to some other Opportunity. *This I think Dr.* Hook *never wrote; for I have not found any Tract of that kind amongst his Papers.* R. W.

The former therefore has these Three Parts considerable in it, which shall be treated of in three distinct Sections. *The former has three Parts.*

1st. An Examination of the Constitution and Powers of the Soul, or an Attempt of Disclosing the Soul to its self, being an Endeavour of Discovering the Perfections and Imperfections of Humane Nature, and finding out ways and means for the attaining of the one, and of helping the other.

2*dly*, A Method of making use of, or employing these Means and Assistances of Humane Nature for collecting the Phenomena of Nature, and for compiling of a Philosophical History: Consisting of an exact Description of all sorts of Natural

Natural and Artificial Operations, or a Method of making Experiments and Observations for the Prosecution and Examination of any Philosophical Inquiry.

3dly, A Method of describing, registring and ranging these Particulars so collected, as that they may become the most adapted Materials for the raising of Axioms and the Perfecting of Natural Philosophy.

Of the Powers the Soul.

Part I.] There are two things considerable, the Imperfections of our Natures and the Perfections as to the first, the Imperfections: The Mind of Man suffers under various Prejudices, which do either darken or clog its Faculties, so as that it cannot exert and make use of them, and these we are subject to.

§ 1. Of the Imperfections thereof, and how they may be helped.

1st. Cause of Prejudice from our own Nature.

First, From our own Nature and Constitution, as we are Men, and indued with such Organs as are capable of taking Information of the Operations of Nature, only by some few peculiar ways of Sensation: Man is not indued with an intuitive Faculty, to see farther into the Nature of things at first, than the Superficies and out-sides, and so must go a long way about before he can be able to behold the Internal Nature of things, and in this Progress there is very great Danger of his miscarrying; for endeavouring to make use of the Informations of Sense, for that end, there are so many ways of mistaking, that most have fallen into them: Some have fallen presently upon abstracted Notions, and flown immediately from a very few particular Sensations to the most General and Universal Conclusions and Theories, others on the other side have been so amazed and confounded with Particulars, that they have only proceeded, groping on after other Particulars, thinking at last they may by chance light upon something that may afford them Information in what they look after: Some others have endeavoured to intermix both these together, but with so very ill Success, that they have left but little Fruit of their Endeavours.

The chief Design of the Senses.

The greatest Design indeed of the Organs of Sense, seems to have been for some other Use than for the acquiring of this kind of Knowledge, and to have a very great Affinity with the Senses of other Animals; which seem to have been made purposely for the peculiar Use of each several Species: The Sight for discovering Conveniences and Inconveniences at a greater Distance as well as near at hand: The Ear, for receiving Warning or Information from Sound, where the Eye could not assist: The Nose, for distinguishing by the Effluvia of Bodies, of wholsome or unwholsome Nourishment: The Taste for the same purpose, by the Dissolution of them in the Mouth, and for the determining of the Quantity requisite to be taken at a time: The Feeling, for the Sensation of External Textures or Motions. But yet the greater Perfection of Ratiocination in Man, may make them capable of other kind of Informations: Though indeed of themselves they afford little as to what we are looking after. The Apprehension also or common Sense is not of the Nature of the things so sensated, but only with some peculiar Reference to our own Structure. Thus some Tastes are sweet or sowre to us, which I make a great doubt whether they are so to the Senses of other Creatures: And those things seem pleasant in the Smell to other Creatures Senses, which to our Senses seem quite otherwise.

Our Apprehensions appropriated to our Species.

So that our Apprehensions of things seem to be appropriated to our Species: And that if there were another Species of Intelligent Creatures in the World, they might have quite another kind of Apprehension of the same thing, and neither perhaps such as they ought to be, and each of them adapted to the peculiar Structure of that Animal Body in which the Sensation is made. Thus we, by having our Organ of Hearing moved by a certain Motion of the Air, caused by a quick Vibration of some solid Body, have a peculiar Conception of Sound; not to be exprest to a deaf Man, or one that has not the same kind of Organ or manner of Apprehension. We do not so conceive of it as of a Notion in the Sonorous Body, but as of a Quality which we know not how to express our Conception of, but as of something that does pleasingly affect our Hearing, and we call that Conception we have of it Sound. But if we observe that Propriety in the sounding Body by the Eye, we have there quite another Idea of it impreſt on our Phantcy, and nothing at all of the Imagination of Sound, but only of a

Body

Body in a Vibrative Motion. And if we sensate that Propriety in the Vibrating Body by our Feeling, we have quite a differing Idea of the same Propriety, and there we have an Imagination of it, which we call tingling or tickling, or Heat: From which it seems evident, that those Imaginations we have of things, are not according to the Nature of the things themselves; but only appropriated to the peculiar Organs, by which they are made sensible to the Understanding: So that had we other kinds of Organs, we should have other kinds of Conceptions of those Effects. And those perhaps we have may be quite differing from what other Creatures have of the same thing. Thus that Constitution of Air, which we call dark, is not so to Cats and Owls, and the like; nor is it so indeed to a Man if his Eyes are assisted by some peculiar kind of Instruments, as I have divers times found by Experiment, wherein I have been able to see to read the Letters and Words distinct in such a Light, wherein, without that help, I have hardly been able to see the Lines. Thus Heat and Cold are only Relative to our Constitution, as is evident by the Weather Glass, which feels many Degrees of Heat before it be sensible to us.

Remedy for these Prejudices from the Senses.

The best Remedy therefore that seems to be against this Prejudice is, to compare the several Informations we receive of the same thing, from the several Impressions it makes on the several Organs of Sense and (by a Rejection of what is not consonant) by degrees to find out its Nature, and thereby to inform the Intellect with a Notion of the thing; which is not according to this or that Idea, rais'd from the Impression of this or that Sense, but by a comparative Act of the Understanding from all the various Informations 'tis capable of receiving, more immediately by any of the Senses, or more mediately by various other Observations or Experiments.

We ought to conceive of things as they are part of, and Actors or Patients in the Universe, and not only as they have this or that peculiar Relation or Influence on our own Senses or selves. And for this cause we ought to be very careful in what Sense we understand Philosophical Words already in use, for these having been for the most part made by such as had those Prejudices remaining on them, and we also having first received in or imbibed the Senses of those words, whilst under the like Prejudices: It cannot be expected but that the Notions must be very confused and inconsistent with the things themselves.

2d. Cause of Prejudice from the peculiar Structure of every Man, or particular bent of his Studies.

Another Cause of Prejudice is from every Man's own peculiar Structure: Every Man has born with him, or contracted by some way or other, a Constitution of Body and Mind, that does more or less dispose him to this or that kind of Imagination or Phant'sy of things, and every one has some kind of Accident or other, that does more or less dispose him for this Opinion or that Operation of the Mind as well as of the Body. Thus some kind of Constitutions of Body does more incline a Man to Contemplation, and Speculation, another to Operation, Examination, and making Experiments, and look what way the Constitution of a Man, or some other Accident has inclin'd him to, that way almost are bent all his other Faculties and Powers. Thus one is for speaking, and another for Writing, and all things are look'd on, or disregarded by such, as they are subservient to such an end: And not only many things, not very instructive, are let pass; but sometimes also many things that have no such Indication in them, are brought in as 'twere by the Head and Shoulders, and wrested, to be made compliable to this or that Opinion. Just as a Man that is troubled with the Jaundice, supposes all things to be Yellow, and all things he eats, till otherwise prevented, serve to augment his Choler, by being chang'd into it: Or a melancholy Person, that thinks he meets with nothing but frightful Apparitions, does convert all things he either sees or hears into dreadful Representations, and makes use of them to strengthen his Phant'sy, and fill it fuller of such uneasy Apprehensions, so is it in Constitutions of Mind as to Philosophy. Thus *Aristotle*'s Physick is very much influenced by his Logick: *Des Cartes* Philosophy savours much of his Opticks: *Van Helmonts*, and the rest of the Chymists of their Chimical Operations: *Gilberts* of the Loadstone: *Pythagoras*'s and *Jordanus Brunus*'s, *Kepler*'s, &c. of Arithmetick and the Harmony of Numbers. The Philosophy, of some Divines, is intermingled with Divinity; of others, with Spirits and immaterial Agents: Astrologers endeavour to bring

all things under the Power and Influence of Cælestial Bodies, and would have them the chief Efficients of the World, and indeed every one according to the things he most fancies naturally, or has accidentally studied, and is most conversant in, endeavours to make all things he meets with, agreeable or subservient thereto. And he is much the more inclin'd to maintain and defend this or that Opinion, if he has once any way publickly owned it, whether in Writing or Discourse, so far too perhaps sometimes, that though at first he defended it when he thought otherwise, yet by continuing to do so for the maintaining of an Argument, or of his Credit, he at last comes to believe it, and the Fallacy, which he endeavoured to put upon others, imposes most of all upon himself.

The Remedies against this. The best Remedy against this Inconvenience, is the finding out of what Constitution ones self is, and to what one is either naturally or accidentally most inclin'd to believe, and accordingly by reasoning and comparing things together to consider what the things themselves hint, and what Intimation proceeds from ones own Constitution.

Next, to accustom ones self as much as can be for a while at least, to a quite contrary Supposal or Practice: Or which is indeed more general, not to receive any Notion for certain, till throughly confirm'd by very Cogent Arguments and Ratiocinations, and always most to suspect that which seems most consonant and pleasing to our Inclination: Thus one, that fancies Novelty should be most cautious of what he admits for Truth or Demonstration that is new; lest his Mind being prejudiced with a Love of Novelties, should otherwise impose upon his Belief and Understanding: Thus one that is addicted to Chymical or Mechanical Operations, should be very cautious of admitting of a Chymical or Mechanical Solution, and so for the rest; for that may seem very probable and rational to one, whose Mind is so inclin'd; which to one of another Constitution will seem most unlikely and absurd: So one, inclin'd to Speculation and abstracting, should bridle his Nature and not fly too soon to the most geral Conclusions, for as a Nature so inclin'd does willingly oftentimes impose upon it self, and longs to be acting, and running in its proper and most known Road, and avoids that Method it is not acquainted with, finding it very uncouth and full of many new Difficulties. So though the reason should be satisfied, and the Phant'sy full of the Truth of this or that Opinion, another Mind otherwise qualified, may find many Flaws and Errors in it, and perceive many things to have proceeded from Prejudice.

A 3d. Cause of Prejudice from Education and the unaccurate use of words. A Third Cause of Prejudice is from Language, Education, Breeding, Conversation, Instruction, Study, from an Esteem of Authors, Tutors, Masters, Antiquity, Novelty, Fashions, Customs, or the like. The Philosophical words, of all Languages yet known in the World, seem to be for the most part very improper Marks, set on confused and complicated Notions, together with the Learning of which Language we have imbibed those confus'd Notions, which are commonly understood by the mention of those Words, these Words therefore being used in our Discourse, and those Notions in our Ratiocinations, must needs very much perplex the Operations of the Mind, and much puzzle and disturb the Ratiocination. The Notions of the Mind therefore ought to be stated aright, and the Signification of many words ought to be more defin'd, divers new Words also to be made and set upon more distinct Conceptions and Notions, and many other words ought to be wholly blotted out and rejected, as either signifying something imperfectly, which is otherwise better expreſt, or else a Phantasm, for which there is no ground in Nature: Education also, Breeding, Conversation and Instruction, do all of them very much work upon the Affection, and serve to sway it this way or that way according to the Will of the Teacher, whereby the Understanding becomes inslaved to the Dictates of Education, and the Ratiocination bound up or fettered by the *Placits* of a Tutor, so as not to be able to lay hold of Truth though never so fairly offer'd: For most of those things being instilled into our Minds when young and tender, and incapacitated to distinguish between Assertions and Demonstrations, and between Opinions and Realities, have taken so deep a Root, and so possest the Mind with Prejudice against many Ways and Methods of Truth, that they are not freed without very much Trouble and Circumspection; and 'tis a kind of Soveraignty

which

which Men do most of all affect, to captivate and inslave Mens Minds to a Reverence or good Opinion of their Abilities, and Doctrines; so that we have not only a great many Enemies to Knowledge and Freedom, lodg'd within our Breasts and Fabricks, but are every way encompassed; and those which seem our greatest Friends, do in this regard prove our greatest Enemies.

And this Bond is so much the more difficult to be shaken off, if together with their Doctrines we have entertain'd an Admiration, Awe, Reverence, or Esteem of the Persons themselves that instructed us, or were the Authors of the Books or Opinions we have approv'd. Add to all these Multitudes of false Opinions, which have been impos'd upon our Belief by fallacious Demonstrations in Discourse and Conversation: For Words being ill set Marks on very confused Notions; the Reason of a Man is very easily impos'd on by Discourse, unless the Mind be extreamly attent, and watchful, not to take any thing for granted, that is not evidently prov'd, and very perspicacious in finding out the distinct Notion of the Word, in every such Sentence, wherein it is used, for the Notions signified by some words being very many and very perplex, unless that Notion there meant be (by some Periphrasis or otherwise) determin'd to be always signified when that word is pronounced; the Circumspection of the Intellect is so slow in examining over Particulars, and running over all the particular Siginifications some words may have, that it may very easily be impos'd upon by a quick and cunning Disputant, and being once impos'd on without being detected, the Admission of that Error is the occasion of bringing in Multitudes of others; Error being a kind of Ferment which tends to the turning or conforming all things to its own Nature, and like an infected Person has Influence on all things it comes near.

The best Remedy, for which Inconvenience, is not to consider so much what the Person is that instructs, as how true the things are he asserts, nor of what Authority those Authors are esteem'd we read; but what Arguments are by them brought for that which they assert, and if we are so over-born with Love, or Reverence, to this or that Author, as to esteem of whatever he says, whether right or wrong, than to imagine what he says to be spoken by one *against* whose Person or Doctrine we have a Prejudice; for that will somewhat incline the Mind to a contrary Opinion, and thereby help to ballance the Inclination of it the better, so that it shall not reject Truth when offer'd on the one hand, nor embrace an Error when asserted by the other. *The Remedy for these.*

Another way is to consider with what Vehemence and Earnestness two contrary Opinions are believed and asserted on both sides, and to consider what are or have been the occasions to incline the Parties to those Opinions or Doctrines they maintain, and as near as may be to distinguish what manner of Actings there are which proceed from Reason, and what from Prejudice, and from thence to endeavour to fortify the Mind with Arguments against Dogmaticalness and Opinionativeuess upon too small Grounds, and to accustom the Mind to an Equilibrium or Indifferency, so as to be sway'd and turn'd to the embracing of Truth from whence or whomsoever brought.

A third way of remedying or rooting out Prejudices already impos'd on us, and of preventing the like Impositions for the future; is an Hypothetical Scepticism, whereby to impose upon our selves a Disbelief of every thing whatsoever, that we have already imbraced or taken in as a Truth: And in so doing, to throw out not only those things we may a little doubt of, but even all those things of which we are most confident, and those especially which our particular Constitutions seem most of all to incline us to believe, rejecting them all as Impostures and Fallacies, that have by some indirect means or other crept into our Understandings, or have been impos'd upon our Minds by some or other that either wilfully or purposely endeavoured to deceive us, which having so done by leasure and degrees, not too many at a time, by much Caution and Circumspection, not without weighing well all the Arguments and Circumstances that can be alledg'd either for or against them by many Tryals and Experiments and Siftings, to take such of them in again, distinctly and determin'd as can produce sufficient Evidence of Truth: Others, whose Truth we cannot make out, to reject them in all our Ratiocinations as uncertain and of doubtful Credit, and not to be relied on; till by farther Tryals or Experience

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the Truth or Falshood of them be made evident, and then accordingly to deal finally with them by a Reception of them into the number of Truths, or a final Rejection of them as Falsities and Errors.

§. II. Of the Perfections of humane Nature, and how they may be improved.

The Second thing to be done, is the finding out the Perfections of our Nature, and the particular Helps we have for Information, and with what means of Discovery we are furnisht, and how those Means may be improved. Now the Faculties of the Soul are Three; Sense, Memory and Reason, or Ratiocination the particular Business, of each of which is to be examined how far their Ability and Power, when in the greatest Perfection extends, and wherein each of them are deficient, and by what means they may be assisted and perfected.

First, As to the Senses their Examination, and how assisted.

The first therefore that will be necessary to this end, will be the Examination of the particular Constitution of our Senses, to see what Propriety of a Body each of them takes notice of, and how far they are capable of assisting in the finding out of that Propriety, and wherein that Propriety of a Body does consist, where the Help of the Senses fails or leaves us in this Inquiry, and then what Instruments will farther assist the Senses in this Inquiry, and how far also their Power will extend, and by what means we may be farther assisted in this Search.

The differing ways of Sensation we find to be Five, which are provided with as many distinct Organs; the 1st. and most Spiritual is plac'd in the Eye, a 2d. in the Ear, a 3d. in the Nose, a 4th. in the Mouth, the 5th. over the whole Body.

The Sense of Seeing.

The Fabrick of the Eye is most admirably contrived for receiving in the Impression of the Rays of Light, and for so disposing and ordering of them, that those Rays that proceed from the several Points of any Object that either emits or reflects Light, and fall on the Cornea of the Eye, shall be all of them collected into so many distinct Points at the bottom of the Eye, and that in the same Order, that the Points were scituated in respect of the Eye, but in a lesser Proportion, according as the Object is farther removed in distance from the Eye, and in a greater Proportion as the Object is nearer; so that the Picture or Representation of the Object in the sensible part, or bottom of the Eye, may according to the Posture or Distance of it from the Cornea, be either less equal or bigger than the Object it self: Whence were the Sense of distinguishing the Parts of the Picture at the bottom of the Eye, as nice and particular as the Body has distinct Parts, we might very easily by this Sense only find out the Texture or Schematism of any Body within our reach; for 'tis very easy by one single Lens of a small Sphere, or of a very Convex Figure, plac'd just before the Eye, to make the Object distinctly visible, when much nearer to the Cornea than the Cornea is to the bottom of the Eye, and consequently the Rays crossing near the Cornea, the Picture or Representation at the bottom must be bigger than the Object it self; but the discerning Power of the Sense is not capable of making Distinction of Parts when they are smaller than such a Bulk, the Terminus of which, I find to my Eye, to be when the Representation is about the Bigness of the smaller Pores of Wood: Which I find by this Expedient, by a convenient single Lens I bring the Object I look on so near my Eye, that the crossing of Rays in the Eye may be about the middle Space between the visible side of the Object, and the bottom of my Eye; from whence it follows, that the Picture of the visible part of the Object is as big as the thing represented: But the Eye being then at most but capable of seeing or distinguishing those Pores; it follows, that (if the Cause of that Distinction be from the ends of the Filaments of the Optick Nerve, as *Des Cartes* ingeniously supposes) the Filaments cannot be smaller than the Microscopical Pores of Wood, and that the Eye is uncapable of distinguishing the Parts of any Picture that are smaller than those: So that any Object being so far removed from the Eye as to make the Picture of it on the Retira less than a Microscopical Pore, that Object becomes invisible, if at least it be but of a dull Radiation; for if it be otherwise of a very bright Radiation, the whole Filament is mov'd by having one part of it powerfully acted on, and so we have a Sensation of the Object, the same as if it were much bigger, and this seems to be the reason why the Stars appear to

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our naked Eye many Thousand times bigger in bulk than really they are, and even as big as through a long Telescope, which would not be if our Sense were sufficiently fine and nice. I could have instanc'd likewise in the other Senses, but this may suffice for an Example.

Having considered therefore the Power and Property of the Sense, we may be so much the better inabled to find out its Defects, and by what means it may be improv'd.

What this Sense informs us off, and how its Defects may be helped.

The Eye therefore presenting to the Sense a Picture of the Objects that are plac'd before it, is capable of Informing of the Sense of Four or Five Qualities of Bodies, first of the Radiation, or the shining or not shining Properties of Bodies, next of the Pellucidity and Opacousness of Bodies. *3ly,* Of the Reflexiveness of Bodies. 4. Of the Figure, Magnitude and Position of Bodies. 5. Of the Motion; when therefore these Proprieties of Bodies are inquir'd after, the Information concerning the three first must be wholly fetcht from this Sense, but the Information concerning the other two may be had partly from this and partly also from some of the other Senses. In the discovering of each of these Properties, the Sense may be various ways assisted, both by Engines, Observations and Experiments.

1st. It informs of the Radiation of Bodies.

As First, for the discovering of the shining Properties of many Bodies, there are these two more immediate Assistances; the first is by placing the Eye and Object in such a place where all other Radiations of Light may be wholly excluded, for by this means, many weak Degrees of Radiation will become visible to the Eye, which in a greater Light would be altogether insensible, and this proceeds from a Twofold Cause; First, because there is no stronger Impression made on the Eye from the Radiation of any other Object, which is the reason why the Stars disappear in the day-time: Next the Eye thereby opens its Apperture much wider, and so admits a much greater number of Rays, whence 'tis that the Eye by a long stay in a somewhat dark Room begins to see and distinguish things almost as well as in a much lighter, because the Apperture is not opened in an instant but by degrees. Hence the Radiation of Gloworms Tails, of the Juice of the Hundred Legged Worm, of rotten Wood, of Salt Water, of Putrifying Fish, of a rubbed or warmed Diamond, and the like, becomes visible to the naked Eye in a dark Room, which disappears and vanishes in a bigger Light, but because we find that the more Rays the Eye is capable of collecting, the better is it able to discover this Propriety where it is very languid; therefore if the Eye can by any Contrivance of Glasses be made capable of collecting a much greater quantity of Rays from a Point, and making them meet on the Retina, 'tis not improbable but that a much greater number of Bodies may be discover'd Radiant than are yet suppos'd to be such, perhaps also it may discover to us the Properties of many other Motions; for it seems not improbable, but that the Motions of Corrosion in many Bodies may generate some faint Degree of Light; perhaps also, the Motion of Fermentation, and many Degrees of Heat, much less than what we now esteem requisite, may produce the like effect. And that this help of this Sense in this Inquiry, is not a Supposition without any ground from the Nature of the thing, will appear first in that Cats and Owls, and Bats, and divers other Creatures, are able to see in a much less degree of Light than is sufficient for a Man's Sight. Next from this, that making Tryal upon this very Supposition with a convenient Lens, I have divers times been able to read in the Night by the help of it, when I could hardly with my naked Eye distinguish the Lines. Now this being done with an ordinary double Convex Spherical Lens, 'tis not improbable but that much more may be done by a double Hyperbolical one, if the way of making it can be found (which seems not altogether improbable to be done with Niceness enough as to this use of collecting the Rays of Light, though in Glass it be very difficult to be done accurate enough for distinct Vision) or by the help of an Elliptical Concave, by placing the Body to be examin'd in one of its Focuses, and the Eye with a Concave Lens before it in the other, and for this use 'tis easy enough to make a Concave sufficiently accurate of an Elliptical Figure.

With some such Glasses it were very desirable that Tryal should be made with several Bodies in a perfectly dark Room, such as an unrubb'd or cold Diamond, with corroding Bodies, with fermenting Bodies, and such as are treated by various other ways.

Farther, If our Eyes ſhould not be capable of being brought up to ſuch a Degree of Niceneſs in Senſation as is requiſite; 'tis not impoſſible but that by ſome Obſervations and Tryals, one may come to the Knowledge of the Truth as to this Inquiry. 'Tis poſſible perhaps to find a way to diſcover whether a Cat or ſome ſuch other Creature can ſee by ſuch a Light, which I think might be many ways done, were it not much eaſier and more certain to make a Diſcovery with ones own Eyes, and that perhaps to as great, if not much greater Degree of Nicety than Cats can.

There may perhaps alſo be found, upon farther Inquiry into the Nature of things, ſome Body that is acted on or mov'd by Light, which is much more ſenſible of the Degrees thereof than the Eye, which, if found, would be a huge Aſſiſtance to a diligent Inquirer into this Property of Body; and for this we may have ſome reaſon to hope, if we conſider, how lately 'tis that the Beard of an Oat was found out for the Senſation of the Moiſture or Dryneſs of the Air: And 'tis not yet above ——— Years ſince I firſt diſcover'd the like, but ſomewhat more nice Property in the Seeds of *Geranium Moſchatum*: *Athanaſius Kircher* tells us, that the Sun-Flower follows the Light of the Sun, but whether true or not, I diſpute not now: Sufficient it is to the preſent Deſign (which is only to hint by what ways poſſibly the Senſe may be aſſiſted) to ſhew that ſuch an Help is not altogether improbable to be found. Perhaps alſo the augmenting the Bulk of ſuch a Body, may make that Propriety become ſenſible which might otherwiſe lie hid.

2dly, Of their Pellucidity. Next as to the Pellucidity, Colours, or Opacouſneſs of Bodies, the Eye may be various ways aſſiſted in the finding out that Propriety and reducing its Degrees to a Meaſure or Standard. One way is, by placing the examining Eye in a Room perfectly darkened, without any Cranny to admit Light into it, ſave only one or two Holes; againſt one of which whilſt the other is quite ſtopt the Body to be examin'd may be plac'd, of various Thickneſſes according to its diſtinct Nature: The more tranſparent it be, the thicker Maſs of Body may be ſeen through, and the more opacous, the thinner muſt the plated Body be: And by this Contrivance a great Number of Bodies will be found *aliquatenus* tranſparent, which are judg'd wholly opacous, and by the Thinneſs, requiſite to admit a ſenſible Degree of Light through, may the comparative Opacity of Bodies be found and determin'd.

A ſecond way whereby the Eye may be aſſiſted in this Inquiry, is by the Microſcope; for the Body being, by beating or otherwiſe, reduced into ſmall parts, the Microſcope does plainly diſtinguiſh thoſe Particles *aliquatenus* tranſparent. Thus the parts of moſt ſorts of Stones when reduc'd to Sand, appear manifeſtly tranſparent, the moſt Metalline and other Colours uſed by Painters, appear to conſiſt of ſomewhat tranſparent Parts, and very many of thoſe Bodies which the Eye is not able to diſcover ſuch the other way, is by this means very eaſily manifeſted; and indeed, there ſeems to be ſcarce any Body in Nature, unleſs perhaps ſome of the white Metaline that are not in ſome Degree or other tranſparent, and this is ſo much the more probable; ſince we find that the moſt compacted, we know in the World, namely Gold, is manifeſtly tranſparent, when beaten very thin and held up againſt the Light.

Next, the Tranſparency, Opacity, or Colours of Bodies may be farther inquired into, by mixing and incorporating ſeveral of them with divers ſorts of appropriated Homogeneous Tranſparent Bodies; that is, with ſuch as with whom they will readily mix. Thus Cochineel, which looks like an opacous dark Body, when mixt with Water that diſſolves it, yields a tranſparent Crimſon Colour. Thus Iron melted with Glaſs yields a kind of Red. Thus Copper mixt or diſſolv'd by ſome Saline Liquors yields a Green, with others a Blew, with others a Purple. Thus many ſorts of Stones and Earths, which ſeemed before perfectly opacous, by this means ſhew their Colour.

3dly, Of their Reflexiveneſs. Thirdly, The reflecting Property of Bodies may be partly diſcover'd and diſtinguiſht by the above-mention'd Methods, and partly alſo by reducing the Bodies into the Shape of a Burning-Glaſs of a determinate Bigneſs, and ſmoothing the Superficies of it very well; for by the comparing of divers of thoſe Inſtruments

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so made, by the Effects of burning they produce when expos'd to the Sun, 'twill not be difficult to determine the comparative Power of reflecting the Rays of Light.

Another way of judging of the comparative Reflection of Bodies, may be by viewing them in a Microscope in several Lights, and with several Apertures; and by pitching upon some one Body to the Strength of the Reflection of which the proportionate Reflection of all the rest may be referr'd; for by knowing the Smalness of the Aperture of the Glass requisite to make each of them disappear, we know also their comparative Power of Reflection.

Tryal also of this Property may be made with the Eye, only assisted with several Apertures, and only finding the Smalness of the Aperture requisite to make the Reflection of Light from such a Body to disappear.

The Use of which Inquiry into this Property of Bodies may be of very great Use, as to the Invention of the Nature and Texture of Bodies.

Fourthly, As to the Magnitude, Figure, and Position of Bodies, though the Eye can pretty well guess at them in Bodies pretty near, and within its reach as 'twere, yet beyond that, and even in that too if Accurateness be required; it is deficient, and does much need the Help of Instruments and Contrivances to assist it. *4thly, Of their Magnitude, Figure, and Position.*

As to the Magnitude and Position of Bodies; the Eye may be assisted by making Experiments with divers sorts of Mathematical Instruments, especially by the Use of some which I shall afterwards describe, by which means the Magnitude, Distance, and Position of the Celestial Bodies, that are so far out of our reach, may be much more accurately measur'd, than by any other sort of Instrument yet made publick to the World.

As for the Figure and Magnitude of some Bodies; the Eye (being unable to distinguish the Position of Parts, when the Appearance of them is less than such an Angle) may be assisted by two sorts of Instruments, namely the Telescope for the appearing Figure of small Bodies, absent, and out of our reach; and the Miscroscope for such minute Bodies as we have access to; the Melioration of both which Instruments would be a Matter of huge Concernment, as to the Resolution of this Inquiry. And I cannot doubt, but that the Industry of some of the many Ingenious Men, that are now imploy'd about it, will be so successful as to accomplish it.

The Figures also of some, inaccessible Bodies may be judg'd by the Observation of divers Circumstances: Thus the ingenious Monsieur *Hygens* discover'd the true Figure of the Body of *Saturn*, which had so much puzled Learned Men before.

Fifthly, The Eye may be various ways assisted for the Discovery of the Motion and Velocity of Bodies; as by measuring the time it has past such a length or space by the help of a Pendulum, and whereas the Motion of some Bodies is so slow that their Velocity does not make a sensible Angle to the Eye, therefore the Velocity of such Motions is best gathered by Consequents, such as all the Motions of the Celestial Bodies, many of which cannot be otherwise discern'd. *5thly, Of their Motion.*

The Internal Motions also of Bodies may be discover'd by various Effects, such as those of Fermentation, Heat, Corruption, Generation, Growth, Decay, Dissolution, Coagulation, and the like, from the accurate Observation of divers of which compared with several other Circumstances, may be very well collected the Degree, Nature and Manner of Internal Motions.

The Telescope also and Microscope may much assist the Eye in this Inquiry; thus the Body of the Sun has been found to vertiginate on its Axis. I did also by the Help of a good Telescope, about two Years since, discover the Motion of ♃ about its own Axis, by means of a somewhat darker spot in the Body of it; the Moon, ♄, and ♃ have also been found to have a Motion of Libration, the Satellites of ♃ and Moon of *Saturn* to make their Periodick Revolution in such or such a time. The Microscope also can make the Motion of the Legs of Mites, and many other small Creatures sensible, as also the Motion of the Hand of a Watch; and perhaps also Miscroscopes may be made so accurate as

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to discover the vegetating Motion of Plants (though I confess I have not yet found the Growth of any so fast as to be quickly sensible through a Microscope) and of corrosive and corroding Liquors, and the like; however in the search after every of these the Eye is not left without many Assistances, whereby it may perfectly discover what it seeks after.

Thus for the finding the Velocity and Strength of falling Bodies, I made this following Contrivance, which succeeded according to Expectation.

A Description of the Instrument for falling Bodies. Vid. the Fig.

The Instrument was thus contrived. See the 1st. Figure in which A B C is the Pedestal or Bottom to sustain the Scales and other Parts. D E a double Beam, or two Beams well fastened together by cross pieces of Steel at the Ends, or other ways, between the two Cheeks of which the Steel Ball F falls from any determinate Height upon the Steel Plate or Basin G; and if by that Fall it moves the double Beam and the Counterpoise H, lying in the Scale I K, it gives the small Spring L a free Passage to slip between the end of the double Beam and the Stay M, by which means there is given a certain Sign whether the falling Body has moved the Scale or Counterpoise so far, as to admit the very thin Edge of the Spring L, the rest of the Contrivance is obvious enough from the Scheme it self. " *That the Reader may the better understand* " *the Use and Performance of this Instrument, I have added some of the Experi-* " *ments made with it, as I find them entered in the Registers of the Royal Society,* " *which I thought might not be unacceptable to the Ingenious.* R. W.

The Account is as follows,

" *The Instrument being thus prepared, I.* (i.e. *Dr.* Hook) *put into the oppo-* " *site Scale* I K, *a* 4 *Ounce Weight* H *that is four times the Weight of the Steel* " *Ball* F, *and letting this Steel Ball or Bullet* F *fall from just the Height of an* " *Inch above the Steel Plate* G (*by cutting the Thread that held it*) *I found it* " *very sensibly to move it; I repeated the Tryal so long, till I found that letting* " *this Ball fall but* $\frac{4}{21}$ *of an Inch above the Plate, it would move the Beam so as* " *to admit the Spring; but if I let it fall from a less Height it would not, then* " *I put in* 8 *Ounces, and by several repeated Tryals, I found* $\frac{2}{3}$ *of an Inch to be* " *the Height requisite for the falling Bullet to pass, before it would move* 8 *times* " *its own Weight, I proceeded farther, and from the Experiments collected in the* " *first Table* A.

" *Afterwards I took a small Ball of Clay that was very ronnd, and exceeding* " *hard, in Weight near a quarter of an Ounce, and proceeding with this as I had* " *done with the Steel, I collected from the several Tryals the Second Table* B.

TABLE A.

$\frac{4}{21}$	4
$\frac{2}{3}$	8
$1\frac{3}{4}$	16
$2\frac{1}{3}$	32
$3\frac{1}{2}$	48
$3\frac{5}{6}$	64
5	96
$6\frac{3}{4}$	128

TABLE B.

$\frac{1}{4}$	4
$\frac{3}{5}$	8
$1\frac{4}{5}$	16
$5\frac{4}{5}$	32
18	64
36	128

" *The first row of Numbers in both which Tables shew the perpendicular Height* " *from which the Balls were let fall, to move the several Counterpoises, which* " *are noted by the second Row of Numbers in both Tables,* 4, 8, 16, &c. *signifying* " *the Counterpoise to be* 4, 8, 16, &c. *times the Weight of the Ball.*

" *Which Tryals and Observations, though they do not absolutely answer our* " *Expectation as to the thing sought, that a Body moved with twice the Celerity* " *acquires twice the Force, yet they serve for several good Uses; for first, it shews* " *us the Difficulty of such Tryals, where though all things as to ones Sense appeared* " *the same, yet some small insensible Circumstances made the Effects so differing,* " *that we need not wonder, if oftentimes when we endeavour to repeat an Experi-*

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" *ment delivered upon good Credit, as done by another with such or such Mate-*
" *rials, thus or thus us'd; though we do all things just according to Prescriptions,*
" *yet we miss of producing the promised Effects. And therefore I conceive it not*
" *less instructive to any one that may attempt to make a farther Discovery of*
" *this kind, to shew wherein our present Tryals were deficient, than to declare*
" *what they did.*

" *Now the first and greatest Defect in our Tryals seems to be, that there is a*
" *yielding in the Materials which we make use of; first, that part of the Ball which*
" *first touches the Plain is a little flatted by the Knock, and consequently a part*
" *of the Force is returned into the Ball, and so lost. Secondly,* The *yielding of the*
" *Plate; thirdly, the stretching the Ears of the Plate, every one of which yieldings*
" *must necessarily take off from the Force of the falling Ball, that it cannot work*
" *the expected Effect so accurately as it would were those remov'd.*

" *Next in this Contrivance, there is besides the Counterpoise of Weights, a*
" *great deal of a massy heavy Body, namely, the double Beam, and the Plate, and*
" *Scale; all which, or at least the greatest part of it, must be moved, and that*
" *with a very quick and sudden Motion before the Spring, though it be so very*
" *thin can get between the End of the Beam and Stay, to make the Effect sensible.*
" *Now this quick Motion it self does require a considerable Strength to effect it,*
" *were the Counterpoise remov'd; for such a Bulk of Body cannot be put into such*
" *a quick Degree of Motion, but by another Bulk of Body mov'd with a determinate*
" *Degree of Celerity.*

" *Thirdly,* The *Scales and Counterpoise may be all mov'd, and yet the small*
" *Spring, though it be so thin as not to be above* $\frac{1}{40}$ *or* $\frac{1}{50}$ *part of an Inch in Thick-*
" *ness, yet is that a Space, and the Beam may perhaps be moved half that way,*
" *and the forcible Resistance of Gravity may make it return back again before it*
" *have mov'd the whole Space, so that it may be moved a little, and yet not so*
" *much as to make it sensible by this Contrivance. Nor would the making that*
" *Spring thiner much mend the matter, since there are other Inconveniences: And*
" *that this is so, I try'd the following Experiment, when in my last Tryal I had*
" *found that the Ball of a quarter of an Ounce required to be let fall from the*
" *Height of 36 Inches, before it would move the end of the Beam so much as to*
" *let in the Spring, when there was 128 times its Weight of Counterpoise, that I*
" *might try whether the same Ball would not sensibly move the same Counterpoise,*
" *though it were let fall from a much smaller Height. I placed the Spring so as that*
" *it was between the Stay and the end of the Beam, but not so far in as it would*
" *spring in if it were left free; then letting fall the Ball at 4 Inches Height, I*
" *found that it had moved the end sufficiently to let the Spring slide in as far as*
" *it would, I put the Spring in Order as before, and let it fall fron* $3\frac{1}{2}$ *Inches*
" *Height, and found it there likewise to move the end of the Beam.*

" *I repeated it again at 3 Inches Height, but though I try'd several times, I could*
" *not find that it had at all moved or let slip the Spring. Now as exact Tryals*
" *of this kind may be very useful in Mechanicks, so could they be made with Bo-*
" *dies perfectly solid, would they be for the Establishment of one of the chief Prin-*
" *ciples of Philosophy, namely, the Strength a Body moved has to move another.*
" *And though* Des Cartes *puts it as a Principle, that* Si Corpus C plane qui-
" escceret essetq; paulo majus quam B, quacumq; cum celeritate B moveretur
" versus C nunquam ipsum C moveret, sed ab eo repelleretur in contrariam
" partem, *and gives this Reason for it,* Quia Corpus quiescens magis resistit
" magnæ celeritati quam parvæ, idq; pro ratione excessus unius supra alteram.
" Et idcirco semper major esset vis in C ad resistendum, quam in B ad impel-
" lendum. *Yet these Experiments do rather seem to hint, that the least Body by*
" *any acquir'd Celerity, may be able to move the greatest, though how much of its*
" *Motion is imparted to the bigger Body, and how much of it is recoil'd into the*
" *smaller be not hereby determin'd.*

But to proceed, I could thus have gone over all the other Senses, by examining their particular Construction, and what Proprieties of Bodies they each of them take Notice of, what Information they can afford us alone, and where they leave us, and by what Instruments and Methods they might be helpt and assisted in the Prosecution of the Inquiry. But these being more proper to be

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instanced in hereafter, when I come to give Examples of this Method for the finding out of particular Inquiries, and my Business at present being only to give a Specimen for the Explication of my Design, and as it is preparatory to the finding out such Helps for the Senses for making Discoveries as may assist a Natural Historian in the collecting of Materials for a Philosophical Supellex, to fill up the Repository of the Memory withal; for the Ratiocination to work on, for finding out the Causes, Manner, and Method of Nature's proceeding in all those Operations, we inquire into. I shall now pass on to consider of those other Faculties of the Soul, namely, Memory and Ratiocination. The Business of the former being nothing else but a faithful Preservation of the things committed to it, and a ready recollecting them when necessary, will be rectified and perfected by this Method of the Philosophick Algebra, and the rectifying and perfecting of the Reason, we shall refer to another Opportunity.

Part II. Of collecting the Phenomena of Nature, for the compiling an History.

The second thing therefore, is a Method of collecting a Philosophical History, which shall be as the Repository of Materials, out of which a new and sound Body of Philosophy may be raised. This is to comprize a brief and plain Account of a great Store of choice and significant Natural and Artificial Operations, Actions and Effects, ranged in a convenient Order, and interwoven here and there with some short Hints of Accidental Remarks or Theories, of corresponding or disagreeing received Opinions, of Doubts and Queries and the like, and indeed until this Repository be pretty well stored with choice and sound Materials, the Work of raising new Axiomes or Theories is not to be attempted, lest beginning without Materials, the whole Design be given over in the middle, for out of this are to be taken the Foundation Stones, on which the whole Structure should be raised, and those ought to be proportioned according to the rest of the Materials; for otherwise there may follow great Inconveniences, in prosecuting of it, here therefore ought to be laid up the more substantial Parts: But as for the most curious and precious things which may serve for the finishing or compleating this grand Structure, they are to be sought for as occasion shall require and prompt. For as in any great building, none can be so perspicacious as to foresee every particular thing he shall need, for the compleating of it, but leaves the Care of providing them till occasions call for them, as being then best able to judge which of that kind of Material which is wanting will be most fitting for his purpose, and so with that proceeds till other occasions call for other Requisites and Helps: And so from time to time furnishes himself with those more choice things, as the Occasions require; so there is none but before he sets upon such a Design, will be sure to provide himself of a sufficient Store of such Materials as he knows altogether necessary, nor will he neglect to lay hold on such things, as offering themselves by chance, put him in mind that he shall have occasion for them before he can finish his Design; and certainly much better it were, if the Architect were so skilful as to foresee to provide all kinds of Materials before he begins; for thereby his Work would be carried on the more compleatly and uniformly, without Necessity of pulling down, or altering, or piecing, or transforming any part, or staying or interrupting.

The Case is much the same in providing a proper History for the perfecting of a new Body of Philosophy, the Intellect should first like a skilful Architect, understand what it designs to do, and then consider as near as can be, what things are requisite to be provided in order to this Design, then those Materials are to be carefully sought for and collected, and safely laid up in so convenient an Order, that they may not be far to seek when they are wanting, nor hard to be come by when they are found: In the choice of which, Care ought to be taken that they are sound and good, and cleans'd and freed from all those things which are superfluous and insignificant to the great Design; for those do nothing else but help to fill the Repository, and to incumber and perplex the User, yet notwithstanding, Brevity is not so much to be studied, as to omit many little Circumstances which may be considerable in the use of it, for as in the laying up of Timber, the keeping on a branching part does make it serviceable for many Designs which it would be wholly unfit for, if it had been squared off, so it will be in the fitting and preparing the Particulars for a Philosophical History,

story, there must be Judgment in the Historian to discern what will be material and useful in general, and what will be more especially adapted for the Inquiry whatever he designs.

This Similitude therefore hints unto us the whole Method of making a Philosophical History, according to which, I shall enumerate the several things necessary to this Design, and according to my Ability, endeavour to explain each Particular in such Order, and so far forth as to me seems most natural and consonant to my present Purpose. But first I shall premise some of the Accomplishments requisite for a Natural Historian.

There seem therefore these Requisites to accomplish one, that intends to prosecute or do any thing considerable in this Work, without which the Collections may very much fail of the desirable Excellency in this or that Particular, though perhaps as to the kind they may contain many good things. § I. *Of the Requisites in a Natural Historian.*

The First is, That he ought to be very well skill'd in those several kinds of Philosophy already known, to understand their several Hypotheses, Suppositions, Collections, Observations, *&c.* their various ways of Ratiocinations and Proceedings, the several Failings and Defects both in their way of Raising, and in their way of managing their several Theories: For by this Means the Mind will be somewhat more ready at guessing at the Solution of many Phenomena almost at first Sight, and thereby be much more prompt at making Queries, and at tracing the Subtilty of Nature, and in discovering and searching into the true Reason of things; and though perhaps none of those Methods of Philosophy he has been accustomed to, may any way direct him in the Contrivance of this New Fabrick, yet 'tis with the Exercises of the Mind as with the Operations of the Body; one that has been bred up, and well skill'd in any Trade, shall go much more readily and handily about it, and make a much better piece of Work of a quite new Design in that Trade, than one that has not been at all us'd to such kind of Operations; there must be a time to bring and fix the Mind to a Regard and Heedfulness of this kind of Contemplation, and a time also to accustom it to Meditation and Contrivance, and a time to acquaint it with rationating from material Observations before it can go about such a Design dexterously. Besides this also, the Mind will, by being acquainted with various Conjectures and Solutions of things, be much sooner and better freed from Prejudice; for by discovering experimentally the Errors in this or that Hypothesis, 'twill be much easier taken off from adhering to any, and so enjoy a greater Freedom of perceiving and imbracing Truth from what occasion soever it be offered.

Next, As he ought to be knowing in Hypotheses, so ought he also to be very well furnished with those things, which will most assist the Mind in making, examining, and ratiocinating from Experiments. And these are chiefly two, Mathematicks and Mechanicks; the one somewhat more speculative, the other more practical: The one qualifying the Mind with a most exact Idea and Pattern of Ratiocination, Demonstration, Invention, and Detection: The other acquainting and instructing it with the Processes of Action, and Operation. He ought first of all, and chiefly to be very well skill'd in Geometry and Arithmetick, the more demonstrative Parts, and Algebra the more inventive Part of it: And this not only, as it furnishes the Mind as it were with Numbers, Weights, and Measures to inquire into, examine and prove all things; but as it also instructs and accustoms the Mind to a more strict way of Reasoning, to a more nice and exact way of examining, and to a much more accurate way of inquiring into the Nature of things: The other more Physical Parts of Mathematicks are also very useful in their kind; shewing a Way and Method of applying the former to Physical Uses and Inquiries. Mechanicks also being partly Physical, and partly Mathematical, do bring the Mind more closely to the Business it designs, and shews it a Pattern of Demonstration, in Physical Operations, manifests the possible Ways, how Powers may act in the moving resisting Bodies: Gives a Scheme of the Laws and Rules of Motion, and as it were enters the Mind into a Method of accurate and demonstrative Inquiry and Examination of Physical Operations. For though the Operations of Nature are more secret and abstruse;

and

and hid from our discerning, or discovering of them, than those more gross and obvious ones of Engines, yet it seems most probable, by the Effects and Circumstances; that most of them may be as capable of Demonstration and Reduction to a certain Rule, as the Operations of Mechanicks or Art. And from those, which are yet somewhat more speculative, he ought to proceed to acquaint himself with others more complicated Mechanical Operations: Such as Chymical, and the Physical, yea even divers Mechanical Operations in many other Trades: For by these Ways, he will be better acquainted and enabled how to deal with Nature, for the procuring and getting more hidden Jewels and greatest Mysteries. But this is not yet enough, for the way to acquire these things certainly is not as yet fully discovered, much less has it been practised, he cannot have a Pilot to direct him certainly, to shew the exact Course, and describe all the Turnings and Windings, and Shoalds, and many other Difficulties that are to be met withal, in this Attempt: Most of these things must be left to his own prudent and wary Management of his own Designs.

And, as *Columbus* did in the Discovery of the New World of *America*, he ought to contrive his Design well; then to procure what Helps and Assistances he is able, lastly, thoroughly to prosecute it, and not be discouraged by the many Crosses and ill Successes he may at first chance to meet with in the Attempt, and afterwards also in the Prosecution thereof.

Thirdly, Therefore being thus well provided, he ought very thoroughly and seriously to consider of his Design; and this he should do first by proposing to himself the end of his Inquiry; then by considering from the Nature of the Inquiry, what things seem most likely to be conducive thereunto, and accordingly to set down those things as *quæsita* or Requisites; then further to consider well, and contrive by what means each of these Properties may be attain'd, *viz.* By what Experiments or Observations, what Engines, and Contrivances are necessary, and how to be used: And for this end it is altogether necessary, that he be able to design and draw very well, thereby to be able both to express his own Ideas the better to himself, to enable him to examine them and ratiocinate upon them himself, and also for the better informing and instructing of others; for there are many things which cannot be made as plain to the Understanding, by a large Description in Words, as by the Delineation of them in a quarter of a Sheet of Paper. Drawing therefore is not only necessary in point of Invention of Mechanick Contrivances and Demonstrations, but for the Registring Particulars, and compiling a desirable History. Next, Having contrived his Methods of Examination, he ought to prosecute them with great Diligence and Judgment, in ordering, using, and deducting from them.

4*thly*, In the Prosecution of each of which, he ought to proceed with the greatest Degree of Candor and Freedom from Prejudice, not to be byassed by this or that Opinion in making of Deductions, nor by the Pleasantness or Gainfulness of the Experiment, or any other by Consideration that does not immediately look at the present Discovery he is searching after; for though those things are not to be wholly neglected, but rather mark'd by the by, and *in transitu*, yet the Mind is not to dwell upon them, or look otherwise after them, than as they are conducive to the present Inquiry, as they manifest a Truth or discover an Error, lest like sweet singing Syrens they seduce their Followers out of their right way to their utter Destruction. He ought also to proceed with the greatest Circumspection and Diligence to find out such things, as are Indications of what he seeks, and from those to take Incouragement to prosecute his Intentions, as *Columbus* did from the decreasing Depth of the Sea, the Drift of Weeds on the Surface of the Water, and the White Clouds that appear'd near the Horizon, and the like to incourage and direct him in his Course.

5. He ought to get what Help he can from others to assist him in this his Undertaking; for 'tis not to be expected from the single Endeavours of any one Man, though the most accomplisht, that any great Matter should be done, Man's Life will be well near half spent, before he can be fit to undertake this Work,

Work, and 'twill be a long time afterwards, before a sufficient Supellex can be gathered by his single Endeavours: Besides, there is much of Expence requisite, which every one cannot so well bear, that may perhaps be otherwise fit for this Employment; he must therefore here also imitate *Columbus*, endeavour to be provided with Ships, and Men, and Money, and all those Assistances he finds requisite for the thorough Prosecution of this Discovery.

6. *Lastly*, He ought, as *Columbus* did, freely and impartially to discover what he finds; but yet with particular and more especial Regard to the great Promoters and Benefactors of this Design, and what Assistances he has receiv'd he ought candidly to acknowledge: And whatsoever he registers, he ought to do it in the plainest, shortest, and most significant Description, the Matter is capable of, and in such a Method as may neither cause Repetition of History, in more places than one, nor the Rejection of some others, because it fits not punctually to his Method: He ought likewise to own what Information any one has contributed toward the compiling of such a History; and to be as careful that he be not impos'd on, either by the Ignorance or Deceit of such as seem to be assisting.

The next thing to be considered is, what the Subject of his Enquiry is; which I shall endeavour to explain, by setting down the General Scheme of the whole Matter, about which a Philosophical History is to treat.

§ II. *The Subject of Philosophical History in general.*

And this is not of less extent than the World, there is no Body or Operation in the Universe, at least if it can be any way brought to our Knowledge, that is not some way or other to be taken notice of in this Great Work; the most precious are here not more considerable, nor perhaps so much as the most trivial and vile: Every thing is here to be taken notice of only as it is lucriferous or conducive to the Discovery of Truth, and for a while at least the Lucriferousness of any that occurs (unless for the Cause of encouraging others in the Search) is to be omitted; lest thereby the Mind be diverted before it have gone through with its first Undertaking. Nor though the Volumes requisite to be filled with this kind of History be many, and so may seem to confound the Mind with the very thought of making use, or examining over the Particulars therein, and much more with the thought of compiling and collecting them; yet if we consider but the Volumes that are already writ on Subjects that have much less of Reality, and those perhaps by some one Man, and the Volumes he has been fain to tumble and search over for the collecting of the Matter contain'd in them, besides the Multitude of Thoughts and Perplexities of Mind in spinning out Niceties and ranging them, we may find the Labour and Perplexities of these Collections of real things, nothing comparable for Difficulty to those of Fiction, and Imagination; for I have very good Reason to believe, that the whole Mass of Natural History, may be contain'd in much fewer words than the Writings of divers single Authors: And the Method of using them will be much more easy, and the Labour of interpreting or understanding them, if done aright, will be almost as easy as to unravel a Bottom when you begin at the right end. The Method of distributing the Matter of Philosophical History, both for making Heads of Inquiry, and consequently also of registring them, need not be very nice or curious, they being in them laid up only in Heaps as it were, as in a Granary or Store-House; from thence afterwards to be transcribed, fitted, ordered and rang'd, and Tabled, as I shall afterward explain to be made fit for Use; for (as I instanced before) a sufficient Store of sound and good Materials, ought to be collected before the Work of Superstructure can be begun.

We will divide the whole Business of Philosophical History into these particular Heads of Inquiry, in which we have not so much proceeded according to the Nature of the things themselves, as according to their Appearance or Respect to us: For though the Earth, in Comparison of the Heavens, be as it were a Point, yet in Relation to its Nearness and Sensibleness to us, it becomes much more considerable, and the Consideration of it and its Parts will take up the greatest Part of this History. We will divide the Subject of Philosophical History into two Parts; to wit, into things Natural and things Artificial.

Natural things may according to their Respects to us, be distinguished into containing or contain'd Bodies; the great containing Body we call Æther, in this may be consider'd either its Magnitude and Figure; or its Parts: Or its Motions: Or its Mixtures: Or the things contain'd by it. These last are either Comets, or Planets, or Stars, the Planets we yet know of are either Primary or Secundary; the Primary are these ☿, ♀, the Earth, ♂, ♃, ♄, the Secundary are the Moon, the Satellites of ♃ the Lunal of *Saturn*. All these, saving the Earth, being remov'd much out of reach, may be compriz'd under one only Head; but of the Earth being nearer to us, we may consider its Parts. By the Earth I understand, all the Bodies contain'd within the Compass of the Atmosphere: In the Atmosphere therefore being that which contains the rest, we may consider either its Figure and Extent, its Parts its Mixtures, its Motions, the things it contains: These last are either greater or less, the greater are the two great Masses of Body, of which the Earth is made up, Namely, Water and Earth; the lesser are Animals. Animals are Insects, Birds, Beasts, Men: In the Water we may consider either its Figure and Extent, its Parts, its Mixtures, its Motions. The things contain'd, these, are either Vegetables or Animals; Vegetables softer, and stony Animals, Insects, Fishes, Beasts. In the Earth we may consider its Magnitude and Figure, its Parts, its Mixtures, its Motions, the things it contains; these may be Metals. Plants, Mushrooms, Mosses, Herbs, Shrubs, Trees, from which Consideration of the Matters of which History is to be written, might be collected Tables or Heads for Inquiry; but because these might seem Dogmatical, and thereby be offensive to some, and might seem to favour of Prejudice, or favour to the *Copernican* Hypothesis, which I have been endeavouring to provide against; I shall make choice of this following Distribution, which is made only according to the Appearance of things.

- The Visible World seems to consist of these Parts.
  - Cælestial.
    - Appearing.
      - Uncertainly. Comets.
      - more Constantly.
        - greater to Appearance, Sun, Moon.
        - less to Appearance, Stars, Planets.
    - not Appearing. Æther, Orbs, or Spheres.
  - Terrestrial
    - Atmosphere. Of which we may consider the
      - Exrent and Figure.
      - Parts.
      - Mixtures.
      - Motions.
      - Things contain'd.
    - Water. Of which we may consider the
      - Extent and Figure.
      - Parts.
      - Mixtures.
      - Motions.
      - Things contain'd.
    - Earth. Of which we may examine and set down what are the
      - Extent and Figure.
      - Parts.
      - Mixtures.
      - Motions.
      - Things contain'd.

From which Distribution of things on the first of these, we may make these particular Heads of Inquiry, which for the Journal or first Book of Entries, will be particular and distinct enough.

Artic. I. *The Histories of Natural things.*

1. The History of Comets and Blazing Stars.
2. The History of the Sun, Moon, Stars and Planets.
3. The History of the Æther.
4. The History of the Height, Extent, Figure, *&c.* of the Atmosphere or Air.

5. The

5. The History of the Variety of its Parts, or several Climates, and in several Regions or Heights.
6. The History of the various kinds of Mixtures it suffers from Meteors.
7. The History of its various Motions, Breizes, Winds, Storms, Hurricanes, *&c.*
8. The History of Insects.
9. The History of Birds.
10. The History of Beasts.
11. The History of Man:
    - Anatomical History of the Internal Parts of Man, compar'd with those of other Animals.
    - Anat. Hist. of the Humors and Motions in the Bodies of Men, compar'd also.
    - The History of the Shapes, Customs, Diets, Ages, Diseases, Cures of Men in divers Countries.
    - The Hist. of Sensation, Motion of the Mind, Memory, Reason, Folly, Madness, Sleeping, & Dreams, *&c.*
12. The History of the Figure, Extent, Bulk, *&c.* of the Water.
13. The History of the Seas, Lakes, Ponds, Rivers, Fountains, Subterraneous Rivers, *&c.*
14. The History of the various sorts of Bodies that are found incorporate, or that may be dissolv'd by it, as Salts, Slimes, Gums, *&c.*
15. The History of Currents, Ebbings and Flowings, Increase and Decrease, Overflowings, Inundations, and Desertings of several Parts, of Voragoes, Submarine Fountains, *&c.*
16. The History of Sea-Insects, compar'd with Aerial and Terrestrial.
17. The History of Fish, both of fresh Water and Salt, describing their Internal Structure, and Shapes as well as Outwards.
18. The History of Sea Beasts, *&c.* Morses, Seales, Tortoises, *&c.* Anatomiz'd and compar'd with other Creatures.
19. The History of the Extent, Figure, Magnitude, *&c.* of the Earth, both in respect of other great Bodies in the World, as the Sun, the Moon, the Sea, *&c.* and in respect also of the Body of Man, or our common Measures.
20. The History of its various Parts, External Mountains, Vales, Plains, Clifts, Places of Reception for the Sea, *&c.*
21. The History of its Mixtures, Metals, Minerals, Stones, Clays, Earths, Sands, Oyls, Salts, *&c.* and the various Constitution of its Parts; the several Regions of it, of what kind of Shells, or Layers of Sand, Stone, Earth, Clay, *&c.* it consists at several Depths.
22. The History of its Motions, Diurnal, Annual, Lunar, or Tide-making.
23. The History of its Internal Motions, Earthquakes, Eruptions, *&c.* Transpositions and Transformations.
24. The History of the Magnetism of it.
25. The History of its Gravitating Power.
26. The History of the Subterraneous Fires, Rivers, Caverns, Damps, *&c.*
27. The History of Mushrooms, Mosses and Plants, Roots, *&c.*
28. The History of Shrubs and Trees.
29. The History of Ground Animals and Worms.

Besides these particular Histories of the several parts of the World, there ought to be several Histories compos'd of the prime sensible Qualities, such as may serve afterwards for the finding out of those Proprieties first which are more simple, such as these.

1. The History of Light and Darkness.
2. The History of Transparency and Opacousness.
3. The History of Colours, commonly distinguisht into real and appearing.
4. The History of Sounds, Musical and Harmonious.
5. The History of Tastes.
6. The History of Smells.
7. The History of Heat and Cold.
8. The History of Gravity and Levity.

9. The

9. The History of Density and Expansion.
10. The History of Flexibility and Stiffness.
11. The History of Malleability and Brittleness.

2dly, The Histories of Artificial and Mechanical Operations.

And these Histories will be most adorn'd and compleated from the History of Mechanical Employments and Operations, and most especially by judicious and accurate Experiments, designedly tried; the true Nature of each of which Proprieties being exactly determin'd, will hugely facilitate all the other Inquiries in Philosophy. It were very desirable therefore, that though these Histories are here placed in the Second Place; yet they were primarily and chiefly to be regarded; for the Knowledge of these, will extreamly rectify the Mind both in propounding Queries, and also in making Examinations aright, for the Nature of all these Proprieties being known in a Body, the true Texture and Constitution of the Body may be much more easily found.

Thus much for the Heads of Natural Histories, next for Artificial. It will be requisite to take notice of, and enumerate all the Trades, Arts, Manufactures, and Operations, about which Men are imployed, especially such as either contain some Physical Operation, or some extraordinary Mechanical Contrivance, for such as these will very much inrich a Philosophical Treasury. And these we may distinguish into these several Heads, according to the various Materials about which they are conversant. We may refer

To Fire. 1. The History of { Chymists, either such as make Tryals on Metals, or operate on Mineral, Vegetable, or Animal Substances.

To Air. 2. The History of { the various Ways of making use of the Air for the Motion of Ships, Mills, Engines, *&c.*

To the Water. 3. The History of { Rowers, ways of cutting Rivers and making them Navigable, Engines for raising Water; for sinking Water, *&c.* for sounding the Depth, the History of Divers, Swimmers, Sailors, *&c.*

To the Earth. 4. The History of { Surveyors, the most expedite ways, as also the most exact.
Miners, their ways of finding the Mineral; of digging, clearing, and breaking through Rocks and Rivers in their Passage, of the various Earths they meet with, as also of their Damps, and other Exhalations.

The Histories also of such as are conversant about Mineral, Vegetable, and Animal Substances, such as these.

To Earths and Clays. 5. The History of { Potters, Tobacco-Pipe-Makers, Glass makers, Glasiers, Glass-Grinders, Looking-Glass-Makers, or Foilers, Spectacle Makers, and Optick-Glass-Makers, Makers of Counterfeit Pearl and precious Stones, Bugle-Makers, of Lamp-blowers, Colour Makers, Colour-Grinders, Glass-Painters, Enamellers, Varnishers, Colour-Sellers, Painters, Limners, Picture-Drawers, Makers of Baby Heads, and Bowling Stones or Marbles, Counterfeit Marble, Wax-work, Casters.
Brick-makers, Tile-makers, Lime-burners, Plasterers, Paviers, Pargiters, Furnace-makers, China Potters, Crucible Makers.

To Stones. 6. The History of { Masons, Stone-cutters, Statuaries, Sculptors, Architects, *&c.* Crystal-cutters, Engravers in Stones, Jewellers, or Stone-Setters.

7. The

7. The History of { Making Salt, Alum, Salt-peter, Vitriol, Gunpowder, Sulphur, Bitumen Naphtha, Sal Armoniac, Sandiver, Kelp, Borax, Pot-ashes, Soap-boilers, Refiners, Colliers. *To Minerals.*

8. The History of { Iron-Mills, and Founding in Iron, of forging it into Bars, of Anchor-Smiths, *&c.* Plate-makers, Nail-makers. *To Iron.*
Steel-making.
Lock-smiths, Gun smiths, Jack-smiths, Edge-tool makers and Hardners; Grinders and Forgers, Armourers, Spurriers, Bit-makers, Needle-makers, Hook-makers, Tool-makers, Wire Lettice and Cage-makers, or Latton-men; Spring-makers, File-cutters, Chirurgeons Instrument-makers, Engine-makers, and Cross-bow-makers.

9. The History of { Plumbers, Shot-making, Ceruse-making, Red Lead making, *&c.* *To Lead.*

10. The History of { Latin-makers, and Tin-men, Type-founders, Printers, of making Soder and Putte, Glass colours. *To Tin belong these Trades, whose Histories should be collected.*
Pewterers, Pipe or Worm-founders, Organ Pipe-makers.

11. The History of { Copper-smiths and Founders. *Copper and Brass.*
Ingravers, Etchers, Embossers, *&c.*
Brass-making, and Founders of Bells, Ordnance, Pots, Nails, and other small things.
Brasiers and Tinkers, Clasp-makers, Scale-makers and Weight-makers, Thimble-makers.
Plate-makers, Burnishers, Roll-Press Printers.
Clock-makers and Watchmakers, Mathematick Instrument makers, Turners.
Wire, drawers, Tinsey-makers, Pin-makers, Taggers.
Trumpet-makers, *&c.*

12. The History of { Smelters and Refiners. *Gold and Silver.*
Gold and Silver-smiths, and Guilders, Coiners, Inlayers, Enamellers.
Gold-beaters, and Wire-drawers, and Throster or Spinners, Lace and Stuff makers, Spangle makers.

13. The History of { Husbandry and Gardning, Botanicks, and Sugar Planters, Tobacco Planters, Saffron, and Ginger, Liquorice Planters, *&c.* Threshers, Ploughmen. *Vegetables.*
Flax-makers, Dressers, Spinners, Lace-makers, Button-makers, Weavers, Calenders, Hatchelers, Whitesters, Painter Stainers, Fustian-makers, Twine and Packthread-makers, Net-makers, Sieve-makers and Serce makers, Rope-makers, Caukers, Sail-makers, Mat-makers, Semsters, Bone-lace Makers, Tape-makers, Straw-work makers.
Malters, Millers, Brewers, Bakers, Vintagers, Vintners, Distillers, Strong-water-men, Alehouse-keepers, and Cider-makers, the Makers of Coffee, Chocolate, and various other Drinks, Victuallers.
Preservers of Corn, Fruit, Hops, Wood, Indico, Spices and various other Drugs, as Meal-men, Fruiterers, Costermongers, Brazil-grinders, Hop-dressers, Wood-men, Madder Planters, Rape-Oyl Makers, Seed-men.
Grocers, Drugsters, Apothecaries, Confectioners, Sugar-Bakers, Smokers, Tobacco-cutters, Hucksters, Perfumers, Garblers of Spices.

Paper and Pastboard making, Stationers, Bookſellers, Printers, Compoſers, Scriveners, Starch-makers, *&c.*
Woodſellers, Barkers and Cole Charrers, Woodmongers.
Sawyers and Saw-mills, Carpenters, Shipwrights, Millwrights, Pump-makers, Joyners, Cabinet-makers, Screw-makers, Muſical Inſtrument-makers, Organ-makers, Carvers, Turners, Fletchers, Bowyers, Archers, Buttonmold-makers, Coopers, Gagers, Basket-makers, Box makers, Comb-makers, Laſt and Heel-makers, Broom and Mop-makers, Bellows makers, Hoop-makers, Lath-makers.

To Animals. 14. The Hiſtory of
Shepherds, Graſiers, Goatherds, Swineherds, Sow-gelders, Grooms, and Horſe-Courſers, Bear and Lyon Keepers, Dog-catchers and Keepers, Rangers or Keepers of Parks, Warrens or Foreſts.
Farriers, and the various ways of Curing Beaſts, Mole-catchers, Rat-catchers.
Hunters, Hawkers, Fowlers, Decoyers, Fiſhers, Draggers, Gunners, Fowl-keepers and Lookers to Aviaries, *&c.*

About the Parts of Animals. 15. The Hiſtory of
Sheep-ſheerers, Fellmongers, Clothiers, worſted Combers, Spinſters, Knitters, Weavers, Cloth-dyers, Fullers, Cloth-workers, Sheerers, Hot-preſſers, Taylors, Drawers, Embroiderers, Tapeſtry-makers, Carpet-makers.
Felt-makers, Caſtor-makers, Cap-makers, Furriers, Hair cloth-makers, and other kinds of Stuff, as Arras, Milleners, Pencil-makers, Bruſh-makers.
Horners, Horn-turners, Comb-makers, Horn-makers, Hafters, Dice-makers.
Upholſterers, Feathermongers, Pen-makers.
Silk Troſters, Dyers, Weavers, Stocking-weavers and Knitters, Ribbond weavers, Gumflower-makers, Mercers, Silk-men, Button-makers, Lace-makers, Embroiderers, Preſſers and Waterers.
Bee-keepers, Silkworm-keepers.
Leather-dreſſers, Parchment-makers, Glovers, Perfumers, Tanners, Curriers, Shooe makers, Bottle-makers, Harneſs and Coller-makers, Sadlers, Coach-makers, Caſe-makers, Trunk makers, Book-binders, Sheath-makers, Leather-ſellers, Leather-guilders, Belt-makers.
Butchers, Cooks, Tallow-chandlers, Wax-chandlers, Cheeſemongers.
Fiſhmongers, Ripiers, Oyle-makers, Soap boylers, *&c.*

There are other Imployments, more particularly about Man. 16. The Hiſtory of
School-maſters, Writing maſters, Printers, Muſick-maſters, Stage-players, Dancing-maſters, Horſe-riders, Fencers, Vaulters, Tumblers, Wreſtlers, *&c.*
Apothecaries, Chirurgeons, Barbers, Laundreſſes, Coſmeticks, Seamſters, Taylors, *&c.*

In the writing of all which Hiſtories there may be two things deſign'd, either a Deſcription of the things themſelves, whereby Inquiſitive Perſons that are ignorant of them, may come to a more perfect Knowledge of them; in order to ſome other Deſign as for Curioſity, or Diſcourſe, or Profit, and Gain, or the like: Or ſuch a Deſcription of them as is only in order to the Uſe of Philoſophical Inquiry, for the Invention of Cauſes, and for the finding out the ways and means Nature uſes, and the Laws by which ſhe is reſtrain'd in producing divers Effects.

And this laſt is that which is chiefly aim'd at in this Deſign (though others alſo whoſe Intenſions are only of the former kind, may find much to ſatisfy their

their Desires) for these being known and applied, not only the Reasons of the ways already made use of in several Trades might be easily known: But each of them highly amended and improved, and by other ways performed with much more Ease, Speed and Certainty.

In the History therefore of Trades, we are chiefly to look after the Physical Proprieties of each, as what is hard or soft, what flexible or stiff, what sharp, corrosive, what odoriferous, balsamick and preservative, what putrifactive and corruptive, *&c.* together with the manner of applying Agents to Patients, and to observe the manner of Natures proceeding, where she is impos'd on by Art, and limited to this or that Degree, and not suffer'd to act otherwise; by what Ways she may be assisted, accelerated, regarded, stopt, and the like, in her usual Proceedings; for these being known, most of the other things will be very easy and follow of course. We ought also, to take notice of the various sorts of Mechanical Engines, which serve to assist and direct the hand in performing many Operations together, with Ease and Speed and certainty: which are not otherwise done without much Uncertainty, Time, and Difficulty; and of the several Slights and Contrivances in Operations, and the order of them, which precede and which follow, and the Efficaciousness of them in this or that Method.

Besides these Trades I have been mentioning, there are many excellent Experiments and Secrets to be found scattered up and down in Mens Practises, which have not come up to that Considerableness in the Commonwealth as to be made a Trade, which yet contain in them divers Circumstances of very excellent Use and Information, those also ought to be sought out and collected and rang'd into their proper Places, if at least they can properly be referr'd to any of the foregoing Heads, otherwise they are to make a particular Head of themselves: Of this kind there are a multitude almost in all Estates and Conditions of Men, which to this Design will be of huge Importance, and will afford very much Information, even out of the most vile and seemingly most foolish and trivial things, and of those which are most common, and therefore pass without regard, because usual, may be collected things of most excellent Use; and therefore, nothing in this Design is to be look'd on with the Eye of the Vulgar, and with Prejudice, according to the Esteem it has obtain'd in the World with the Generality of Men, who generally judge or esteem of things only for the immediate Pleasure or Profit they afford, and look no further; therefore 'tis not equal to make their Esteem who understand them, the Standard of the value of things for this use. So that a diligent Naturalist can go no-where, but he may find a Subject for him to contemplate and examine, but especially in such Places as are most or least frequented, for the Obviousness in the one, and Difficulty in the other, has made Multitudes of considerable Observations to be neglected.

§ III. *The Methods of making the Enquiries.*

Having thus cursorily summ'd up the chief Heads of those things that are fit to be the Subject of Natural History, I shall next adjoyn a Specimen of what things are to be inquired after in them, that so any other that shall have an Opportunity, and willing to promote this Design, may accordingly, whatever the thing be he designs to write a History of, first propound to himself the things, which upon a serious Consideration of the Matter, he shall judge to be most likely to be instructive for the discovering of the true Nature of that which he inquires into.

For it cannot be expected, that any one should be alike able to make Queries of those things in which he has not been much, if at all conversant; as one that has had an Opportunity of acquainting himself more particularly with the Nature of it, and has imbib'd in (though he knows not how) a great deal of imperfect Knowledge of the Proprieties of it. He ought therefore to consider with himself, what things there are in the Subject he would inquire into, which being told him, he should be able to know the true Propriety, Nature and Texture of it: And supposing he had met with some one that could resolve him, what Questions he would ask him, by the Resolution of which he should be able to find out what he seeks; and accordingly he ought to set down those Questions in Writing, that so he may have a Scheme before his Eyes what are the things he looks after, what his Scope and Aim is.

And

The way of answering the Queries.

And having set down these Queries, he ought in the next place to consider what things seem requisite to attain those ends; what means he can imagine may be conducive to the solving or answering those Questions, that is, what Observations, Examinations, or Experiments would seem conducive thereunto, and accordingly under every such Query or Question, he ought to set down the things requisite to be known for the obtaining the full Knowledge of a compleat and full Answer to it; afterwards with Care and Diligence he ought to make Examination and Tryal of what he has propounded, one thing after another, with much Circumspection, for accordingly as these Queries are made with more or less Judgment, and as the means conducive to the Resolution of them are more judiciously pitcht on, and diligently try'd more or less considerable, so will the Particulars to be entred in the Diary be; and the more or less useful for a Philosophical Treasury. In the making of which Experiments and Tryals, it were very desirable that the Inquirer would first make Tryal of them once all over, and observe diligently and enter into a Paper by themselves as many Particulars as he can discover worth noting, and then a second time to make them over again. In the doing of which, it would be very convenient to get some such Person to be present as has not been acquainted with Experiments on that Subject, though ingenious and inquisitive in other Physical Searches, because such a Person may take notice of many Particulars which are in themselves very observable, but were and would still have been neglected because of their being obvious, and because the Inquirer having been long accustomed to the seeing of them without thinking them any ways considerable, will be now very prone to do as formerly, slight and neglect them, and this will be instructive to him in shewing him in what things he is most likely to be overseen in, as well as shewing him the things themselves. The Tryal of these Experiments, 'tis very likely, will much further his Knowledge, and shew him perhaps the Solution of some of his Queries, as well as the Error and Insignificancy of others; and may perhaps much better instruct him how to make his second Class of Queries, and how to proceed in the solving and answering them, they will not only facilitate the Labour of making and accustome his Mind to a greater Circumspection, but will suggest also various ways of examining and experimenting, which without this Method of inquiring would not have been thought of.

And though indeed the Multitude of Queries that may be made upon every Subject, may seem to make this Work infinite and impossible to be compleated, yet if Men would but prosecute thoroughly, according to the ways I propound in this Tract, such kind of Inquiries in order to the Discoveries of the Proprieties of some Bodies, or for finding out the Nature of some general Qualities. I cannot doubt but that such Endeavours would produce so considerable Discoveries, as would not only serve for the Explication of that one Body inquir'd into, but of Multitudes of Bodies of the like Nature; and every such Invention will ease the Inquiries in most other Bodies, half in half, after the same Propriety. As to give an Instance propounding to my self to find out the Reason of the Lightness of Cork. I set down among other ways of Tryal to examine the Texture of it with a good Microscope, hoping that possibly I might thereby be able to discover its Texture, to this end I examin'd several Pieces of Cork, whose sides I had cut very smooth with a Razor, but the glaring Reflection from the Multitude of sides that compose its Surface made me unable, though I try'd it in several Lights to discern any kind of Pores, I bethought me therefore of shaving off a very thin Sliver of Cork, and laying it on a black Ground, I could with my Microscope then plainly perceive the Texture of its Substance, that it was as porous as a Honey-comb; that is, all over full of small long Pores, upon and down, through the length of which were interspers'd many cross Diaphragms, or Valves, by which means the Air is imprison'd in very curious close Boxes. Finding these in Cork, I proceeded to find the same in Wood, not doubting but the Lightness of that might proceed from some such Cause, I made tryal with Wood both green and dry, shav'd after the same way, but in green Wood it succeeded not at all, but I could perceive divers larger up and down the dry. I conceived therefore, that it might be the Juice of the Plant which had fill'd those Holes, and therefore considering that in

An Example of the Method.

Charcole

Charcole all that superfluous Juice is wasted, and evaporated, I made tryal of viewing a Coal in a Microscope, and even beyond my Expectation, I could discover such Multitudes of them and so small, that I could hardly at first believe my own Eyes, till trying the Experiment over and over again, I found the same Propriety was not only to be found in one or two other kinds of Wood, but was common to all sorts of Vegetables that I was able to charr.

Thus the Experiment of *Saccharum Saturni*, by dissolving Lead in an acid Liquor, and evaporating away the watery part, will hint to us a way of discovering the Tastes of all kinds of Bodies; that is, by dissolving those reserved and tasteless Bodies, in some convenient *Menstruum*, for being once dissolv'd, it becomes dissoluble also, by the Vehicle of that *Menstruum*, to the *Saliva* or Juice in the Mouth, or Tongue which seems to be the Organ of Taste.

Thus the finding out the Cause of Fluidity, Heat, Gravity, Brittleness, *&c.* in one Body, will much facilitate the Inquiry after the like Properties in any other Body, so that though indeed upon every specifick Body to be examin'd, there may be a Multitude of Queries propounded, yet the more præceeding Bodies have been by this Method examin'd, the fewer of them will there remain to be answer'd.

The Queries that may be made on the first Head, I shall refer to a following Discourse, concerning the late Comets, and of the Nature of Comets in general. *The 1st Head, of Comets.*

The Questions on the Second may be some such as these.

The 2d Head, of the Stars and Planets.

The Difference between Stars and Planets?
How many Planets, Primary, or Secundary?
And how many fixt Stars?
In what Order plac'd?
Of what Figure?
Of what Magnitude compar'd to the Earth?
How far distant from the Earth?
In what way they are mov'd?
With what Velocity?
In what time they perform their Revolutions?
What Heat, or Light they have?
From what Cause their Heat or Light proceeds?
What Influence they have on each other, or on the Earth?
Whether they are constant or changeable in being or appearing?
Whether constant in Magnitude and Figure?
Whether constant in Motion and Distance?
Whether constant in Light, and Heat, and Influence?
What Proprieties are common to them with the Earth?
Whether included in Orbs, or swimming in Æther?
Whether the Ambient Body move them, or they the Ambient?
Whether moving together with the Ambient, or mov'd through it?
What the Consistence of the Ambient Body may be?
How much it may hinder or retard their Motions?

Divers of these may be referr'd to the Third Head, concerning the Solidity or Fluidity of the Æther, the Motion of it and the Resistence of it to Bodies mov'd through it, and of the Transparency and Communicativeness of it as a Medium: There might be many other things also propounded on this Head, as whether it permeates all Bodies, be the Medium of Light, be the Fluid Body in which the Air is but as a Tincture? Whether it cause Gravity; in the Earth, or other Cælestial Bodies? Whether it assists in the Action of Fire and burning, and in the Dissolution of other Bodies by *Menstruums*; in the Fermentation of Bodies, and Multitudes of the like; which will be dispers'd up and down in the Queries, on several other Subjects, and are there best resolv'd, though they may afterwards be referr'd and transcribed under this Third Head. *The 3d Head, of the Æther.*

The Queries on the Fourth Head concerning the Atmosphere, may be some such as these.

The 4th Head, of the Atmosphere, as to its Extent, &c.

Whether the Atmosphere, or Air be defin'd, or not, by a Superficies?

Whether it be not indefinitely extended upward, and continually more and more rarified the farther 'tis distant from a gravitating Body, as the Earth, Moon, *&c.*

Of what kind of Figure the grosser or more vaporous Air near the Surface of the Earth is; that is, Whether it be not much lower near the Poles than under the Torrid Zone?

Whether the Torricellian Experiments made at several Altitudes from the Earth, may not determine it?

Whether the Refraction and Gravitation of the Air, examin'd in both places by Instruments, may not clear this Query? Since 'tis demonstrable that where the Refraction is greater with an equal Degree of Pressure, the Density of the Air must needs be much greater near the Surface.

With what Bodies it is mixt? Whether with Water, Wood, Earth, Animal Substances, and Vegetable Substances, and with all sorts of Liquors and Spirits?

Whether it helps to nourish the Fires kindled within the Bowels of the Earth?

Whether it encompass the Sun and Planets, and that each of them have a peculiar Atmosphere, as well as they have a gravitating Power?

Whether the Fire, in the Sun, is not maintain'd by the Air that incompasses it?

Whether the Spots in the Sun may not be Clouds of Smoke, or Vapours, rais'd up into that Atmosphere?

Whether the Combustion of Comets may not be ascrib'd to the Dissolution of them by the incompassing Air, which is somewhat more condensed near them?

The Queries on the Fifth Head, of the Variety of the Parts of the Air, may be some such as these.

The 5th Head, of the Variety of the parts of the Air.

Whether the Air be not a kind of Volatile or small ramify'd Bodies swimming in the Æther, like a Tincture in Water or in some such fluid Body? Or,

Whether the parts of it are infinitely fluid, or definitely solid, and if solid, then

Of what Figure and Magnitude, how they are kept asunder, or what fills the disseminated Spaces between them?

What is the Cause of making them capable of so vast a degree of Expansion, and yet of being able to preserve their Elastick Power outwards.

What Condensation it is capable of bearing by Pressure from an Engine: Or from being let down to the bottom of a very deep Sea, or from Cold or from being let down a great Depth into the Earth?

What refractive Power it then has compar'd with the ordinary Air?

How much the Air may be rarified by Heat, by Exsuction, by the Torricellian Experiment, by Engines, by Vapours and the like?

By what Degrees the Air expands it self, being carried upwards, and from the Surface of the Earth, and whether this comparative Expansion be the same in divers Countries, and in differing Seasons of the Year?

What the Height of the Air is that bears the highest Clouds, what are the Height of Thunder Showers, Hail Showers, white dry Clouds, Halo's, Maccarel Skies, and the like?

What difference between the Air in those very high Places of the Earth, as *Tenariff*, the *Alps*, and the *Andes* in *Peru*, aud other Places as to Healthfulness, or Aptitude for Burning or Respiration, or the Flight of Birds, or the like?

From what Bodies the Air may be generated anew, or whether that Air so made be not such as had been formerly imprison'd?

By

By what Varieties of Operations it may be produced, and by what Helps?

How the Air so generated may be preserved in the Form of Air?

How any kind of Air may be made to loose the Form of Air, and to be condens'd into a solid or fluid Body?

How much the Air in the Torrid Zone differs in Heat, and Dryness, or Moisture, or Rarefaction, or Pressure, or the like, from the Air nearer the Poles?

In what Proprieties it chiefly differs from other Liquors?

To the Sixth, Of the various kinds of Mixtures the Air suffers from Meteors, these Queries may be propounded.

The 6th Head, of the various Mixtures the Air suffers.

What is the Cause of the sudden thickning or clearing of the Air?

From what Power so great a Quantity of Water as has been observed to fall in some Thunder Showers, should be collected or gathered together?

Whether the Heat of the Sun alone, or some internal Heat in the Bowels of Earth should raise up so great a Quantity of Water?

Whether there be any such Meteors, as Earthy ones, rais'd up into the Air, and if so what becomes of them? Whether Smoke and Dust and such like Fumes do not fall, as fast as the Air cools, to the Earth?

Whether there were ever any such thing as a Thunder-bolt, or other such massy Body thrown out of the Air?

How much more space is fill'd by generated Vapours, than by the Water from whence they are made?

Why all Rains and falling Water are fresh?

Whether from the Coalition of divers sorts of Vapours together, there be not ingendred a new Quantity of Air, and the rest falls down in Drops or Flakes, as in the Experiment of making *Tartarum Vitriolatum*, whether that may not be the reason of the Figure of the Flakes of Snow, *&c.*

What is the Reason of the Shining or Light of the Star shootings, and in what Region or Height they are generated? Whether this may not be observed easily enough by two Confederates?

Whether they have any thing of Fire in them, or whether the Light may not be an effect of their rapid Motion?

Whether the rising of certain Steams from the Earth into the Air, may not be the Cause of precipitating the Exhalations, by causing the Air to throw off its Load in the same manner as a charged *Menstruum* will relinquish its dissolv'd Body, when it is penetrated by another Liquor of a contrary Nature, since by such kind of Experiments may be very well represented in little, almost all the Phenomena of the Changes of Air in the great Ocean of the Atmosphere.

What are the Causes of the Rain-bows, and their Colours?

What are the Reasons of the Duplication, Triplication, Quadruplication, *&c.* of both the Rain-bows? Which are obvious enough when the Bows are very vivid.

What are the Reasons of Rings about the Sun and Moon, and of their varying Bignesses at several times.

Why the under Superficies of Clouds are smooth, and seem to lie at the same level Distance from the Earth, whereas the Tops are Mountainous and unequal?

Why there are sometimes divers of these Regions of Clouds one above another, and in what those Clouds differ?

What is the reason of the various Figure of the Clouds, undulated, hairy, crisped, coyled, confus'd, and the like?

What is the cause of the Redness, *&c.* of high exalted Vapours?

What is the reason of those Multitudes of small Cobwebs that cloth the whole Face of the Ground after a Fogg? And why there are divers such white Substances flying up and down in the Air after such Fogs?

What is the cause of Lightning, whence that accensible Matter is rais'd up into the Air, and how collected, and how kindled?

What Artificial Experiments, with Fumes or Spirits accensible, will help to explicate them?

Whether

Whether all these Phenomena may not be solv'd by Chymical Experiments (of which kind I may perhaps hereafter manifest some not vulgar.)

Whether Fire in general be not the effect of the Air's corroding or dissolving a heated combustible Body? How it comes first to be begun or kindled, how preserved and continu'd, and how destroy'd, why it rises in the Air whilst it lasts, but quickly vanishes?

By what other means Fires may be generated, continued, made more intense, and much more violent?

What is the Nature and Properties of Niter or Salt peter, as to this Particular?

What the Mixture Coal-dust performs in Gunpowder, and Alcalys in fulminating Powders?

The 7th Head, of the Motions and Qualities of the Air.

To the Seventh, to wit, What are the Motions or Qualities of the Air? These Questions, and divers others of the like kind, may be propounded:

What the Air contributes to the Generation and Corruption of Bodies, whether Mineral, Vegetable, Animal, *&c.*

What it contributes to the Preservation or Destruction of Lifeless Bodies, by hardning, drying, rusting, fermenting, *&c.*?

What it contributes to the Nourishment of Vegetables that grow in it? Since the Air is a kind of fluid that encompasses all things in it, after the same manner as the Water in the Sea incompasses the Vegetables that grow in it.

What is the use of it in Respiration, whether Fishes, Worms, Insects, *&c.* have any use of it; or whether Water be not of the same use to Fishes, that Air is to the Anmals that live in it? Whether the comparing of the one with the other will not much facilitate the Explication?

What is the use of it in Fire? Whether it does not perform that Action after the manner of a *Menstruum?*

Whether that Property in Air which promotes burning, be not of the same Nature with that of Salt peter?

By what means Fires may be extinguished, by dry Bodies, by wet, or fluid Bodies, by the Air, and divers other liquid Bodies?

What Flame is, the Expansion of it compar'd to the Density of common Air?

Why Fire or burning Bodies produce Light, Heat, Smoke, Ashes, Salt, *&c.*

What the Air contributes to Corrosion and Dissolution of Bodies?

What it contributes to the Fermentation, and Concoction or changing of Bodies?

What are its Motions, constant, anniversary, periodical, accidental?

What are the Reasons of Breizes, Winds, Storms, Hurricanes, Whirlwinds?

What are the Velocities and Strengths of each of these, and the Concomitants?

What are the Ebbings and Flowings of the Air discover'd by the Barometer, to what Regularity reducible, from what Cause they proceed, whether from the rising of new Vapours, or from the flowing in of the Air from other Climates, or from the Motion of the Earth, Moon, *&c.*

What are the Motions of the upper Parts of the Air, whether in the same way, and with the same Velocity with the lower part of the Atmosphere, why the Clouds that are plac'd one higher than another in several Regions and Stations, are sometimes observ'd to go various ways at the same time, and none of them perhaps the same way with the Wind below.

Whence the Air is able to bear up the Clouds that seem denser Bodies, whether from the Abatement of Gravity, or from the greater Cold and Density of the Air, at that height than near the Earth, or whether it be not more Dense as to Expansion, than the Clouds though the cloudy be more dense in respect of Opacousness.

Hence the Air is able to carry up Smoke, Dust, and several bulky Bodies that are manifestly heavier, and why most apt in Summer when 'tis most expanded, whether it be not from longer Continuance of Heat, and from the Dryness of the Air in the Summer, and from the sudden cooling, and the interspersed Moisture of the Air in Winter.

How

How it becomes able to sustain the heavy Bodies of Birds and Insects, and the like, and by what means it may be serviceable to raise and sustain much greater Bodies?

How much the Air impedes the Velocity of Bodies mov'd through it?

What part of the Air is the Medium of Light?

What is the Transparency or Opacousness of the Air, and from what Causes they proceed?

How much better a Body may be seen just upward at a Distance, than at the like Distance in a Horizontal or level Posture?

At what Distance a Body may be distinctly seen in a Horizontal Posture?

What is the comparative Reflectiveness and Refractiveness of the Air?

By what means may the Inflection or Multiplicate Refraction of the Air be found and determin'd?

What is the reason of the Undulations of the Sun and Moon, and bigger Planets, and of the twinkling of Stars?

What are the Causes of the appearing Blewness, Yellowness, Redness, *&c.* of Bodies through the Air?

By what means the Air becomes the Medium of Sound, whether the more dense or rarify'd, moist or dry, transparent or opacous, be fittest for that Conveyance?

With what Velocity Sound is conveyed through the Air, whether it may not be conveyed swifter by Strings well stretcht, or solid Bodies?

Whether it proceeds by strait or curve Lines?

Whether it be not alter'd by Winds, *&c*?

By what means it becomes the Medium to convey Smells?

How it dissolves or licks up the odorous Steams and Effluvia of Bodies?

Whence it comes that so small a part of an odorous Body is able to tinge, or scent so great a Quantity of Air?

What are the several Temperatures of the Air, as to Heat and Cold, Dryness and Moisture in several Regions of the Earth, and at several Heights above the Surface of the Earth upwards and below the Surface, downwards in Wells, Mines, *&c.*

How many various ways there may be of making Thermometers and Hygroscopes to be visible at a great Distance, by the help of Perspectives, by which those Temperatures of the Air may be found without going up or down into those Places?

What is the Cause of the Congruity or Incongruity of the Air, and how many Phenomena of Nature may be solv'd thereby?

What is the comparative Gravity of the Air in several Climates and Regions, and Seasons of the Year?

The Degrees of the Elastick Power of the Air, how caus'd, augmented, destroy'd, *&c.*

What are the Degrees of Pressure in several Regions, Heights, Climates, *&c.* the Effects thereof, and Phænomena solvable thereby?

These few Instances, I hope, may serve for a Specimen of what I mean by the Method of propounding Queries on any Subject, to be examined by accurate Observations and Tryals, before the Writing a Natural History of it.

After the Queries have been thus propounded and ranged, the next thing will be to consider what Materials are to be got for the solving of them, and answering our Doubts, what Histories and Observations from abroad, and what Experiments, Observations and Tryals at home will be necessary to be obtained and made: What Instruments, Engines, and Contrivances, will be assisting to this End, how far the Senses themselves will help us, and where they leave us to seek other Helps, and this a serious and unprejudiced Meditation, and considering of the Nature of the thing will best hint. And accordingly we ought to set down under each Queries, what means can be thought of for resolving and answering of them, which Tryals and Ways ought to be prosecuted from beginning to end vigorously, with Diligence and Accurateness, and to be Registered as fast as made, that no considerable Circumstance may be forgotten. And always

§ 4th. *The Method of answering the Enquiries.*

ways upon tryal as things occur, that seem to be assisting towards the solving of another Query, than they were intended for; they ought to be registered under that, as an additional Help of solving that Doubt, for the Memory is frail, and may quickly forget even those things that are of most Importance, and does not without much Labour and Trouble at best, recal all Circumstances that are considerable at the time when they are most requisite. By this Method also, the Imperfections of History will be amended. And tho' indeed this Process of Reasoning and Inquiry may seem nothing else but what every Man would do, and does indeed continually practise in all kinds of Inquiry: Yet has it this vast Advantage above the common way, where the bare Powers of the Senses, Memory and Understanding are relied upon, that it perfects these Faculties to the highest pitch they are capable of, and that is indeed as much as can be hoped for from Art: Every thing being here reduced to Regularity, Certainty, Number, Weight, and Measure; for whereas in the common ways of Ratiocination, Examination and Inquiry, all things are trusted to the immediate Power of the Faculties of the Soul, *viz.* the bare Senses, Memory and Reason; in this they are none of them left, without their Armour, Engines, and Assistants, the Senses are helped by Instruments, Experiments, and comparative Collections, the Memory by writing and entering all things, ranged in the best and most Natural Order; so as not only to make them material and sensible, but impossible to be lost, forgot, or omitted, the Ratiocination is helped first, by being left alone and undisturbed to it self, having all the Intention of the Mind bent wholly to its Work, without being any other ways at the same time imployed in the Drudgery and Slavery of the Memory, either in calling particular things to Memory, or ranging them in Order, or remembring such things as belong to another Head, or in transposing, jumbling, ranging, methodizing, and the like; for first all things are set down in their Order, the ultimate End, the intermediate, and other Ends that are aimed at in order to the great one, the Steps and Ways that lead to each of these, then Engines and Helps are propounded; the Progress, that has been made and the Distance to come, is plainly to be seen for all things are registred in their due Order, as fast as made.

Next, it is not troublesome to find what thing is to be done in the next place, the way of proceeding is chalked out, nor will the Mind be much troubled to run over all the particular Instances and Heads of Inquiry, they are all presented at once to the View: Their Order, Congruity, Disagreement, Similitude, *&c.* are all manifest to the Eye, quickly to be examined, recollected, reviewed, otherwise placed, blotted out, or the like, according to occasion, and nothing need be forgotten or omitted, or put in a false Order, if but a small parcel of Diligence be made use of.

The means of Collecting Observations.

The last thing therefore is, to consider of the means of collecting Observations, and making such Experiments as seem likely to determine the Inquiry, either Negatively or Affirmatively, either in part or totally, from whence these Materials are to be collected, and by what means? For according to the choice of the Experiments, such most usually is the Information. Such Experiments therefore, wherein Nature is as 'twere put to Shifts and forc'd to confess, either directly or indirectly the Truth of what we inquire, are the best if they could be met with: But these being hard to find at the beginning, it will be best to be first a little acquainted with the Method of Nature, in her most evident Manifestations of her self, to follow her meerly upon the Light of common Observations and Experiments, such as are very obvious upon that Subject, till we are somewhat acquainted with the ways she seems most inclined to follow, and so by degrees can follow her closer and closer at the heels, for by this means we may be able to guess where she begins to make a Deflexion out of her common Road; which way her Paths lie, at least whereabouts we lost her, and were able to follow her no longer with our bare Senses: And there we ought to make use of the Helps of our Senses, of Microscopes and Telescopes, for the discovering the minute Figure of divers kinds of Liquors and Menstruums; for discovering latent Tastes: Of Thermometers and Hygroscopes for discovering Degrees of Heat and Cold, Dryness and Moisture, and other tangible Qualities which our Senses are unable to distinguish: Of exact Scales, weighing in Water,

Water, *&c.* for comparative Gravity, and Expanſion of Bodies: Of Baroſcopes, for Gravitation and Preſſure of the Parts of Fluids one upon another: And ſeveral other Contrivances which a good Mechaniſt will eaſily invent upon occaſion, as the Subject ſuggeſts: By which the Informations of the Senſes may be advanced and more certainly determined.

By theſe means are to be ſearched out the Properties of Bodies, whereof the Hiſtory is to be written, and where we can find no farther ways of proceeding to deeper Searches, and Nature ſeems to leave us in the Lurch, or paſs away by unſeen Paths, there ought to be ſet up as it were a Land-mark to direct us where to begin again to ſearch, if making Tryal in one way we find our ſelves miſtaken, and thus we may a ſecond or third if poſſibly we can by any means light upon ſuch Experiments or Obſervations, as may inable us to gueſs which way ſhe was moſt likely to take; but if upon Tryal we find it to be a buſineſs of much greater Difficulty, the Progreſs how far we have gone is to be regiſtred, and the *non ultra* together with it, and ſo that kind of Inquiry may be laid by for a time, till ſomewhat more of the ſecret Workings of Nature are learnt from ſome other Proſecutions of her, in other ways, for Nature is ſo very ſubtle and reſerved, that there will need a very great Stock of Patience as well as Skill to be able to diſcover her Paths and Methods. As in inquiring after the Adequate Cauſe of Expanſion, we find that moſt Bodies as well fluid as ſolid, Metals, Quick-ſilver, Stones, Glaſs, Water, Spirit of Wine, Oyle, *&c.* are expanded by Heat, but finding alſo that the contrary Quality to Heat, Namely, intenſe Cold does produce the ſame Effect as that Water frozen into Ice is more rarified than the Water: We are here at a loſs to find what way Nature ſhould take with two quite contrary Agents, to bring forth the ſame Effect, here therefore we ſet up a Mark, and make an Attempt to find what way Expanſion is perform'd by Cold, we find that moſt Ice when examin'd is all over beſprinkled with diſſeminated Bubbles; till we have traced Nature a little farther, we inquire therefore, whether Nature has not taken that way of rarifying that Body, but we may find that even thoſe pieces of Ice which through the beſt Microſcope is perfectly clear and free from thoſe ſmall Bubbles, has a greater Expanſion than the Water out of which it was frozen, becauſe it will ſwim in it, and next becauſe that the Refraction of Ice is leſs than the Refraction of Water. This laſt ſeems to hint that Nature has taken this way of making Ice lighter than the common Water, by precipitating a groſſer or heavier part of the Water to the Bottom, and by collecting the lighter and more rarify'd Parts and freezing them, as may be in part obſerved in the freezing Salt Water; but that neither is this the way that Nature has attempted, this Experiment will ſatisfy us, that taking two clear pieces of Ice, and ſuffering one of them to thaw and the other to remain frozen, the Ice will ſtill ſwim upon the Water, whence 'tis evident that the Water is the ſame as to Weight. Beſides we find that the whole Bulk is expanded, and not the frozen part made lighter and the unfrozen heavier; for we find it to break the containing Veſſel if it be ſuch as will not freely give it room to expand; ſo that we muſt here ſet up a reſt, till we may come to the Knowledge of it ſome other way.

An Inſtance in the Cauſe of Expanſion.

By theſe ways are we to proceed to collect all the moſt common and obvious Experiments and Obſervations, that ſeem to have any thing of Information in them as to the Nature inquir'd after, or are very ſignificant to any other Nature, yea though we cannot preſently foreſee what uſe there may be of it, yet as in collecting Timber for a building, hewing off all the Superfluities and trimming it to be fit for the Repoſitory; we ſhould lay it up in the place of things of uncertain Uſe.

But to proceed, the ways of diſcovering the Properties and Powers requiſite to be well underſtood and made uſe of in the compiling of a Philoſophical Hiſtory, may be theſe three following,

Three ways of diſcovering the Nature of Bodies.

I. By the Help of the Naked Senſes.
II. By the Senſes aſſiſted with Inſtruments, and arm'd with Engines.
III. By Induction, or comparing the collected Obſervations, by the two preceding Helps, and ratiocinating from them.

First,

Article 1st. By the naked Senses. First, By the naked Senses are discovered the more obvious and superficial Proprieties of Bodies such as these,

Shiningness, or not giving any Light.	Gravity, or Levity.
Transparency, or Opacity.	Coarsness, or Fineness.
Reflexiveness, or Refractiveness.	Fastness, or Loosness.
Colour, or Colourlesness.	Stiffness, or Pliableness.
Sonorousness, or Dulness.	Roughness, or Brittleness.
Smell or Taste.	Clamminess, or Slipperiness.
Heat, or Cold.	Figure, or Motion.
Dryness, or Moisture.	Place, or Position.
Fluidity, or Consistence.	Action, or Passion.
Density, or Rarity.	Parts, or Number.

These are as 'twere the first Elements or Letters of Information, and therefore ought first to be learn'd and understood, before we proceed further into the deeper parts of Inquiry. But we are not here to stay; for this, like the Knowledge of Letters, without knowing how to spell with them, or use them, is little worth; for our Senses are of such a Constitution, that they are very apt to mislead us in those things where their Power reaches, and in many things they leave us without being able farther to assist us.

Article 2d. By the Senses helped and assisted. The Defects therefore being naturally two, we ought to provide against them with two Artificial Helps; first, for the more certain determining and defining the Sensations, and reducing them to a Standard, and next for the Discovery of those sensible Properties in Bodies, which our Senses are not able to reach, and defining them also.

1st. Reducing Sensation to a Standard. First, For the exact determining and defining of the Quality or Degree of the Proprieties, Powers, and Affections of Bodies, we ought to provide such Instruments or Standards, as may be capable of receiving all Degrees whereof that Propriety is capable, after which Search is made: That so by making the Standard receive the same Degree of the Propriety with that in the Body to be measur'd, the Division of the Standard may give the determinate Quantity or Degree, whether the Inquiry be after the Quantity of its Extension, Time, Motion, Action, or Passion.

Secondly, For distinguishing the Quality of some of them in answer to what kind of this or that general Propriety they belong to; there ought to be peculiar Contrivances that so every thing may be more exactly defin'd, and nothing may be left to the unaccurate and casual Information of the Senses, but that every thing that is taken into Philosophical History, may be capable of being accurately determin'd by Instruments. Now though it be very difficult to determine exactly in all; there being some of them, such as the Smells and Tastes of Bodies, which never have been brought to any kind of Theory, and of which therefore we have so very imperfect Notions that we have not words for many, and even those Names we have are very ambiguous and determine little, yet 'tis not impossible but that even these also may be reduc'd to a Theory and Standard; for the Variety of Colours is not less than the Varieties of Tastes and Smells, and yet 'tis not difficult to derive them all from two Heads, and the Degrees of them; namely, from the Degrees of Yellow, and the Degrees of Blew, and from the Interposure of White or much Reflection, and Dark or little Reflection: For all the Colours in the World are made up of the Mixtures of some of these Degrees, with the Intermixtures of White and Black, which make them only appear more faint or foul. And it seems not improbable also, but that with Diligence there might be found out such a Theory of Tastes and Smells, as that from the Mixture of some few with their Gradations, might be explain'd all the Tastes and Smells in the World. The well determining of which Inquiry, seems to be likely to afford us as great Assistance towards the Discovery of the Nature and Constitutions of Bodies, as to their Medicinal Use, as any way imaginable. Now though this nice distinguishing and defining the Degrees of some things be very necessary, yet in other things it is often times needless and insignificant,

insignificant, for in such things wherein Nature does not observe such Nicety in making use of this or that peculiar Degree or Mixture, but seems indifferent to all; in such things the distinguishing that Propriety in any one particular on which Experiment or Observation is made, will rather be prejudicial than assistant in discovering the Nature in general, but in other things where Nature seems to be bounded, and to act by a certain Method, and to keep within such Limits, in those the Limits and Bounds are to be observed, as in observing the Colour of any Terrestrial Animal: 'Tis not very material to define exactly what Colour it is of, because we find Nature uses a Latitude; only this may be noted, that though the Colours of Terrestrial Animals of the same Species are often very various, intermixt with White and Black, and no one Colour perfectly clear or bright is to be found amongst them, yet in the Colours of Birds there are indeed to be found all Varieties of Mixtures, but generally the Colour is somewhat more fixt to the Species, and the most of them more clear and orient: Which last does discover somewhat of Distinction between the Parts and Substance of Hair and those of Feathers, namely, that the Parts of Feathers are far more clear and small, than those of Hair, and consequently 'tis not improbable, but that the constituent Parts may be more porous, defecated and fine. So likewise the Bounds of Heat, between which Nature has confin'd it self for proportioning the Animal and Vegetable Life, and beyond either of which Life cannot subsist, are to be as exactly observ'd as can be defin'd, but the peculiar Warmth of this or that Animal is not so nice: So likewise for Gravity the lightest and heaviest Animal, Vegetable, or Mineral Substance, and so for the rest.

In other things where the exact Degree is very necessary and Fundamental to the Constitution of the Body, in that case the greater Diligence and Skill is used in the determining of it the better. Thus in determining the Specifick Weight, Density, Colour, Malleableness, *&c.* of Gold, or any of the other Metals: The more exact the Experiments are, the greater Information we receive from them of the Nature of those Bodies.

For the making of these Standards and Measures, to determine the various Degrees of several Proprieties, there may be divers Contrivances for each peculiar Property, and some of them more fit, convenient, and exact than others. The Degrees of Light may be determin'd by Comparison to the Light of a Candle, of a determinate Bigness, plac'd in a long dark Room or Gallery, and by examining the shining Body at several Distances from that Light; as suppose the Light or Shining of a Gloworm be to be determin'd in such a dark Vault, I try at several Distances from the Candle whereabout the Light begins to be visible; in departing from the Candle, and whereabout it begins to disappear in approaching towards it, and that Place I mark for the Degree of the Light of Gloworms; by the like Method I try the Light of rotten Wood, decaying Fish, Diamonds, heated Metals, *&c.*

Observation 9th. and 10th.

The ways of determining Colours, many skilful Painters and Dyers know very well without Instruments, but by one not so skill'd, they may be defin'd by a way I have mention'd in my Micography, which I therefore now omit to repeat.

Time of lasting, Velocity of Propagation, greatest Distance of Extension.

The Acuteness and Loudness of Sounds, and Sonorousness of Bodies, may be easily enough measur'd by a sound Pipe of a determinate Bigness, and by the Strength of the Blast that is given by poised Bellows to blow it, other more loud Sounds may be determin'd also by shooting small Guns with various Charges, or by the Distance they can be heard, and the like.

Smells and Tastes being not yet reduc'd cannot be so exactly measur'd and defin'd, but they may be somewhat determin'd, by comparing them to the Smells and Tastes of Bodies that are most common.

The Distance and Velocity of Propagation, the Cold Air from Snowy Clouds.

Heat and Cold may be many ways discover'd, by Weather-Glasses and Thermometers of several kinds; the way of making and determining which, I have shewn in my Micrography, or else by Burning-Glasses, together with the help of the Thermometers: For if a Burning-Glass of a known Number of Inches in Diameter be able to melt Gold, and Iron, and Copper, and Stones, *&c.* in such a determinate Quantity of Time; and that the Reflection from a part of it be able to raise the Standard to such a Degree, it follows, that thereby all De-

grees of Heat may be easily determin'd; as suppose, for instance, it be desired to determine the Degree of the Heat of the Flame of a Lamp, intended by a strong Blast, we find that such a blown Flame is capable of heating Glass Red hot, and melting it in such a space of time.

To reduce it therefore to the Standard, 'tis easy to see what Aperture of the Burning Glass will produce the same Effect in the same time, and what Aperture at the same time (for this is very necessary to be known) will raise the Thermometer to such a Degree. The Degrees of Cold also may be easily determin'd by the Thermometer, as I have elsewhere shewn.

The Degrees of Dryness and Moisture in the Air, and sometimes also in other Bodies, may be distinguished by the Hygroscope, of which I have explain'd the way of making and using in my Micrography. Stiffness and Pliableness, Toughness and Brittleness, are sufficiently obvious, by comparing them to the Pliableness or Stiffness of pieces of unhardned Iron of peculiar Bignesses and Shapes, and to the Toughness of Wire of a determinate Bigness: Now though in all these things we cannot come to a Mathematical Exactness, yet it will be sufficient if we come as near to the Truth as the Matter is capable of; for we find that Nature it self does not so exactly determine its Operations, but allows a Latitude almost to all its Workings, though as I said before, it seems to be restrain'd within certain Limits, and beyond those is neither excessive on the one hand or defective on the other.

The Specifick Gravity of Bodies may be determin'd by weighing in Water.

There are as many various ways also of determining all the other Proprieties, and reducing them to a Certainty or Standard, but these may suffice for an Instance, to shew what I mean by the determining the Degrees of the Proprieties in several Objects.

As for the determining of the Figure, Number, Motion, Velocity, Power, Time, and the like, the ways are sufficiently easy, and the ingenious Inquirer will upon the occasion, find various Contrivances to determine them.

2dly, By helping the Senses to discover what unassisted they could not, &c.

The second way of assisting the Senses, is either first by enlarging their Power, or Sphere of Activity, and extending it much farther than that assign'd them by Nature; or else secondly, by reducing other things to such a Constitution, as to bring them within the Power of the Sense. For the Performance of each of which there are various means to be used.

1st. By enlarging their Power.

And first, for the enlarging the Power of the Sense, and making it capable of sensating many things, which without those Helps would not have been discerned or fallen within the reach of those Senses; of these there may be many for the assisting of every Sense, but some of them have been more cultivated than others, and brought to a much greater Perfection, but yet not to the highest pitch they seem capable of, but they are every day more and more improv'd, and it may be hoped, that this Age may produce the perfecting of some of them.

As for the Sight Microscopes and Telescopes.

Of this kind are Microscopes and Telescopes for the Sight, the one for discovering the Figure and Magnitude of the small Parts of such Bodies as are within our reach, the other for detecting the Figures and Magnitude of such Bodies as are by the Greatness of their Distance, reduc'd to so small a visible Appearance as that the naked Eye is unable to distinguish either their determinate Bigness or their Figure, these may be Helps both of Invention and defining: And as they are indeed the greatest Instance that can be given of the Improvement of the Power of the Senses; So the perfecting of them is the most likely way to afford us the greatest help for the Detection of the Nature of Bodies. For the Eye is the most Spiritual and most capacious Sense we are endowed with, it affords us the most sudden, most distinct and instructive Information of all; with this we expatiate through the Universe, and pass from the one end to the other in the twinkling of an Eye, by this we compare the Magnitude and Measure, the Distances, Motions, and the Velocities of all those vast Bodies which are disseminated up and down through it, and none of the other Senses tend so much to perfect the Imagination as this. Now whereas the Power of the Sight in Discovery was not able to distinguish of Objects that appear'd to the Eye under a less Angle than about a Minute, by the help of these it is able to distinguish such as would not appear bigger than a third. So that according to this

this Calculation, the Power of the Eye is increaſed near 4000 times as much more as it was before, and we are capable of diſcovering things 4000 times further off, and 4000 times nearer the Eye than we were without them. And it ſeems not improbable to me but that each of them may be improv'd ſo far as to inlarge that Power 4000 times 4000 times the firſt Dimenſion, eſpecially in ſuch Objects where the imperfect Tranſparency of the Medium, or the Defect of Light does not hinder this Effect as in things very near the Eye, or in Objects very near the Zenith.

The Hearing.

The Senſe of Hearing does not altogether ſo much inſtruct as to the Nature of things as the Eye, though there are many Helps that this Senſe would afford by a greater Improvement, there may be a Poſſibility that by Otocouſticons many Sounds very far diſtant (I had almoſt ſaid as far off as ſome Planets) may be made ſenſible, at leaſt the Noiſes of Thunder might be diſcover'd at a much greater Diſtance than it can be by the Ear without theſe Helps, and hereby perhaps the Variations and Changes of the Weather might be predicted much longer before-hand than now they are, and Ships at Sea might perhaps diſcover an Enemy of Weather coming by the Hearing, as well as they can now diſcern an Enemy's Ship by the Sight. As for the hearing of Noiſes made as far off as the Planets, I cannot, I confeſs, my ſelf ſo far throw off Prejudice, as not to look on it as a very extravagant Conjecture, but yet methinks I ſhould have had the ſame Thoughts of a Conjecture to find out a Help for the Eye to ſee the ſmaller Parts and Rocks of the Moon, and to diſcover their Height and Shadow, before I had ſeen or known the excellent Contrivance of Teleſcopes. And though methinks from what Experience I have had of Sounds, I am apt to imagine them not capable of being propagated to ſo great a Diſtance; yet when I conſider again, that by very ordinary and caſual Tryals as it were, I have been able to hear Perſons diſcourſe diſtinctly where others in the ſame place have not heard any Noiſe or Whiſper, I would fain perſwade my ſelf againſt concluding or building on the Impoſſibility of ſuch things as I am not able demonſtrably to prove not poſſible.

The Internal Motions of Bodies may be diſcover'd by Sound.

There may be alſo a Poſſibility of diſcovering the Internal Motions and Actions of Bodies by the ſound they make, who knows but that as in a Watch we may hear the beating of the Balance, and the running of the Wheels, and the ſtriking of the Hammers, and the grating of the Teeth, and Multitudes of other Noiſes; who knows, I ſay, but that it may be poſſible to diſcover the Motions of the Internal Parts of Bodies, whether Animal, Vegetable, or Mineral, by the ſound they make, that one may diſcover the Works perform'd in the ſeverals Offices and Shops of a Man's Body, and thereby diſcover what Inſtrument or Engine is out of order, what Works are going on at ſeveral Times, and lies ſtill at others, and the like; that in Plants and Vegetables one might diſcover by the Noiſe the Pumps for raiſing the Juice, the Valves for ſtopping it, and the ruſhing of it out of one Paſſage into another, and the like. I could proceed further, but methinks I can hardly forbear to bluſh, when I conſider how the moſt part of Men will look upon this: But yet again, I have this Incouragement, not to think all theſe things utterly impoſſible, though never ſo much derided by the Generality of Men, and never ſo ſeemingly mad, fooliſh and phantaſtick, that as the thinking them impoſſible cannot much improve my Knowledge, ſo the believing them poſſible may perhaps be an occaſion of taking notice of ſuch things as another would paſs by without regard as uſeleſs. And ſomewhat more of Incouragement I have alſo from Experience, that I have been able to hear very plainly the beating of a Man's Heart, and 'tis common to hear the Motion of Wind to and fro in the Guts, and other ſmall Veſſels, the ſtopping of the Lungs is eaſily diſcover'd by the Wheeſing, the Stopping of the Head, by the humming and whiſtling Noiſes, the ſliping to and fro of the Joynts in many caſes, by crackling, and the like; as to the working, or Motion of the Parts one amongſt another, methinks I could receive Incouragement from hearing the hiſſing noiſe made by a corroſive Menſtruum in its Operation, the Noiſe of Fire in diſſolving, of Water in boyling, of the Parts of a Bell after that its Motion is grown quite inviſible as to the Eye, for to me theſe Motions and the other ſeem only to differ *ſecundum magis & minus*, and ſo to their becoming ſenſible they require either that their Motions be increaſed,

or

or that the Organ be made more nice and powerful to sensate and distinguish them [to try the Contrivance about an Artificial Timpanum] as they are, for the doing of both which I think it not impossible but that in many cases there may be Helps found, some of which I may as Opportunity is offer'd make Tryal of, which if successful and useful, I shall not conceal.

Smelling. As for the Sense of Smelling, though it has been less cultivated than that of Hearing, and seems to be of much less Extent, and to have much less Influence upon our Knowledge than either of those I have already mentioned, it being only for the distinguishing of the Effluvia and Fumes of Bodies, which are dissolv'd by and fly upon and down the Air; yet if we consider the Nature of it aright, we shall find that it is capable of a much greater Degree. We find that a Hound by this Sense is able for a good while after to discover where his Game has past, which possibly may arise from the Steams or Efflux of its Body, which perspiring through the Pores of the Skin, and coming into the Air are easily precipitated down upon the Track which the Creature has past over, and so lie loose upon the upper Surface of it, and thereby they easily touch the Nose of the Hound, which in following his Game he usually either rubs over the Grass, or Ground, or at least lays it so very near, that with drawing in the Breath at his Nose, by strongly sniffing; the Volatile Salt, which is in the Effluvia of all Animals is easily rais'd and drawn in with the Air, and that Sense being very acute in this Creature, it easily perceives the smallest Impression on it.

There may be multitudes of ways of assisting this Sense, some of which I have already hinted in the Preface of my Micrography, as I have also concerning some Assistances that may be thought of for the helping of the Senses, of Tasting and Feeling, which may serve as a Specimen or Example to shew what my meaning is in this Particular.

2dly, By making the sensible Qualities in the Object more powerful. The Second way therefore of assisting the Senses in Discovery, is by making the sensible Qualities of the Object more powerful than naturally they are of themselves for affecting the Sense, or more proportionate to the Power and Faculties of them. This may be various ways performed according to the particular Nature of the Objects that are disproportion'd to the Sensory. For

1. First, Some are quite obscur'd and buried in the matter, so as not at all to affect the Sense, these therefore will need to be excited and made active and vigorous by Art; thus the Tastes of Metals and divers other Bodies are discover'd, by opening and loosning the Bodies of them with appropriate Menstruums; thus the Light of a Diamond is made visible by rubbing, The Inky Black Colours of Galls, or the Juice of Oak is made visible by mixing Coperas, The Sound of a Bell is discover'd by striking it, the Smell of Sal-Armoniack is freed by mixing Quick Lime, the biting Smell of Mustard-Seed is freed by bruising and grinding. The internal Heat of Corrosive Menstruums is made sensible by mixing dissoluble Bodies with them, the Gravity of the Air is manifested by being weighed in an evacuated Vessel, the Greeness of Gold is discover'd by being beaten very thin, the Greeness and Blueness of Copper by Dissolution, the Salt of Vegetables by calcining, and Multitudes of the like.

2. Secondly, Some are very languid and weak, and so affect the Sense to which they are appropriated so very little that they are hardly discernible, such as these therefore will need to be assisted by Art, and to be made more vigorous and powerful. Thus the Heat in the Air or Sun Beams, in the coldest time of Winter, is hardly sensible to the touch; but if the Rays be united by a Burning-Glass, they will not only be able to warm, but also to burn the Finger; thus when the Air has very few Effluvia in it of an odorous Body, so that we can hardly smell them, if drawing in the Breath through the Nostril we make a great Quantity of that Air pass through it, those few that are collected and united out of the Air by this means become sensible. Thus the Smells of many other Bodies are so languid and faint, that they are hardly discernable without being either heated or rubb'd, the Flexibility of Glass is manifested by drawing it out into very small Threads. Thirdly, many things become insensible from their Slowness, these ought either to be accelerated or to be sought after by

other

other means which I shall shew in the third way of acquiring Information of the Effects of Nature. If they are such things as are within our Power to promote, their Motions are to be accelerated and promoted either really or in Appearance; thus supposing the Experiment were true that some Authors have delivered to us concerning the Acceleration of Sallets, we might possibly be able to see the Motion of Vegetation, as we might also, if that Story be true which *Clusius* tells us, of the strangely growing and rising Tree; thus the Motion of the Hand of a Watch may be seen by making it go faster: As to the making them appear so though they really are not accelerated, this is done by the Telescope for the Cælestial Bodies, for by the help of long ones of that kind, the Motion of the Sun and Stars is almost as plain as that of a Bowl, the like is done also by viewing the Shadow of the Sun when cast on the Ground, or a Wall, by a Body at a great Distance from the shadowing Body.

Thus also the Sound of a String very slackly strain'd is not to be heard, but by being strain'd harder it yields a very brisk Sound. Iron heated to one Degree of Heat has not acquir'd Motion enough to make it shine, but if farther wrought on and agitated by Heat, it shines very bright and clear.

Thirdly, Some Objects are too strong, and so the Sense is not able to indure the examining of them: In this case, the vigorous Influence of them on the Sensory is to be abated; thus the Body of the Sun is so bright as to be able to destroy the Sight, but if it be veil'd with a Fog or Cloud, or the Sight be veil'd by a deep colour'd Glass, or a small Aperture, or the Reflection of it be view'd in a Bucket of Water, the Eye may without much Trouble behold and view it. Thus the burning and corrosive Liquor of Oyl of Vitriol, or the like, which would burn the Mouth and spoil the Sensory, when allay'd by the Mixture of much fair Water, becomes a very pleasant Taste, and suited well enough to the Organ: Thus the Sound of Bells in a Steeple is so loud, that the Ear is hardly able to distinguish the differing Tones, but if the Ear be placed at a convenient Distance it does plainly perceive the Harmony, and easily distinguish each several Note and Tone. 3.

Fourthly, Other Objects there are, which are so minutely dispers'd through other Bodies, that unless there may be many of them collected together, or that that Matter through which they are disper'd be separated from them they are not capable of affecting the Sense. Thus Salts may lie invisible in Water, till by Evaporation the Water be separated, and Coral dissolv'd into Vinegar becomes invisible, till collected by Præcipitation into a visible Powder; thus Vapours dispers'd through the Air become small, and to the naked Eye invisible, till they are united closer together in a Cloud or Mist, the invisible Stars which are dispersed through the Æther, become not visible without being many of them united into a Galaxie, or cloudy Star, thus the Tinctures also of several Liquors are hardly visible till much of the more Watery and Transparent Parts are evaporated. 4.

Fifthly, There are other Objects of the Sense, which though in themselves very active and powerful, yet by being mixt and united with Objects more powerful, their Action on the Sense becomes imperceptible, because overpower'd by the stronger Influence of the associated Objects: Thus the Light of the fixed Stars in the Day-time becomes invisible by reason of the greater Light of the Sun which fills the Air. Now the way of making these Objects sensible, is by removing the Influence of the more powerful Object, either by destroying, weakning, abating, or if it be capable of it, by strengthning the Powers of the weaker. Thus (if we may believe what is affirmed by many Authors) the Stars may be made visible in the Day by placing the Eye at the bottom of a very deep Well, they may be also made visible by a total Eclipse of the Sun in the Day-time, and the like. Thus the Melody of a sweet Voice is not heard among a noise of Trumpets or Drums; thus the Pallate cannot distinguish the Sweetness and Variety of such Tastes as are mingled with others more strong and powerful; therefore even the best Drinks relish ill after eating sweet things, thus 'tis commonly said, that the smelling of Hounds is spoil'd by suffering 5.

ing them to smell of strong scented Bodies, thus the Light of a Gloworm, or Diamond, or the sparkling of a Cat's Back by rubbing is not to be seen but in the dark, and the Gravity of the Air seems Lightness when encompassed with Water, which is much heavier and more powerful, but if the Water and all other incompassing heavy Fluids be remov'd, the Gravitation of it becomes very manifest.

6. Sixthly, There are other sensible Qualities, which cannot be distinguish'd for want of Opposites and contrary Qualities. Thus in a Full Moon the Irregularities of the Surface are not discover'd, for want of dark Shadows to be intermixt with the brighter Reflections; thus the Taste of Bodies is better perceiv'd by being tasted after other Substances of a different Taste, the Brightness of any Colour is better discern'd by being interpos'd between Colours of another kind. And 'tis a Maxim in Musick, that Harmonies become more pleasant and grateful, that is, affect the Sensory better by having Discords intermingled: Thus Cold is better felt after Heat, Roughness after Softness, Dryness after Moisture, Sweetness is better tasted after Sowerness, and the like in all the Senses. As for the Medicinal assisting of the Senses, I leave that to the Physicians.

There remains a third way of inquiring into the Nature of Bodies and Operations, by which we may be able to write a more accurate History of them, for all these Ways I have already mention'd, though in themselves very requisite, and as it were the Letters or Elements to what follows; yet if the Natural Historian proceeds no further in his Examination, his Information will be very imperfect, and he that shall afterwards come to make use of it will find himself necessitated almost to begin the whole Inquiry anew, to make over again all those Experiments and Observations that he finds Registred, and to intermingle divers others to the end that he may find out that which ought to have been ready prepared to his hands; and in Truth, without prosecuting this third way 'tis not possible to make Experiments with any Judgment, that is, to know which Experiment is more or less significant, or of greater or less Concernment as to the Discovery of the Proprieties sought, for most Experiments are like single Letters which seldom signify but when they are joyn'd and compounded in Syllables or Words; nor can the History be freed from infinite Repetitions and Interpositions of Experiments and Observations, which are either very insignificant or at best indicate nothing else but what is much better manifested in some of the other Entries and Remarks, and so serve only to fill Room needlesly and perplex and weary the User or Student of it: For 'tis not fit that every Experiment that is made should be registred, but of a Number of good Observations and Experiments, such ought to be chosen and pick'd which are as it were the Epitomy of the rest, and comprise in short and plainly all that is more largely and widely diffus'd and obscur'd in others.

Art. 3d. *or the Third Way of discovering Nature by Induction.*

That therefore which will regulate and rectify both the former ways of proceeding is this Third, which is an Inquiry into the Nature of things by the Effects produced at a greater Distance, and more remote from immediately affecting the Sense, and this is by putting of several Observations and Informations together, and collecting from them, and by reasoning and deducing from them, so as to proceed, to the culling and chusing of the Experiments and Observations already made, and to the inventing of such farther Experiments and Ways of searching, as shall be most significant to the Inquiry; for this will not only make the History much shorter, and more compendious, but much plainer, significant, and full.

The third way therefore of discovering Nature, is by the Observation of a great Number of Effects and Circumstances; and these, tho' very many, may be very well reduced under these two Heads.

First, By observing the *Effects* themselves produced.
Secondly, By observing the *manner of Proceeding*, or means made use of.

Again, The *Effects* themselves may be *Intermediate* or *Ultimate*.
1, 2, The *Intermediate* may be either, *constant*, *necessary*, *and always interpos'd* or *accidental*, and sometimes present sometimes absent. 3, The

3, 4. The *Ultimate* also may be either *necessary* or *accidental.*

In the second place, The *Manner* also of Natures proceeding may be either more *obvious* or more *secret*, and both these may be observed either in several Bodies, or else in several Operations.

The more *secret* are such wherein the manner of proceeding is more obscure and difficult to be found, and not yet discoverable by the Senses, or any other known way.

These more occult and secret Workings of Nature are diligently to be noted and examined.

The manner of the more secret workings of Nature.

1. First, The Operations of Bodies are to be more especially noted which seem to produce Effects, by means of which we have not the least Information immediately from our Senses, such as we call Sympathetical and Antipathetical, *&c.*

2. Next, Operations of Bodies at a much greater Distance, such as we use to call Influences or Influxes.

3. Lastly, we must observe the yet more spiritual and more subtile Operations of Phantsy and Imagination, Memory and Ratiocination: Both of sleeping and waking living Creatures, how they work on their own Bodies, and whether they work on others?

The more obvious are such wherein the Agents, Patients, and Means are more plainly to be discerned by the Senses, or other commonly known ways, which may be such as these following.

The manner of the more obvious workings of Nature.

1*st.* In general, how Nature proceeds in generating, increasing, weakning, and destroying the same Proprieties in several States of the same Body.

2*ly*, How Nature proceeds in distributing the same Proprieties in several Bodies, in what Bodies it has placed a dawning or beginning of it, in what a middle Constitution, in what the highest Perfection, in what a decaying, in what it has quite extirpated it?

3*ly*, How Nature proceeds in Conjunctions or Combinations; that is with what other kinds of Proprieties, the same Quality is joyned in divers Bodies? With which it flourishes most, with which it withers, with which most usual, with which most seldom?

4*ly*, How Nature proceeds in Separations or Disjunctions, that is, what Propriety it seldom or never joyns in the same Subject?

5*ly*, To observe the Transitions of Nature, how from the Destruction of one Propriety it generates this, that, or another, whether that be the same in all Bodies, or how it varies? as sweet into sowre, *&c.*

6*ly*, To observe the several ways Nature takes in several Bodies to produce the same Effect.

7*ly*, To observe how, where, and when Nature makes use of the same Body or Means to produce differing Effects, as Condensation and Rarefaction by Cold, *&c.*

8*ly*, To distinguish as near as may be, when there seem to be more than one Cause conducive to the producing of an Effect; which of them is most powerful, which less, which least, and this by varying one and th' other of them, and observing the Issue. And by observing the Effects of each, when mixt with other Bodies in other ways.

9*ly*, To observe the Resemblance and Discrepancy of Natures producing the like Parts in differing Kinds, Species, or Individuals?

10*ly*, To observe the Transition of Nature in the Forms and Proprieties of Creatures, how it passes from one to another, *&c.*

11*ly*, To observe where and how Nature seems sometimes to be frustrated, and how and where it fails or misses in producing its usual Effects.

12*ly*, To observe the Deviations of Nature in framing Specifick Bodies, and the several Circumstances that attend upon such Deviations.

13*ly*, To observe the Deviations of Nature in producing Individuals such as Monsters, *&c.*

4*ly*, To

14*ly*, To obſerve the concomitant Proprieties of Individuals in their greateſt and loweſt pitch of Perfection they ſeem capable of.

15*ly*, To obſerve the various workings of Nature in various Places, and Times, how ſuch Circumſtances alter her Courſe, as Birds in the Air, and on Land, Fiſh in freſh and ſalt Water, Men in *Guiney* and *England*, &c.

16*ly*, To obſerve what things ſeem moſt conducive to the Perfection or Imperfection of Productions.

17*ly*, In particular we are to obſerve, eſpecially and more attentively, the workings of Nature where ſhe ſeems to be peculiar in her manner, and ſeems not any where elſe to follow the like Method.

18*ly*, To obſerve and enquire after what middle way, or ſomewhat reſembling Method can be found, which is as 'twere interpoſited between this peculiar and the more common Method.

19*ly*, To obſerve how much, and by what Degrees Nature is made to alter its Courſe by Art.

20*ly*, To obſerve where and by what means Art cauſes Nature to deviate where it aſſiſts, promotes, perfects, impedes, diverts, deſtroys the uſual Courſe of Nature.

21*ly*, To obſerve the Natural and Artificial ways of producing the ſame Effect, as diſtilling ſalt Water, hatching Eggs by Artificial Heat, *&c.*

22*ly*, To obſerve the Difference between Bodies produced by Nature and thoſe by Art.

23*ly*, To obſerve the differing ways of producing the ſame Effect by Art.

24*ly*, To obſerve with what Circumſtances Nature and Art do ſometimes exceed each other.

25*ly*, To enquire and try how many Mechanical Ways there may be of working on, or altering the Proprieties of ſeveral Bodies; ſuch as hammering, pounding, grinding, rowling, ſteeping, ſoaking, diſſolving, heating, burning, freezing, melting, *&c.*

26*ly*, To enquire and try how many Mechanical Ways there may be of ſeparating Bodies; as winnowing, ſifting, waſhing, filtering, ſtraining, wringing, preſſing, diſtilling, evaporating, precipitating, Chryſtallizing, burning, copelling, freezing, ſhaking, knocking, *&c.*

27*ly*, To inquire and try how many Mechanical ways there may be of uniting and incorporating Bodies into one another; as by melting, Diſſolution, jumbling, charring, digeſting, Inſolation, by mixing a third, by taking away a part, by Compreſſion, by opening, by Time, *&c.*

28*ly*, To inquire and attempt by what means Bodies may be changed or tranſmuted, from one thing to another by a real change of all their former Proprieties and ſenſible Qualities, and by having acquired new ones, being altered in their Conſiſtence, Colour, Bulk, Gravity, *&c.* as the Mixture of Tin and Copper, *&c.*

29*ly*, To obſerve, or rather contrive, by what Means or Supplements Nature may be more ſenſibly explained, that ſo the Nature of inſenſible Operations may be more eaſily gueſſed at and imagined.

In the making of all which Obſervations, Tryals, and Inquiries, great Care and Judgment muſt be uſed in exactly determining the Quantity, Quality, Time, Place, Space, and ſeveral other Circumſtances of the Ingredients, Effects, Proceſſes, Doubts, *&c.* that all things may be reduced to ſome Certainty of Number, Weight, and Meaſure, and that nothing may be left to doubting, Heſitation, or Gheſſes, that no part of theſe Materials which are for the Foundation may be defective or faulty, which may endanger the whole Superſtructure.

There are many other ways of makinguſe of and deducing from Experiments and Hiſtories, for the raiſing of more general Axiomes, and for the building of a Body of Philoſophy, than theſe I have mentioned, which I muſt refer to ſome other Opportunity; theſe ſeeming to me ſufficient to inable a diligent Inquirer to ſet his hands to promote ſignificantly this great Work of compiling ſuch a Philoſophical Hiſtory, as ſhall be both ſufficient and adapted for the perfecting the Knowledge of the Works of Nature. And theſe being once well under-

ſtood

stood and practised, all the other will easily follow: That therefore these may be the more plain and easy to be understood, I shall endeavour farther to explicate each of them, and to exemplify them with some easy and obvious Instances.

The first way therefore of discovering the Power and working of Nature more mediately, is by the constant and more necessary Effects, which are produc'd by the working Power, before it produces its final and ultimate Effect, and these serve as a Torch, Drum, or Light, by which we may be guided in our pursuit of Nature, and be inabled to distinguish by what Steps, and which way Nature proceeds.

1. For instance, Suppose it be inquir'd to know whether the Sun be a fired or burning Body, Here the Body to be examin'd is so far off, that we cannot make any Tryals or Examinations of it, and 'tis of that Bigness that it cannot be expected to be consum'd in many Ages, and so the ultimate Effect is not to be look'd after; the Helps therefore of knowing may be some such as these, what are the intermediate Effects of all Fire? Heating, shining, emitting some kinds of Fumes and Vapours, wasting the Body it burns, and usually at last consuming it: These therefore are the things to be look'd after, and diligently examin'd; as first whether the warming of the Earth by the Sun Beams be not in the same manner perform'd as a Body; suppose an Apple is warm'd by the Fire, whether the Cause of Subterraneous Fires and Earthquakes may not proceed from the Heat of the Sun, as Blisters and Eruptions on the side of an Apple that is roasted by the Fire. Next, Whether the Colour of its Light be not like that of Flame, especially that of Nitre and Sulphur. Thirdly, Whether it yield any Smoke or Fumes, and especially whether such *maculæ* and *faculæ* as have been discover'd in it, can be observ'd when at the Brink to be elevated above the Surface of the Sun: These must be made with great Diligence and very accurate Glasses, as must also this last, which could it be certainly known would afford us the greatest Probability, and that is the discovering of the Body of the Sun to diminish and grow less, which perhaps to After Ages may not be impossible, if with very accurate Telescopes this Age do exactly determine the Diameter of the Sun. Thus the Scorbute, and many other Diseases, are a long while discoverable by certain Symptoms almost insensible and scarce regarded, before it comes to rage with its more direful Effects: By which means a diligent Observer may detect the very Inclinations of Nature, and then surely much more easily turn them. Thus the Observations of the Change of the *Nuclei* of Comets is an Argument of the wasting and Consumption; thus also, by the daily Progresses of the Motion of the Comet, we may easily judge of the Distance and Velocity and way of it.

Instances in the Effects themselves.

2. Secondly, Nature may sometimes be discover'd by comparing accidental intermediate Effects; these as they are for the most part not thought of, and are a Product of Providence, so do they generally afford very singular and excellent Information, and usually much more than the more constant and necessary and expected Circumstances. Thus by an abortive Birth, much more may be learnt of the manner of Formation in the Womb, than by only examining a perfect Infant: Thus the passing of the Comet very near some Star, so that the brightest part of the Tail seems to cover some Stars, and yet very little eclipse their Light, is a help to judge that the Substance or Consistence of it is very much rarify'd, and somewhat of the Nature of Smoke; Thus also by the Curvity of the Tail of the Comet, and by the Deflection of it many times a good way out of the straight Line, which passes through the Body of the Comet, we may find that it cannot be caused by Refraction, as many suppose, but is rather a real Body.

3. Thirdly, Nature may be discovered by the constant ultimate End, or last Effect of a Principle. Thus somewhat of the Nature of a Comet may be discover'd by the end of it, and this we find always to be by degrees growing smaller and smaller, and fainter and fainter, till it disappears; and as it daily decreases in Bulk, so does it also in Motion, whence 'tis not improbable that

the Cause of both is from the Increase of Distance, and the Obliquity of the Line of its Motion to the Eye. Whereas, if it should accidentally happen, that the Comet should dwindle away and vanish, or be suddenly extinct when in its greatest Velocity and Brightness, 'twould be an Argument that its Constitution were of another Nature than what we shall hereafter indeavour to shew it probably to be, which may serve as an Instance to explain what we mean by our

Fourth Method of tracing Nature by the accidental ultimate Effects. An Instance of this 4th way may be this; suppose the thing sought for be the Cause of Earthquakes, Here if we inquire after the End or Events of them, we shall find that they have sometimes ended in strange and monstrous Eruptions of Fires, and Smokes, and Waters, and the like, casting forth great Quantities of burnt and melted Sulphur, Sands, Stones, Earths and Minerals, together with new Rivers and Streams of boyling Waters, sometimes raising, otherwhile sinking Mountains, sometimes raising, sometimes sinking Islands, sometimes digging, sometimes filling Caves. Hence 'tis not improbable, but that Subterraneous Fires are the chief Cause of those direful Effects, and that those Fires may be fed by Supplies of Nitrous and Sulphureous Substances, with which those Places usually most abound, that are or have been subject to these Accidents; for 'tis not else imaginable without the Supply of Niter, how those Fires should continue to burn, since I have not yet found any Substance whatsoever that would burn without a Supply either of fresh Air or Niter (the Reason of which I hope I have given in my Micrography) and 'tis very hard to imagine how such vast Fires should be supply'd with a sufficient Quantity of fresh Air, unless there be many Ventiducts under Ground, whereas we have no Knowledge of any: Or unless by the Influx of Springs and Rivers, the Vapours of the Water may serve to supply the Defect of Air, which whether so or not some further Inquiries and Experiments ought to be made; and though they should not be found to be sufficient for this Effect, yet they seem very much to contribute to the Violence of the Commotion and Eruption, which the breaking of Æolipiles, and small Dubbles of Glass seal'd up Hermetically half fill'd with Water, seem further also to illustrate.

2dly, Instances in the manner and means of Natures Operations, first the more secret.

5. A Fifth way of discovering Nature, is by taking more especial Notice of such Operations and Effects of Nature as seem to be more secret and reserv'd, working on Bodies remov'd at some distance, such strange Effects as our Senses are wholly unable to shew us any probable Cause thereof; for by discovering the true Reason of such Effects, we give our selves a new or Sixth Sense, which will open us a large new Prospect into Nature that we dreamt not of before. An Instance of this may be the Verticity or Direction of the Load-stone towards North and South; the Gravity and Attraction of the Earth towards its Center, the Influence of the Moon on the Waters of the Sea, or on Vegetable or Animal Bodies, the Attraction of Jet, Amber, Red-wax, and the like: we should very much labour to find out all the Assistances we are able for the perfecting of such Discoveries, by collecting all such Experiments together, and by comparing them one with another, that so the Mind may by some of those ways hereafter to be mentioned, discover first the Similitudes and Diversities of such Operations, and may the better be enabled to know what further Observations and Experiments are necessary for the Discovery of their Nature. Such Operations and Experiments therefore are to be sought after for from their Discovery, the Causes of much greater Effects may appear. The Verticity of the Loadstone may perhaps explain to us, why the Axis of the Earth keeps a Parallelism whilst it moves about the Sun; and the Explication of Gravity may shew us the true Cause of the Circular Motion of the Moon about the Earth, the Satellites about *Jupiter* and *Saturn*, and the Primary Planets about the Sun, and may also shew us the reason of the Currents, Ebbings and Flowings of the Tide, and the like, which I may hereafter more fully explain.

6. A Sixth way of discovering Nature, is by taking particular notice of such secret Proprieties of Bodies as cause them to unite or not unite with other Bodies,

or

or as cause them to operate, or not to operate on contiguous Bodies, these are Proprieties of Bodies of which the Sense can give us no other Information, but of the Effects; and therefore the Discovery of the Causes of these will give us another, or a 7th Sense, whereby to watch and follow Nature. Of this kind is the Animation (as I may call it) of Iron by the touch of the Loadstone, the Dissolution of hard Bodies by appropriate Menstruums, the Congruity or Incongruity of Fluids with Fluids, or of Fluids with consistent Bodies [that is, a Propriety whereby Fluid Bodies will readily unite and intimately mingle themselves, or adhere to some kind of Bodies, and will by no means unite and mingle with or adhere to other] the raising Fermentation by Addition of Leaven or Yeast, the firing a Heap of Powder by a spark of Fire, the destroying many Thousands by the Infection of one Man, the Impregnation of a whole Cluster of Eggs by one treading of the Cock; Experiments therefore and Observations of this kind should be carefully sought after, and all the Circumstances and Accidents diligently mark'd, measur'd and defin'd, for that these Proprieties whatever they be, seem to be some of the most considerable Instruments which Nature makes use of in all, or at least in some of the most considerable of its Productions. I have, I hope, made it probable at least, that Fire is nothing but the Dissolution or Corrosion of Sulphureous heated Bodies, by the Air as a Menstruum, and had I here a proper place, I hope I could shew that Fermentation is somewhat Analogus, or of the same kind with Dissolutions or Corrosion: If therefore we can by deducting from Observations and Tryals, find the true Nature of this Propriety, what a Multitude of things will there be explicable thereby, for though at first sight all these kinds of Experiments seem little instructive, because their Operations for the most part are such as fall not under our Senses, yet when their Nature is detected, that we know how to unlock those Mysteries, then we shall find their great Usefulness.

7. Further, Another way of discovering Nature, is by taking more especial notice of such of her Works, wherein she seems to act yet more secretly and farther remov'd from the Detection of our Senses, such as in the Formation and Configuration of Bodies: And here we are to observe all such things as vary and change those usual Methods, for if herein her Workings also can be detected to be Mechanical, it will not then seem impossible but that some of the most considerable Effects of Nature may be detected by Mens Industry, and to this end all kind of Impressions on the Phantcy are to be observ'd what kind of Alteration they make in the Body, as in the Formation of the Fætus, in causing Miscarriages and Abortions, in curing or producing Diseases; for these kind of Actions, we term more spiritual, because our Senses help us not at all in discovering of them, and they stand up as an Opprobrium to Philosophical Inquiry, as being generally believ'd impossible to be detected, and much less reduc'd to such a Degree of Science as might tend to practise, yet if we more seriously consider the Progress of Nature from the more simple and plain Operations to the more complicated and abstruse, we may from them deduce a great Argument of Incouragement. For we shall find it to make but very small Steps, and to add but a little more in one thing than in another, to make it a degree higher in Perfection; there is but a small difference between Earth and strong Concretions, between such Concretions and Salt, between the crystallizing and shooting of Salt, and the Vegetation of Mould, and less between the Vegetation of Mould and Mushrooms, and but a very little between the Vegetation of Mushrooms and Moss, and as little between Moss and Grass, and between Grass and the most bulky Vegetable, and no great matter between the Vegetation of Plants and Zoophyts, and there is no great Difference between Maritime Zoophyts and Oysters, Blubbers and the like; between those and Periwinkles, and other kinds of Shell-fish, between Shell-fish and crustaceous Creatures, between those and Fishes, between Fishes and amphibious Creatures, such as Morses and Sea-Calves, and the like, between those and Aerial Animals, *&c.* All such Operations and Experiments therefore as tend to the Illustration of one of these, are more diligently to be remark'd.

8. To

The more obvious workings of Nature explained.

1. To proceed to the more obvious workings of Nature; *the first way of discovering them, is by observing the Method or Progress of Nature in generating, increasing, weakning or destroying the same Propriety in divers States of the same Bodies*, for hereby may be discover'd what things and Circumstances are adjuvant, and what destructive of this Propriety: As suppose Greenness be the Propriety sought for, we may observe that that Propriety is most, and in its greatest Perfection when the Plant is so, and that before the Plant is come to Maturity and is too moist, waterish, and tender, it inclines or is ting'd too much with Blew, and afterward, as it decreases in Moisture and grows more dry, the Yellowness increases; and as it more and more dries and grows old, so the Yellow is more and more heightned, till at last it ends almost in a Red. So that Blew seems more appropriate to Liquidity and Moisture, and Yellow to Dryness and Sulphurousness; unless by comparing it with other Effects of the same kind in other Bodies, as in the Generation of Colours on melted Metals, where Yellow beginning first, then Red, and after Purple, according as the vitrify'd Skin grows thicker and thicker, we may suppose that the Blewness proceeds from the Thickness of those Parts which afford the Colour by their plentiful Supply of Moisture, and that as that Moisture decreases and dries away, and those Colour-making Bodies grow thinner and closer together, so the Colour grows by degrees Yellower and Yellower, *&c.*

Again, Suppose Liquidity be the thing to be observ'd, we shall find that Water for Instance, when cold beyond such a degree grows very consistent, solid, and hard, when it only suffers a gentle degree of Heat or Warmth, it becomes liquid and moist; but if Heated beyond that degree, it becomes Aerial, Fluid and Rarify'd. Suppose Light be the Propriety to be trac'd, we may find that Fish when fresh or newly dead shine not or afford no Light, when they begin a little to taint and ferment as 'twere, they begin to shine and glare, but as they grow more putrid and rot, so again the Light decreases and at last goes quite out. So that it seems for the producing Light in such a Body there is requisite a determinate Degree of Fermentation or Corruption: Suppose the ebbing and flowing of the Sea be inquir'd after, we find that the new Moon makes the ebbings and flowings very great; as the Moon goes further and further towards the first Quarters, so those Motions do more and more decay, and are lowest or weakest at the Quarters again, as the Moon goes further from that and nearer to its Opposition to the Sun, so the Tides again increase, and after Decrease to the last Quarter, and after it again increase to the New Moon: For this it remains yet farther to be observ'd whether *cæteris paribus*, the Tides are greater at the Full or the New Moon, or whether less at the first or last Quarter; for from the determining of these, there would be many helps afforded for the discovering of the true cause and reason of them. Suppose Specifick Gravity be inquir'd after, we are to inquire what Body there is which in several States of it hath several Degrees of it: And for this we may find Air, which according as it is more or less rarify'd, so has it more or less Gravitation, whence we may deduce the Rarefaction and Condensation of Bodies does diminish or augment their Gravity, and 'tis not improbable as we shall add by and by, but that this Propriety is general, that the comparative Gravity and Levity of Bodies depends upon their comparative Condensation and Rarefaction.

2. *The Second way of discovering Nature may be, by observing how Nature proceeds in distributing the same Propriety in several Bodies.* As suppose Gravity be the Propriety inquired after, we may find among Fluid Bodies, that in Flame 'tis very little or nothing at all, in Air but very faint, in condensed Air somewhat more, in Oyl of Turpentine 'tis yet more prevalent, in ordinary rectify'd Spirit of Wine a little more, in Water greater, in several Saline and Chymical Liquors, yet more prevalent, as Oyl of Vitriol, Oyl of Tartar, *&c.* in Quick-silver most of all, by which Progress we may learn that Gravity has little to do with Fluidity; for that almost the heaviest Body in the World is fluid as is also the lightest, and there are few intermediate Degrees of which there may not be found some fluid Substance. And this will be farther manifested also, if we consider the Dispersion of it among consistent Bodies, for there

there are consistent Bodies almost of all Degrees of Gravities. But on the other side, we shall find that Gravity has a great Dependence upon Rarefaction and Condensation, for always the most rarify'd Bodies seem to be the most light, and the most condens'd the most heavy, for as in Flame it seems to be least, so in Gold does it seem to be most prevalent.

3*ly*, Another way of discovering Nature, is by such Observations and Experiments as do manifest the Method of Nature in Combinations or Conjunctions, that is, how and with what other; the Propriety sought for is combin'd in several Bodies. As suppose the Propriety of Heat be inquir'd for, we shall find that in the Sun and in Fire it is joyn'd with Light, but in Corrosion of Metals by Saline Liquors and in Fermentation, and in rubbing Motions, without it; whence we may conclude Light or Darkness not necessary to Heat: Next Heat being produc'd by Oyl of Vitriol and Oyl of Turpentine mixt, and by two solid Bodies rubb'd together, shews that neither is Fluidity or Consistence essential in the Production of Heat; from the Heat in Flame, and boyling Water, we may conclude Dryness and Moisture likewise not to be essential; from the being able to make both Gold and Air hot, both Gravity and Levity, and Density and Rarity, appear not to be essential, but from a constant Conjunction of an internal Motion of the Parts, where there is Heat; may be concluded, that those two have some Dependance one upon the other. From the almost constant Combination of violent Heat and Light, we may conclude them to have some great Affinity, as also because in most Bodies Fluidity is joyn'd with some degree of Heat; we may conclude those also to have much Affinity, but how much, and in what manner must be determin'd by some of the other ways of Inquiry.

4*ly*, Another way of discovering Nature, is by tracing her ways in disjoining or separating Proprieties, that is, very seldom or never joining them together in the same Body; as Fluidity and Sonorousness, Shining and absolute Cold, Malleability and Transparency, Sweetness to Smell and Taste, Hardness and Toughness, Levity and Density. These and their Contraries are chiefly to be observ'd, because such as these do still lead us nearer and nearer to the Mark we aim at, and do as 'twere circumscribe Nature, and bound it so as that we know it cannot go beyond such or such Limits.

5*ly*, Another way of tracing Nature, is by observing the Transitions it makes from one Propriety to another; of this kind of Observations and Experiments great Multitudes should be collected, that so the Affinity and Dependance of one Propriety upon another may be the better understood: For by this means the Circumstances also being well observed, the Nature of any one of those Proprieties being known, the other cognate Propriety will easily be discover'd. As Sourness and Acidity does usually follow Sweetness in most kinds of fermenting Liquors, as in Wine, Beer, Ale, Metheglin, *&c.* And in the making *Saccarum Saturni*, Sweetness seems to return again from Sourness. Sweetness by Combustion or Heat very often degenerates into Bitterness: And Bitterness by long keeping seems to turn into Sweetness, as in Hopt Beer long kept, Bitterness, Acerbity, and Sowrness in unripe Fruits, by Maturity turns into Sweetness; the Bluish Greeness of Buds of Plants by degrees turns perfectly Green, and as they decay degenerates into Yellow, as I noted before; Plumbs, Grapes, Mulberries, and the like, being of a palish Green at first, by degrees turn Red, and at last Blue; the Colours on tempering Iron or Steel are first of a Straw Colour, then Yellow, then Red, then Purple, then Blue, and so onwards. To this Head may be referred many of those excellent Experiments of the Transmutation of Colours, publisht by the Incomparable Mr. *Boyle*, Cabages by an Inclination to Putrefaction do often produce a most fragrant and Musk-like Odour, but suffer'd to putrify quite, their Stink is not to be indur'd; Apples also by Putrefaction do oft produce very pleasing Smells; Musk also is said to be the Corruption of the Flesh and Blood of a kind of Dear: But generally all kind of putrify'd Substances, especially Animal, ingender very loathsome Smells, which seem to be caus'd by a very penetrant and volatile Salt, which by the Dissolution of the Texture of those Substances is let loose, and being very Aerial

readily mixes and joins it self with the Air, from whence at first it seems to have been taken.

6ly, Another way of discovering Nature, is by endeavouring to find by what ways Nature produces the same Effect in divers Bodies, whether always the same ways, or for the most part by differing, or by some few; and among all these Experiments and Observations, we are to make choice of such especially, wherein the Propriety sought for is produced by some Cause that seems least incumbred with perplexing Circumstances.

As for instance, Whether Nature produces Heat in the Sun, in Fire, in Motion, in Fermentation, in Baths and hot Springs, in quick Lime slack'd with Water, in the Operation of corrosive Menstruums, in Animals, *&c.* all the same way, or whether differing ways: That is, whether the Sun be not a Sulphureous and Nitrous Earth or Globule fir'd and consum'd, or dissolv'd either by it own Nitrousness, or by the Circum-ambient Air, whether that and our common Fire be not much the same kind of Operation (but with differing Menstruums and differing Dissolubles) with that of corrosive Menstruums; and whether Fermentation be not a kind of Dissolution or Corrosion, whereby the Parts work upon one another, and whether quick Lime slack'd by Water will not prove the same kind of Operation, Namely, the working of the Alkali in the quick Lime on the Body of the Water; whether Baths and hot Springs proceed not from Subterraneous Fires, and those maintain'd by a nitrous and sulphureous Fuel there plac'd; whether the Heat in Animals be not caus'd by the continual working of the Liquors and Juices of the Body one upon another, and more especially by the uniting of the Volatile Salt of the Air with the Blood in the Lungs, which is done by a kind of Corrosion or Fermentation, which to me I confess seems somewhat more than probable; First, Because that only those Animals that breath much are very hot, all other kinds of them are even cold to a Man's touch, as Fishes, Snakes, Frogs, Cameleons, *&c.* Next, That all those Exercises which cause the Blood to circulate much, and consequently to make the Animal breath much, do make the Heat to increase, and the expir'd Vapours to be more copious. Thirdly, That such as stir little, and consequently whose Blood does circulate but slowly, breath but little and seldom, and are generally most cold in Constitution and grow Flegmatick, and at last short-breath'd, and are very apt to fall into Fevers or Excesses of Heat and Inflamations as it were; because those Parts which should have been wrought on by the Air, and thereby have been brought to another kind of Constitution and concocted, are in great Quantity laid up in the Blood: So that at last the Blood becomes over-charg'd by them, and the Lungs become stuff'd and stopt, Whence wanting the Preservative Salt of the Air, they upon all occasions are apt to cause unnatural Fermentations and Putrefactions which inflame and destroy the natural Texture and Constitution of the Blood, Humours and Parts, and so vitiate oftentimes and destroy the very Principles of Life. Further, the Ebullition of Steams into the Lungs, which are carried out with the Breath by Expiration, may probably be caused by the Ebullition of the Blood upon the mixing of the Salt of the Air, somewhat after the Nature, as Oyl of Tartar will bubble by the Affusion of Volatile and Acid Salts, now whether so or not, deserves to be further inquir'd into. But this by the by; Another Instance, to illustrate this Head, may be the Method Nature uses in generating Colours: That is, whether the Colours in the Rain bow, in Triangular Crystal and Gems, in Bubbles and plated Bodies, in Flowers, Woods, Leaves, Stones, *&c.* In Liquors and Flame be all of the same kind, and from one and the same Principle disguised under several Masks or Vests; or whether Nature has not almost in every of them taken a differing way. This will be found by reducing each of them to the most simple Principles, and by endeavouring to find out whether there be not some one Principle wherein they all agree; for if it can be found that all of them do depend upon Transparency and Refraction, and that by destroying that Principle in any of them all the Colours will immediately vanish, 'tis a very great Argument that that is the chief Cause of all those Appearances, and all the rest are but accidental and circumstantial, somewhat of this kind I have endeavour'd to explain in my Micrography. A Third thing

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may be the Method of Nature, in producing Light, in some we find it to be effected by a violent Dissolution of the Body, as in Fire, and perhaps in the Sun, in others we find it to be an Effect of a very gentle and scarce sensible Dissolution, as in Fish and rotten Wood, and perhaps the Gloworm; in others the Effect of a gentle Heat or Motion, as in a Diamond and *Bononian* Stone, from another Cause in the Scintillation of the Hair of a Cats Back when strok'd much and quick in the dark, from another Cause in the shining of the Juice of a 100 legg'd Worm when kill'd in the dark. From another, the shining of *Ignes Fatui*, Dews, Sea-water, and the like. Now from the comparing of these several ways Nature makes use of for the producing of these Effects, it will not be difficult to find that there is one Principal Cause of all, which is in almost each of them conceal'd under a differing covering. Now by casting away all those Circumstances, which by comparing them one with another, will be found needless and accidental as to the producing of Colour, we may quickly come to that which is the only true and adequate Cause.

7*ly*, Another Method of Discovery may be by taking notice of all such Processes of Nature, wherein by the same effective Principle it causes quite differing Products: For by distinguishing and defining carefully the considerable Circumstances of such Operations, the Nature of both of them will be the more easily found. As why Heat for instance, does in Bricks first by a gentle degree cause a Condensation, and shrinking, and hardning; and afterwards by a more violent causes a Rarefaction, Liquefaction and softning, if we observe well the Circumstances we may find that the first is caus'd only by the flying away of the more watery and liquid Part that kept the other a little further disjoin'd, whereby those more solid Parts slide and fall nearer together, whereas even then those more solid Parts were not condens'd but rarify'd, as all other solid Bodies are by a sensible degree of Heat; and as for the other Effects they are but a further Augmentation of the same Product. Another Instance may be the Condensation and Rarefaction of Water by Cold; the Reasons of one of which Operations seem a little more abstruse, and deserve to be farther inquir'd into; Namely, why Water should continue to condense more and more, till it comes to such a degree of Cold, and afterwards according as the Cold increases, so does the Expansion of the Water into Ice. The Discovery of the true Reason of which Experiment will very probably afford us a much larger Prospect into the ways of Nature than we have yet been Masters of, towards the finding of which it will be requisite to take notice of and examine well all the Proprieties of Ice and Snow, such as are the seeming Blebs or Bubbles generated, the Figures of falling Snow and the Figures of frozen Snow, both which are very strange and extreamly pretty; the Figures and manner of the freezing of Ice, the Refraction of Ice, and the Lightness of it, and the like.

8*ly*, Another way of Discovery, is by indeavouring to find out such Experiments as may distinguish between two or more Principles, and shew what the Influence or Power of each of them is towards the producing of that Effect whereunto they seem both or all to concur: Of this kind there are Multitudes in Natural Operations, which Operations are very seldom so single as to be perform'd and perfected by one active Principle only, but to the producing of almost all its Effects, Nature for the most part makes use of two, three, or more co-operating Principles; the distinguishing the adequate Power of each of which is one of the most difficult things in all Philosophical Inquiries, such Methods and Rules therefore as assist us in this Performance, ought especially to be look'd after. As for Instance, in the Fulmination of Gunpowder, what the several Offices of the three Bodies of which it seems necessary to be compounded are, what Part the Nitre, what the Sulphur, and what the Cole acts; the like in the fulminating Powder, describ'd by *Glauber*, made of Salt of Tartar, Sulphur and Nitre, whose Operation seems to be quite differing from that of Gunpowder, and nearer to approach to the Nature of *Aurum Fulminans*, which is a third thing of this kind to be observ'd, made of the Powder of Gold precipitated out of *Aqua Regis*, by Spirit of Urine, or Salt of Tartar; and seeming to want the Sulphur, which seems necessary to the other two, unless

unless the Gold may be said to supply it; the like Inquiry may be made concerning the Cause of Dissolution: As for Instance, of Gold in *Aqua Regis*, whether the Gold it self do not contribute as an active Principle, to the dispersing of it self in the *Aqua Regis*, as well as the *Aqua Regis* doth to the Penetration or corroding the Gold; and in the *Aqua Regis*, what the Sal Armoniack, and what the Nitrous Spirit contributes towards that Action. And herein the ways for Discovery must be by varying either the several Ingredients themselves if it can be, and by observing in what the new substituted ones differ from the other either in Quantity, Quality, Time, manner of operating, and the like, or else by indeavouring to vary and alter the Quantities of the Ingredients themselves; and by observing diligently all the Circumstances of the succeeding Effects. Or else Thirdly, something may be learnt by mixing one or two other Ingredients, and observing and comparing their Effects to consider in all of them in what common Nature they all agree, and in what they most of them differ, what Bodies seem to promote, and what to hinder those Operations.

9. Another way of tracing Nature is by observing the Resemblance or Discrepancy of Natures working in the producing the like parts in differing Kinds, Species, or Individuals. This Method is very luciferous, and produces very copious Matter of Information, for by observing how Nature varies its Method according to several Designs we may easily by comparing, and rejecting, quickly arrive to some positive Information, what the Use and Business of each part is; as for instance, by observing the Keys of Sicamores, Maples, *&c.* and finding in them a tender, but perfect Plant wrap'd up and clos'd in a Box or Case, so as to preserve it from taking Injury, which by being buried in the Ground in warm Weather does by degrees swell and break the Shell, and grow up in a Plant: And comparing this with the like Process of most other Seeds, though the Plant or Web of them be not so visible, we may conclude that they also have the same Principle in them though somewhat farther remov'd or hid from our Sense: And by comparing these with the Eggs of Serpents, Crocodiles, Æstridges, Tortoises, and Multitudes of other Oviparous Insects, who lay their Eggs in convenient Receptacles, that the Heat of the Sun or Air may hatch, we shall find it very probable that Nature takes the same course both in the one and the other; but with some difference, that in some she seems to operate more openly, in others more secretly and reserved. And by comparing likewise the Method of Nature in the Formation of the Fætus in the Womb, we may find reason to conclude, that all kinds of Vegetable and Animal Bodies are propagated by much the same Ways and Methods, though somewhat varied in Circumstances, the Observation and diligent Examination of which by Experiments will hugely promote this Inquiry. Thus also by comparing the Contrivances for Motion in the Leaves and Branches of the sensible Plant, with the Muscles and Instruments of Motion in Insects, Birds, Beasts, Fishes, scaled, shell'd, and crustaceous, each of them seeming in some particular or other to differ, and by joyning to these several other self-moving Bodies, as the Beard of a wild Oat, the wreathed Seeds of Muskgrass, the shrinking of Gut-strings, the Expansion of fired Gunpowder, the Corrosion of acid Liquors, *&c.* we shall find many helps to judge of what is most likely to be the true cause of the Motive Power of the Muscles: For every Discrepancy in these brings us a step nearer to the thing sought for, by lessning the Bounds, or at least by fixing the Terms within which it must be found.

10. Another way of Discovery is by taking notice of the Transitions of Nature, by what degrees and steps it passes from one thing to another in the Formation of Species; for this will afford very great Light, how to find out which Product of Nature is most simple, and which most complicated, which the most perfect, and which is farthest from it, and wherein the Additions or Defects lie. And accordingly from this we shall be the better inabled to find out the Significancy and Use of each part: As suppose from a Man Nature seems to descend to an Ape, Monkey, or Baboon, which we may find in very many things to imitate Man very exactly, as in its Figure, Gate, and Jesture, as is testified by ——— in his Natural History of the *East Indies*, in frowning, grinning, and laughing

laughing, as divers Travellers assure us, but seem to want the Use of Reason and Speech, the things wherein they differ in Figure from Men are chiefly these; that the comparative Bulk of their Brain is much less in Proportion to their Bodies than that of a Man, as has been excellently well observ'd by the Learned Physician Dr. *Willis*, that they are all over cover'd with Hair, that their Heads and Noses are flatted, and their Mouth thrust out, tending somewhat towards the Shape of other Beasts; that their Legs and Arms are much shorter in proportion to their Bodies than those of Men, and that their Spine, and consequently the Spinal Marrow is yet spun out longer and smaller into a long Tail: And which may be further taken notice of, that those which have naturally the longest Tails are usually *cæteris paribus*, the furthest remote from imitating the Actions of a Man, and do seem nearest approaching to the Capacity of other Brutes. And there is no doubt but that a diligent Observer may by accurately anatomizing each, and comparing them together, find divers other considerable Variations which are of a kind of middle Constitution, between those of a Man and those of other the most brute Creatures; which may much inable an Inquirer in finding what parts of a Man seem most to contribute to the Perfection of his Natural Parts. Another Instance may be this, to observe the Transition of Nature between the Figure of precious Stones, and the crystallizing of Salts, between the shooting of Salt, and the growing of Mould and Mushrooms; and its Transition from Mushrooms to Moss, and from Moss to Grass, *&c.* The accurate Observations of all which Transitions, together with all the Circumstances that attend upon them, will with a Clew almost lead us from the Explication of the most plain, single, and obvious Phænomenon, to the Understanding of the inmost and most secluded Process of Nature.

11. Another way of Discovery, is *by taking Notice of all such Experiments and Accidents as shew the Frustrations and Failings of Nature*; for all such Experiments as these, the Circumstances being diligently noted, afford very essential Distinctions, and do very much direct, circumscribe, and limit the Mind in its search: and, by shewing what things are destructive to it and over-rule and govern it, and what pervert it and turn it out of its Course, it very much fits the Mind for positive and affirmative Knowledge of the Causes of those Effects. For instance, Let the Nature of Fire be the thing sought for: Here we are to look chiefly after such Experiments as shew the failing of Nature in this Operation, such as these; the falling of Water on the Fire makes it immediately go out, query whether from the Coldness or Moisture; that 'tis not from the Coldness is evident, because boyling Water will produce the same Effect, nor is it from the Moisture, because then Spirit of Wine would do the same thing which yet it does not; query further therefore, whether it be by keeping off the Menstruum of the Air, if so, then the keeping of that Body any ways from coming to it will do the same Effect. To confirm this, we have many Instances of the Frustration of Nature; as that a Candle will presently go out if inclos'd in a Vessel, whereby the fresh Air is excluded: The like it will presently do, if it be included in a larger Vessel, and the Air drawn out. Coles likewise will do the same, if included in a close Vessel, nay though by a pair of Bellows included in the Box with them, they be all the time blown upon by them, as I have several times shewn before very many illustrious Spectators.

12. Another way of Discovery, is *by observing the Deviation of Nature in framing Specifick Bodies*, such kind of Operations wherein Nature seems to step a little aside out of its usual Rode, and seems to take up a new Method in forming: Now these though in themselves they seem at first to amaze and perplex the Mind, yet when by diligent Examination and Inquiry the Vail that covers them is remov'd, and it be discover'd to which of the more common Operations of Nature it belongs, and wherein it differs from them, then does it as the former, highly assist the Judgment in determining the true Nature of that Principle, by manifesting what great Influence these or those accidental Concurrents had in altering or disguising it so as to make it appear somewhat extraordinary and miraculous. As for instance, the Loadstone seems to be an Instance of the Deviation of Nature out of its usual Method, and seems to con-

tain ſome Principles in it altogether extraordinary and very wonderful, but when we have taken this excellent Compoſition to pieces, and found that it is reſembled in ſome of its Proprieties by the Motion of an Uniſon String, in others by the Attraction of rubbed Jet, Amber, Wax, *&c.* that both its Axis may be varied Mechanically into another Poſture, and that its Poles may be turn'd end for end, and that its Vertue may be quite deſtroyed as well as Mechanically augmented; that it has a Dependence on the Earth, and is mov'd by it, as having the firſt and chief Magnetical Principle which moves all the reſt; that the Sun, Moon, and all other the Planets, have the ſame or alike Vertue with this of the Earth, and that the Loadſtone has given the occaſion of the Diſcovery of all theſe: When we conſider this Inſtance, I ſay, we may plainly ſee of what great Uſe Obſervations and Experiments of this kind are, for the finding out of the Methods and Ways of Nature which are ſomewhat beyond the Diſcovery of our Senſes. Another Inſtance may be a Diamond, which for two or three Proprieties ſeems extraordinary, the firſt and chiefeſt is Radiation in the dark, after it has been gently rubb'd or ſtruck, which gives us a new manner of producing Light ſeeming to depend on the other Property, namely, an extraordinary Hardneſs, and affords anew Difference or Help of Rejection: For ſince in this Experiment there is neither Combuſtion nor Flame as in Fire, nor Moiſture and Putrefaction as in Fiſh and rotten Wood, nor a Motion of Animal Spirits, which ſome pretend to be the Cauſe in Glow-worms and Cats Eyes; nor any previous Light, which ſome have imagined to inhere and remain like a Liquor in the Object till it be evaporated or dry'd, as in the Bononian Stone, by the help of this one extravagant Inſtance all theſe Suppoſitions are rejected, as not at all neceſſary to the Exiſtence of Light, and only this one eſſential Propriety ſeems to be ſet up in the ſtead of them; namely, a very quick Vibrative Motion, which a Body of that extream Hardneſs ſeems only capable of from ſo ſmall and ſudden a Percuſſion, as that has been obſerved to ſhine with. Another Inſtance of this Rule may be the Apparition of Colours in the Triangular or Sexangular Stiriæ of Cryſtal, for therein Nature ſeems to generate a lovely Variety of Colours after quite another way, than it ſeems to do in other Bodies whether Vegetable, as Flowers, Leaves, Woods, Fruits; or Animal, as Blood, Gall, Hair, Feathers; or Mineral, as Metals, Marchaſites, Scoria, Vitriols, *&c.* in all which, ſome Authors will needs have a various Temperament of Sulphur and Mercury to be the chief and principal Cauſe. Now by this one Experiment or Obſervation of Cryſtal, theſe and divers other phantaſtical Hypotheſes about Colour are overthrown, and by examining it thoroughly it may be found that this does demonſtrate only one thing neceſſary, namely, a conſiderable Refraction enough to obliquate the Puls of Light, as I have in my Micrography indeavoured more fully to explain. Such Experiments as theſe do hugely ſtrengthen the Diſcurſive Faculty, and (at one Blow as it were) inables it to cut off all thoſe numerous Heads of Hydra, which when cut off one by one do a-freſh ſpring up again, and create new and greater Difficulties, but by watching Nature and taking hold of this opportunity of the Deviation of it, the Victory becomes eaſy and ſpeedy.

13. Another way of Diſcovery, is *by taking notice of all ſuch Productions of Nature, as are differing from the reſt of the ſame Species*, and are therefore truly eſteem'd monſtrous and wonderful by the Generality, but a Philoſophical Hiſtorian has ſomewhat elſe to do than admire them; for theſe are indeed the moſt inſtructive and the richeſt Commodities he can meet with. His Buſineſs therefore is diligently to ſet upon examining of it both as to the Cauſes of it, and as to the particular Effects, and to indeavour to find out wherein lies the Deviation in what conſiderable Circumſtances they differ from the moſt uſual Effects, and wherein the Myſterie of Nature's proceeding after ſuch a manner lies, what Cauſe it was made it thus deviate. One therefore that is fit to make Obſervation of this kind, muſt firſt be very well skill'd in the moſt uſual ways of Nature of that kind, ſo as that he may be able readily to detect all the Aberrations of Nature: Nor is this Knowledge indeed ſufficient, but he ought to be ſomewhat knowing alſo in the Uſes and Deſigns of the parts of that Species whereof the thing under Examination is an Aberration; for 'tis none of the

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least Helps, towards the finding out the Nature of the thing sought for, to be able to know and judge what things are material and considerable enough to be observed; for 'tis not the setting down of every little Variation, of which there be Multitudes in every individual of the same Species, whereby they differ one from another, most of those being to be past over as the Effects of a *lusus naturæ*; that is, of many little Circumstances which perhaps 'tis impossible ever to be able to take notice of, or find out, there being continually such Multitudes of them and those so complicated: Nor again on the other side are small, nay almost unperceivable Variations in some cases to be past by where the Causes can be certainly found, or where those though never so small Variations, become considerable toward the producing greater Effects; for sometimes those Variations which seem greatest and most conspicuous are very inconsiderable, and as to the promoting of Natural Knowledge scarce significant. So that 'tis not every one that can be presently fit for this Undertaking, but it requires a long and sedulous indeavour and accustoming ones self to observe the Methods and Courses of Nature; without which endeavour'd 'tis much to be fear'd that the History so written will be full stuff't with Impertinencies, and contain very little of any thing solid, material and useful. Of this kind there are Multitudes of Instances among Animals, Vegetables, and Minerals, all kind of extravagant natural Actions, Generations, Vegetations or Accretions, Diseases, Casualties, Conjugations, and Separations, and the like; being to be numbred under this, and every one in their several Kinds, if accurately examin'd, affording choice and rare Informations which assist us beyond any other way, how to command and regulate Nature, by either promoting or furthering it in its usual Method.

14. Another way of Discovery is, *by observing the concomitant Proprieties of Individuals in their greatest or highest, and in the lowest pitch of their Perfections or Existences.* As the former was of the extravagant and preter-natural Concomitants in a preter-natural State, so this of a Natural: For though the former be an excellent Method of Discovery, yet that alone, and of it self is not sufficient; we ought as well to know what things and Circumstances accompany the natural Progresses of Nature as well as the preter natural, that by the comparing these two together the Differences between them may more manifestly appear. As for instance, that in an Infant the parts are soft, moist and tender, and as very unfit for Animal Motion so have they very little, till after a certain time most of those parts begin to grow a little more dry and stiff, but yet retaining Plenty of Natural Juice and Moisture, whereby all the numerous Parts of the Automaton (like those of a new and clean Clock, that has been a little us'd to take off the Roughness and is well oyl'd) easily and glibly move and slip by one another and consonant hereunto, that Constitution of Body is ever in Motion, eats much and acts much, is quickly wound up, and whurr 'tis quickly down again, and a new supply of Aliment must be had. And thus it continues to be wound up and run down, till by degrees the Oyl begins to be a little spent, and to grow somewhat more stiff, and the Parts to be well worn and adapted one to another when it arrives at its best going; the Child being become a Man, his Parts by much Exercise become very prompt and habituated, they move not so much as at first but more steady and regular, the parts become more firm and consistent, the *Humidum Radicale* seems to be perfectly concocted and brought up to its just Consistence, being neither too thin and watery, or too thick and clammy: But as he grows older the Parts grow dryer and stiffer, and less fit for Motion; the Natural Moisture is grown too thick and slug, and the parts begin to shrink and shrivel, and to be clogg'd and worn, and all the Motions become slower and more heavy, and the parts grow quickly weary, a little Food serves long; the Juice in many parts of the Body become so charg'd with excrementitious parts thereof, that it turns into a kind of hard or stony Consistence: and like an old decayed and foul piece of Clock-work, here a Pivot is worn loose in his Socket, there the Oyl is thickned with Dust and Filth, as almost to stop the Motion: Here a Wheel is bent, and there a Tooth is worn out, and the like. Now as these things which are the common Accidents of Watches, and do generally happen to all

sooner

sooner or later, according as they are better or worse used, are very easy to be found by a diligent Observer, though altogether ignorant of Watches; and by comparing the several Accidents one with another, he may at last be able to understand a Watch thoroughly, and know wherein the Goodness or Badness of one consists, and what is good and bad for it, so may one that is wholly ignorant of the Fabrick of any Natural Body be able to learn the Nature of it, by observing the several Accidents that happen to it in the several States and Conditions of it.

15. Now as the Observation of the various Accidents of Bodies in several States is one way of Discovery, *so another way may be of observing such Variations as happen to Bodies from their being produc'd at differing times, or in differing Places, of the same Medium, or in differing Mediums, or with a differing Quantity*; for each of these kinds of Observations do further manifest to us by what Rules Nature works, and by what things it becomes regulated and circumscrib'd. Of this kind may be the observing of the difference between the Shape and Nature of a wild *Irish* Man (or such a one as has nothing of Education to biass him) and one of *Saldania* or the *Cape of good Hope*. The Difference between the Stature, Age, Strength, Shape, *&c.* of Men at the beginning of the World and now. The Difference between the Fins of the flying Herring and the Wings of a Bird, between a Crab and a Spider, *&c.* the one being an Insect of the Water, and the other of the Air. The Difference between Beasts of the same Species under the Pole, and under the Line, *&c.*

16. Another way of Discovery is, *by observing what things most conduce to the Perfection or Destruction of any Production*: This is differing from the next but one preceding, in this, that there we considered only such things as accidentally were found Concomitants with the several Conditions not so much considering them as Causes; but here out of many of those former, we segregate and collect such as seem very active and contribute either to the better perfecting, or to the Destruction or Overthrow of such a Body. As suppose that Fire be the Subject enquired into, we shall find Nitre or fresh Air, and some Sulphureous Body, to be that which most powerfully makes that Operations, and that nothing does destroy and hinder it so much, as the separating of the intermediate Contract of those two Bodies, by the throwing on of Water or any other incombustible and sluggish Liquor.

17. Another way of Discovery is, to find out and enumerate *all such Operations of Nature as wherein it seems to work after a peculiar manner, and very differing from her more usual Methods*; for by this means many Circumstances are cut off, which being generally the Concomitants in her more usual Method, are therefore more liable to be thought essential to the producing of the Propriety sought. For Instance, the Flying Herrings commonly observed flying in great Sholes in the Torrid Zone, may seem as an excellent Instance to manifest that to the Business of flying, there is no need of Feathers about the Body, nor in the Wings, nor in the Tail, as most imagine; and the Poets seem to confirm it by the Story of *Dædalus* and *Icarus*, since this Fish has nothing but Fins and Scales: Nor secondly, is there any need of a flat Tail, such as all kind of Birds have and Bats; for the Tail of this Fish stands edge-ways: Nor thirdly, is there any need of Joynts in the Arm, or Stems of the Wing, as in the Pinnions of Birds, and in the Fingers of the Bat; nor is it so necessary that the Stem of the Wing must needs grow in the Center of Gravity, since this is not observ'd in this Creature, and divers other such Circumstances which were generally believ'd to be necessary Circumstances to the Business of Flying by the Peculiarity of Nature, in Shaping this Fish after this kind, and induing it with the Power of Flying, they are all of them discovered to be only most proper for that peculiar Creature to which they were adapted, and where no such Accomplishment is bestowed on a Creature by Nature, 'tis as proper if we would supply that Defect artificially to make use of one way as well as the other, and perhaps could there be made an Artificial Repository or Magazine of Strength, which for Weight and Bulk would not be too cumbersome; 'tis not impossible

impoſſible to fit a Pair of Wings for a Man to fly with, which may be contriv'd ſomewhat after the manner of the long Fins of theſe flying Fiſh. Suppoſe Congruity be the thing look'd after, the thorough conſidering of the Nature of the peculiar Species of it between Iron and Magnets, will help to cut off many Circumſtances which divers Inſtances in other Bodies do ſeem to make neceſſary.

18. Another way of Diſcovery is, *by inquiring after and diligently obſerving what middle way of Nature there can be found between thoſe extravagant and the more common ones.* For ſuch as theſe ſerve as a *Vinculum*, to conjoyn both theſe together by ſome common Nature, which is to be found in the third, and thereby hugely promote the Explication of both the other. As ſuppoſe, Congruity be the Nature ſought, the more common ways of Congruity are between divers Homogeneous Fluids and Solids that are immediately contiguous; the more rare and ſingular is between two Load-ſtones or two Magnetick Irons, or between a Loadſtone and Iron contiguous and at a diſtance, between theſe too may be interpoſed the Attraction of Amber, Jet, Wax, *&c.* which as they ſometimes act at a diſtance when they are rubb'd, and alſo on the Bodies contiguous, very much help to explain the Congruity both in the one and in the other.

19. Another way of diſcovering the Methods of Nature's working is, *by obſerving and comparing the Productions of Art with thoſe of Nature.* And for this purpoſe it would be very requiſite to have a perfect Account of all the Productions of Art, ſuch as are diſpers'd up and down in ſeveral Trades and Occupations of Men, whether for Profit or Pleaſure; and eſpecially all thoſe excellent ways of working on Bodies by Chymical Operations, ſuch as Menſtrua, Miſtion, Digeſtion, Fermentation, Diſtillation, Calcination, Fuſion, Freezing, and the like; every of which as they admit of a vaſt Variety, ſo do each of them ſerve as ſo many Torches to light us in the dark Paſſages of the Labyrinth of Nature, where the Aſſiſtance of the common Works of Nature, like the Radiation of the Sun, cannot go along with us. For inſtance, ſuppoſe we compare an Automaton with an Animal, as I mentioned a little before by the by. Or ſuppoſe we compare Paper or Hats with the Skin of an Animal, becauſe the Texture of thoſe two ſeems of much Affinity with this, we ſhall find the Method of Nature prettily explicated by them: For in both thoſe Artificial Products we find that the Artiſts endeavour firſt to cut, grind, or beat into ſmall parts the Materials they are to uſe, then to make them ſoft, light, and ſupple with Water or other Liquor, then to diſpoſe, place, or put it into ſuch Forms or Moulds as may ſhape it into what Form they deſign it, then they there ſo work and order it, that the Moiſture may by degrees waſte, and the ſolid Parts unite more cloſely together, adding to it ſuch glutinous Matter as may make it fit to ſtick, hold and grow ſtiff, firm, and ſtrong together; and laſtly, by ſeveral ways they ſmooth and colour, or beautify the Surface: All which Particulars may be underſtood more fully by my Deſcriptions of thoſe Trades, and the Explication of their ſeveral Operations, which I muſt reſerve for another Opportunity. Now Nature in preparing the Matter that does repair the Skin or Fleſh of the Body, ſeems to proceed much after the ſame Method, the Food is choſen, then groun'd or chewed, then digeſted or brought into the Form of a Milk or Froth, then diſpers'd over the Body, by degrees thicked, and laſtly poliſhed. Now though every Particular does not exactly hit, yet there are many that ſeem to have a great Affinity, and ſerve to prompt the Intellect, and very much to help the Fancy and Imagination to conceive of thoſe things, and of the Method of Nature, and they will ſerve greatly to inſtruct the Mind what things are to be look'd after and examin'd in the Proceedings of Nature: And the more Variety there are of theſe Artificial Inſtances, the more will the Mind be quickned to Inquiry, and the more taken off from Prejudices, or an Imagination, that becauſe the Proceſs of Nature in one part may agree with one part of the Artificial Proceſs; therefore that all the other parts of the one moſt agree with the other parts of the other, for when we ſee that even Art can uſe the ſame Beginning, but yet very differing intermediate Proceedings,

and yet at last by both produce the same Effects, we shall find cause to think that Nature may do so much more. And therefore I might have added to Paper and Hats, Silks, and Cloths, and Linnen, and divers other such Artificial Contextures which have every of them a differing way of proceeding to perfect the End.

20. Another way of Discovery is, *by observing where and by what means Art causes Nature to deviate or alter its usual Course, where it assists, promotes and perfects, and where it impedes, diverts, or destroys.* Of this there are Multitudes of Instances in all things, about which Art has been used, and therefore needs not exemplifying; but certain it is, that this Method affords extraordinary Help for Discovery of the true Nature of the efficient and material Causes of things: For knowing what in Art is able to change, and divert the Proceedings of Nature, and what to stay or promote them, it will not be difficult to find what they are that are thus wrought upon, since it seems very probable that they must be somewhat of the Nature of those in Art which promote them, and somewhat of a contrary Nature to those that do alter and impede them. As because 'tis found by experienced Gardiners, that Artificial Heats ripen Fruit, 'tis not improbable but that 'tis a convenient Degree of Natural Heat that contributes most to that Effect. Now as we should observe diligently the Causes or Ingredients which do co-operate with Nature, so should we also observe in what Quantity it is most assistant, by what Steps and in what Degrees it assists the Circumstances of Time, Place, manner of Application, Operation, and the like; for without the Determination of these Particulars, the Informations will be lame and imperfect, and nothing of Certainty can be built on them, for that which is assistant in one degree, at one time, in one Place, or at such a Distance, is perhaps destructive and pernicious in another: This will not only help the Mind to judge of what the cause is, but the Degrees and Circumstances of Time, Place, Quantity, *&c.*

21. Another way of discovering Nature is, *by observing and comparing the Natural and Artificial ways of producing the same Effects.* For having the Artificial way in our own Power, and being able to alter and change, and vary it: We have much greater Helps to find out the true Reasons and Causes of those Operations, and having found them in Artificials 'twill be very easy to apply them to Naturals, and this way of inquiring where the Subject is capable of it, is the most easy of any I have yet mentioned, and the most instructive, and does more immediately inform the Sense and the Imagination with a true Idea of it, obliterating and dispelling dark and confus'd Notions. Thus, for instance, had we not found an Artificial way of hatching Eggs by a gentle and equal Heat from whatever cause it proceeds, we should have been very apt to have fancied strange kind of irradiating and plastick Influences from the brooding Hen to the hatching Eggs, but by the *Egyptian* Experiment of hatching them in Dung and Ovens, or Stoves, which has been tried other ways very successfully in *Denmark* (as *Bartholine* affirms) and in *England*, and elsewhere, with the gentle Heat of Digesting, and Lamp Furnaces; and also by the hatching them oftentimes in Womens Bosoms, and divers other ways, 'tis evident that such Phancies will easily vanish. Thus many People are still very apt to fancy a certain attractive Vertue in the Sun, which by a kind of Magnetism does draw up the fresh Water out of the Sea, leaving the salter part behind, and by that its Power does keep it suspended in Clouds: Whereas if we consider that any other Heat to that Degree will do the same thing, whether the Heat be placed above or below, or on one side or t'other, we shall then find cause to think that 'tis not an attractive Vertue of the Sun that performs this Effect, but that 'tis the Heat of the Sun which working on the superficial and fresher parts of the Water warms them, and by degrees rarifies them into the Form of Air, which having much heat and Agitation in them, do so far expand themselves as to make them more rarify'd in *Specie* than the Circumambient Air, which being therefore heavier than them causes them to ascend in the same manner as Water makes Air, or Oyl, or any other Liquor lighter than it self to ascend to the Top. This way does very much discover the naked Truth and Simplicity of things, by taking away the Vizour under which it lay disguised. Much in the same manner as

Travellers

Travellers judge of the Beauty of the *Persian* or *Indian* Ladies, whom they never saw, by observing and examining such as they have more Liberty to see and converse with.

22. Another way of discovering Nature is, *by observing the difference between the Products of Nature and those of Art.* And without this Head indeed the former way cannot be compleat, and therefore this has an immediate Dependance upon it: This way does farther assist the Mind to find out and fix the essential Differences and Proprieties of Natural Actions; for by comparing these kind of Observations with the former, we shall be able to judge better of the differing Nature of those Operations, and what Propriety 'tis in the one that makes the Workmore perfect, and what 'tis makes the other miscarry. Thus the Reason why Rain Water seems to be more pleasant than distill'd, seems to be partly from the Saline or Nitrous part of the Air which does somewhat purify it, and partly also from the gentle or moderate Heat of the Sun which acts upon the Surface of the Water, and partly also from the greater Coldness of the outward Air, which being therefore heavier does sooner carry up the Vapours, though but a little rarify'd; the distilled Water on the other side contracts an Empyreume from the greater Heat, which is apply'd at the bottom, and so the whole is much heated, and from the Pentness of the Vessel, whereby all those Parts that rise, though many of them are Saline and Terrestrial, are driven over with the Vapours, and must necessarily fall and unite again with the Water in the Recipient; whereas in the Air they serve to another purpose, for the Collection of those Parts together at the top of the Clouds, and there kindling, seems to be the cause of Lightning and Thunder.

23. Another way of Discovery is, *by observing the differing Materials, and ways of producing one and the same Effect by Art.* For this does mightily free the Mind from Prejudice, and from being too much imbued with any one Experiment or Method of proceeding, and each of them does much contribute to the Explication of the rest. Thus by observing that the spirituous part of Urine may be extracted out of it, either after it has stood a considerable time to putrify, or immediately after the Intermixture of quick Lime we may learn, that Putrefaction is nothing but a kind of Corrosion or a working of some of the parts of the Urine upon others, and thereby a setting others at Liberty. Thus the being able to make a very Volatile Spirit, and Salt with Horns, Bloods, Flesh, Hair, Hoofs, *&c.* of Animals, we may learn that all the parts of Animals seem to be much of the same Nature, but only diversify'd and drest under several Textures and Schematisms; and by observing that Spirit of Soot yields much the same kind of Spirit, we may thence perhaps with some Probability argue, that the cause of these Effects may proceed from a Corrosion or mixing of the Salt of the Air with the Materials that yield those Substances; the Operation of the one being made in the Chimney, and of the other in the Lungs or Heart, though indeed that which seems to be the Empyreume in all Liquors may perhaps not improbably be suppos'd some such thing as this Volatile Salt, and may perchance be caus'd only by the exceeding Violence of Heat.

24. Another way of Discovery is, *by observing with what Circumstances Nature and Art doe sometimes exceed one another.* For these kind of Observations as they discover the Excellencies of the one, so do they also the Defects of the other, and each of them contributes to the Explication of the other, and do put the Mind upon Inquiry how to supply those Defects. For instance, that Crystal and Diamonds are made by Nature of an Hexangular Prismatical Figure perfectly transparent and exceeding hard. Art on the other side is able by Decoctions and Evaporations, to make a Body somewhat transparent, and of the same Figure, but very soft and brittle, and easily either fusil or dissoluble again in Water, Namely, Salt Peter. This will prompt one to enquire what may be the cause of the more perfect Transparency, and of the much greater Hardness; that is, to find out by what means Niter may be so ordered as to be made perfectly transparent, hard, and fixt: Or else to inquire by what means Crystal

may

may be made as easily liquefiable as Salt Peter, and by what Menstruum it may be melted away, as that Salt is into warm Water. Somewhat like the former of these Inquiries may perhaps have formerly raised in the first Inventors of Glass a Desire and Endeavour to find out such a way, whereby these things might be performed; and those Tryals perhaps might produce Glass; as I think 'tis not to be doubted but that by this means the tinging of Glass into all kinds of Colours was sought after and found. Another Instance wherein Art excels Nature, may be in Chymical Distillations and Separations which is no where naturally done, and the Inquiry how and where this is or may be perform'd by Nature, may prompt unto us perhaps somewhat of the strange Operations perform'd in Animals, and stir us up to examine whether those may not be Nature's Chymical Vessels; and to inquire also by what means those combustible Substances that cause Lightning are separated from other Vapours collected together, and afterwards kindled: A Collection therefore of all Experiments and Observations that seem to shew something of this Nature, will greatly quicken and excite the Mind, and inform it of what things are material to be inquir'd, and what Circumstances are very significant and instructive.

25. Another way of Discovery will be, *to enquire after, to try and enumerate how many mechanical ways there may be of working on, or altering the Proprieties of several Bodies.* For the being well instructed and knowing in these, will exceedingly adapt and fit the Mind to trace the Method of Nature, and to judge which or likeliest to which of those ways Nature performs her Operations inquir'd after; it will much rectify the Imagination, and take it off from an Inclination to unconceivable and confused Apprehensions of things. Thus, methinks, the Operation of corrosive Menstruums on Metals, or dissoluble Bodies, may hint to us a way how the Air may operate on combustible Bodies, or such as are dissoluble by Air exceedingly heated. Thus the Observations that by the cutting off a part of any Stone from one side of it, does alter the Center of Gravity of it: And that a Musical String, wherever it be stopp'd, if it be struck does make the longest Vibrations in the middle, may prompt unto us perhaps somewhat of the Reason of the changing of the Poles of the Magnet upon the paring off one side. Were this way well practised, certainly Men would not have such strange, wild and unconceivable Notions of the Works and Effects of Nature: For as it seems to do nothing unintelligibly, so are there very many things that it manifestly performs mechanically: For instance, all Animal Motions and the Instruments thereto belonging. We should therefore endeavour to be acquainted with all the various mechanical ways of Hammering, Pressing, Pounding, Grinding, Rowling, Cutting, Sawing, Filing, Steeping, Soaking, Dissolving, Heating, Burning, Freezing, Melting, and the like; of which there are various other Species, and each of these have Multitudes of Individual ways, very much differing from one another, as many of which as can be attain'd unto, should be understood and examin'd to inform and regulate the Conceptions of the Mind, and to remove those Puerile and Childish Fancies that we suck'd with our Milk, and learnt with our Language.

26. Another Help of Discovery will be, *to inquire out, and try how many various mechanical ways there may be of separating Bodies joyn'd and mixt.* Such as Winnowing, Straining, Wringing, and Pressing, Washing, Distilling, Evaporating, Precipitating, Subliming, Crystallizing, Burning, Coppelling, Freezing, Shaking, Knocking, and the like; each of which will furnish the Mind with their differing Circumstances and Proprieties, so as by comparing those various kinds of Separations in the workings of Nature, with these it will be the better inabled to judge to which of them they have most Resemblance, and will be better fitted to detect in what Circumstances they vary, or are differing from them; and the easier understand what Particulars are notable and what are not.

27. Another

27. Another Help of Discovery will be, *to inquire and try how many various mechanical ways there may be of uniting and incorporating Bodies into one another.* Such as Jointing, Binding, Screwing, Pinning, Hooking, Shaking, Tumbling, Churming, Kneading, Melting, Dissolving (for the Dissolution of some parts seem caus'd by the uniting of others) to which may be adjoyn'd Burning, in which there seems to be several Unitings as well as Separations; Digesting, Infusion, Freezing, Insolation, by mixing a third or fourth, *&c.* by taking away an Impeding part by Compression, by opening and divers other ways and Methods, some of which are more obvious and visible, others more secret and obscure, and themselves will need further Explications: All which ways should, if possible, be well understood and reduc'd to a certain Theory, that so by that means other more subtile and curious workings of Nature, might by the Help of them be more exactly detected and defin'd.

28. Another way of Discovery is, *to seek after and attempt by tryal all such ways, whereby Bodies are really chang'd from one thing to another.* And for this purpose it matters not whether it be from worse to better, or from better to worse, or neither: For each, as to this Design, may be alike useful. Of this kind may be such Bodies as are chang'd by all sorts of Corruptions, Vegetations, Animations, Vitrifications, Incorporations, Combustions, Digestions, and several other Chymical Operations; or any other Mechanical and Artificial way whatsoever, whereby all or any of the former Proprieties or sensible Qualities are really changed and destroyed, and new ones generated in their Stead, such as the Alteration of their Consistence, Colour, Bulk, Gravity, *&c.* An Instance of this may be the Body produced by the melting together of Tin and Copper, which make a third Body quite distinct in most of its Proprieties from either of those other two; 'tas quite a distinct Colour from either; 'tis of a Consistence abundantly harder than either; 'tis exceeding brittle; whereas the others are both tuff, 'tis much heavier in Specie than either of them, and so for divers other Proprieties, it seems wholly differing from either of the two Ingredients of which it is compounded.

And lastly, A most general Help of Discovery in all kind of Philosophical Inquiry is, *to attempt to compare the working of Nature in that particular that is under Examination, to as many various, mechanical and intelligible ways of Operations as the Mind is furnisht with.* For this will not only make the Mind very attent, and earnest, and circumspect, in observing, but will also hint many considerable Circumstances to be inquir'd after, and Experiments for examining and explicating of them: And which is much more than either, will hugely assist the Ratiocination and Invention in detecting the true Causes of things. As burning compar'd with Dissolution, *&c.*

These are some of the various ways by which Nature may be trac'd, by which we may be able to find out the material Efficient and Instrumental Causes of divers Effects, not too far removed beyond the reach of our Senses, and which do not very much differ from such Effects as are more material and obvious to our Senses. But as for the Discovery of the more internal Texture and Constitution, as also of the Motion, Energy, and operating Principle of Concret Bodies, together with the Method and Course of Nature's proceeding in them: These will require much deeper Researches and Ratiocinations, and very many Vicissitudes of Proceedings from Axiomes to Experiments, and from Experiments to Axiomes; and are indeed the Business of the Philosopher, and not of the Historian, the Method of which I intend, God willing, to handle in the second part of this Philsophical Algebra; which explains the way of making use of the *Penus Analytica*, of raising Axiomes, and more general Deductions from a sufficient Stock of Materials collected according to the Method of this first part, with Integrity, Judgment, and Care.

Having thus past over cursorily the Methods and Means of Inquiry, we will next consider the Manner and Order of entring what things are to be Registred, and in what manner, and to be rejected as useless or noxious.

In the making of all kind of Observations or Experiments there ought to be a huge deal of Circumspection, to take notice of every the least perceivable

Circumstance that seems to be significant either in the promoting or hindering, or any ways influencing the Effect. And to this end, as I mentioned before, it were very desirable that both Observations and Experiments should be divers times repeated, and that at several Seasons and with several Circumstances, both of the Mind and of Persons, Time, Place, Instruments and Materials: For all these do very much contribute to the Discovery of Circumstances. And an Observer should endeavour to look upon such Experiments and Observations that are more common, and to which he has been more accustom'd, as if they were the greatest Rarity, and to imagine himself a Person of some other Country or Calling, that he had never heard of, or seen any thing of the like before: And to this end, to consider over those Phœnomena and Effects, which being accustom'd to, he would be very apt to run over and slight, to see whether a more serious considering of them will not discover a Significancy in those things which because usual were neglected: For I am very apt to believe, that if this Course were taken we should have much greater Discoveries of Nature made than have been hitherto. For I find it very common for Tradesmen, or such as have been much versed about any thing, to give the worst kind of Description of it for this purpose; and one that is altogether ignorant and a Stranger to it, if he be curious and inquisitive, to make the most perfect and full Description of it. And the like may be observed also in such as travel into other Countries, that they will give a better Description of the Place than such as are Natives of it; for those usually take notice of all the things which because of their Newness seem strange, whereas a Native passes over those because accustom'd to them. I grant that a Native, or one that has been more accustom'd and vers'd in a thing or place, shall be able to answer Questions propounded much better: But a Stranger shall be best able to make the Queries; every Experimenter and Observator therefore should endeavour to be himself both the Inquirer and the Answerer, he should indeavour to make himself as knowing and as much vers'd in any thing he is to describe, and to suppose himself as ignorant and unacquainted as if wholly a Stranger: For as the one will make him inquisitive, so the other will inable him to solve his Doubts. And that his Attention may be the more weakned and rous'd, it will be necessary that he should look upon every Circumstance as the most significant and essential to the producing the Effect, and to continue so to do till he find sufficient Reason to the contrary, by having thoroughly consider'd and examin'd it: For though I confess that this his Supposal will be often frustrated, yet I dare assure him, that it will divers times also prove much otherwise, as I have very often found. And 'tis one considerable Step towards Science, to know the Negative Properties of things, for by that means the Affirmative Properties are made somewhat more defin'd and circumscrib'd.

Of Registering Experiments. Now what I have here spoken of, Attention and Diligence in making Observations and Experiments, the same I would have also in registring; at first let all Circumstances be entred as considerable, unless they are so very obviously otherwise that they appear so at the first examining of them, but yet even in that case also 'tis good to be a little doubtful that possibly something may be at first overseen, which being discover'd would cause other Thoughts and Opinions of it; they can be easily struck out, as soon as they are by further Observations or Experiments prov'd insignificant, and if entred in few words they will not take much room; besides there are very many things, which though perhaps insignificant to the present End or Design, may yet be very notable to some other. If it be found such, 'twill be very good when obliterated in one place, to be inscrib'd in another, where at least it may keep its place till some other thing much more significant to the same purpose, may give occasion to displace it.

Now Observations, Experiments, or Circumstances are not to be esteem'd according to the common Opinion of the World, nor are they to be look'd upon as they are curious or not, or pleasant, or strange, or gainful, or sumptuous, or esteem'd by the great, the grave, the otherwise Learned part of the World, or any of those other kinds of Valuations which are put upon them for other ends, and by Persons altogether unable to judge of their Significancy as to this great and useful Design: But he that is a true Philosophical Historian, will find

find quite other Reasons to advance their Value and fix his Esteem of them. He may perhaps see Cause to account those the most precious and rich, which are generally esteem'd the most vile and sordid; he may perhaps discover that to be the richest Ambergrease, which another takes for Grease fit for naught but to noint his Shoes: Those things which others count Childish and Foolish, he may find Reasons to think them worthy his most attentive, grave and serious Thoughts; and those things which some are pleased to call Swingswangs to please Children, have been found to discover Irregularities even in the Motion of the Sun it self. Other things which the Generality would account an Employment about Niceties and Trifles, he finds to be the shortest and easiest way to his Journey's end, and from the missing of the Hundred part of a Grain, perhaps in his Statical Experiment, finds the Mass of Metal to be many Hundred Pounds worse for Allay: And from the turning of a Straw, is able to foresee a Change in the great Ocean of the Air. He ought therefore to fortify himself against these kinds of Prejudices, which are too to apt to obtrude into his Mind, and prepossess him against a clear View and Observation of Circumstances as they are in their own Nature, or as they are significant to the Design of perfecting Philosophy, and not to neglect or pass by any of them as trivial, or childish, or filthy, or base and mean, and the like; but having always his main End or Aim before his Eyes, to make that the Touchstone, whereby to find the Value of all his Inventions.

What Influence Authority ought to have.

And as these things are not to sway him in the things of his own Invention, so neither should they have any Influence upon him, as to those things which he receives from others, Authority therefore should have no other Argument of Prevalency, but as it was affirmed by an inquisitive, judicious, and most strictly veracious Person; one that is not found to vent Affirmations rashly or negligently, or for any other by Respect, but meerly for the sake of Truth, and because he had by Observation or Tryal found it so, or for some very considerable reason believed it such; one that is very circumspect in chusing and placing his Words, and that is not observ'd to use too much the Superlative Degree, nor to be too confidently positive in his Assertion. Wheresoever therefore any thing is registred upon the Authority of another, there ought to be put in the Margin a C, a P, or a D, according as the Authority is Certain, Probable, or Doubtful: Nor needs there any other Naming since they are only to be respected according to one of these Considerations, or at most nothing but the bare Name of the Person. For 'tis not Epithets taken from Antiquity or Novelty, or Honour, or Greatness, or Will, or Eloquence, or any other Learning but Experimental, that will be significantly added upon this Account: And therefore a Philosophical Historian should indeavour to look through all those Visards, and to see only what Truth or Probability at least he can spy underneath; beside, that such kind of Additions fill Space, and so expand the History into a wider Space, whereas it ought to be compris'd, as I shall afterwards shew in as little room as possible, so as to appear and come under View all at once that the Eye may the more quickly pass over it from one Particular to another, as I shall afterwards more fully explain.

The third part of the manner of Registring Natural Histories.

The next thing to be taken care of is the manner of Registring: And this, as it ought to be done as fast as the Experiment is made, and as soon as the Observations or Circumstances occur, because of the Frailty of the Memory, and the great Significancy there may be in some of the meanest and smallest Circumstances; so ought they afterwards to be several times reviewed and examin'd, and rang'd into a better Method, and abbreviated in the manner of Description; so that as nothing be wanting in the History, so nothing also be superfluous in the words. In the Choice of which, there ought to be great Care and Circumspection, that they be such as are shortest and express the Matter with the least Ambiguity, and the greatest Plainness and Significancy, not augmenting the Matter by Superlatives, nor abating it by Diminutives, not inclining it to this or that Hypothesis, or accommodating it to this or that Author's Opinion; avoiding all kinds of Rhetorical Flourishes, or Oratorical Garnishes, and all sorts of Periphrases or Circumlocutions, omitting the Citations of Authors, or the Recital of Opinions, and Sayings, or the like; in the second Review and Writing of which, 'twill not be amiss to write it in a very fine piece of

of Paper, and to enter it in the most compendious manner of writing that the Historian is acquainted with, such as some very good Short-hand or Abbreviation, whereby the whole History may be contracted into as little Space as is possible; for this, as I shall more fully explain in my second part, is of huge Use in the Prosecution of Ratiocination and Inquiry, and is a vast Help to the Understanding and Memory, as in Geometrical Algebra, the expressing of many and very perplex Quantities by a few obvious and plain Symbols: And therefore 'twere to be wisht, that we could express the whole History in as few Letters or Characters as it has considerable Circumstances, somewhat of the manner of doing which in my second Part.

Now these Histories being writ in brief, in a small piece of very fine Paper, 'twill be very convenient to have a large Book bound after the manner of those that are very usual for keeping Prints, Pictures, Drawings, *&c.* in, to preserve them smooth and in order: On the sides of which, in the same manner as those Pictures are kept, it would be convenient to stick on with Mouth Glew, or some such Substance in the best Method that can be thought of for the present; the several small Schedules containing the abbreviated and complicated Histories of Observations or Experiments, as they are last written on fine Paper, for by the Contrivance of this Book, which for Brevity's sake I will call a Repository, not only all the Histories belonging to any one Inquiry may be placed so as to appear all at one View, there being two large sides of Paper to be fill'd with these Schedules: But they may at any time, upon occasion, be presently remov'd or alter'd in their Position or Order, that which was plac'd first may be plac'd middle-most, or last, or transpos'd to another Head, or a little remov'd to suffer another to be interpos'd, the Convenience of which will quickly upon Tryal be found to be very great, as also it has another Convenience that many of those Schedules which seem to be of the same Significancy may for a time be placed all one over another, and so at last the choicest and most excellent of them may be preserv'd and plac'd in their room, and all the rest as superabundant, and in particular less significant of the same thing may be remov'd elsewhere, of which an inquisitive and diligent Historian will very often find great Use. On these large sides he may place them either according to the Method of the Queries, which he has at first propounded to himself, or according to their first appearing Plainness, or Difficulty, or after any other Method of Inquiry, or Proceeding, which every one will be best able to adapt for himself, according to the Subject whereon he makes his Inquiry, or according to his particular Aim and Scope in examining it, or according to the Knowledge he has already acquir'd in it.

As for the Queries which he at first propounds to himself to be examin'd on that Subject, he intends the History of, those will be most conveniently written either in some other small long Book, or else better in a single Sheet of Paper, either of which may at the same time be expos'd to the View with the Schedules on the sides of the larger Repository, and as 'twill be no great Labour to write over the one anew according as further Information shall give occasion to add or alter Queries, so 'twill be much less to transpose and range the Method and Order of the Schedules in the Repository.

Now because oftentimes much more may be expressed in a small Picture of the thing, than can be done by a Description of the same thing in as many words as will fill a Sheet; it will be often necessary to add the Pictures of those Observables that will not otherwise be so fully and sensibly exprest by Verbal Description: But in the doing of this, as a great Art and Circumspection is to be used in the Delineation, so ought there to be very much Judgment and Caution in the use of it. For the Pictures of things which only serve for Ornament or Pleasure, or the Explication of such things as can be better describ'd by words is rather noxious than useful, and serves to divert and disturb the Mind, and sways it with a kind of Partiality or Respect: Besides that, it fills up room, and occupies the Mind with the Ideas of things which are little significant in the present Inquiry.

And therefore all those kind of Pictures of the outward Forms and Beauties, and Varieties of the Species of Nature, are to be referred to another Head, where

where indeed they will prove very significant, but to a peculiar kind of Inquiry, as I shall shew more at large in my second part. All things indeed ought to be registred very exactly and defin'd and determin'd all according to their Proportions in Number, Weight, Measure, Time, Place, and Circumstances; but all in brief, and yet sufficiently significant.

Together with these Schedules of History, 'twill be convenient to interpose small Schedules of particular Deductions, or Conjectures, or Queries, or Causes of Doubt, or receiv'd Hypotheses, and the like; but these, as they should be expreſt in a very few words, so that they may be the more obvious, and may thereby the less disturbe the Mind in its Inquiry: So 'twill be best to have them written with an Ink of some other Colour, as Red or Green, or the like; for this will much assist the Memory and Ratiocination, as I shall afterwards manifest more at large.

The Promise of our Author at the end of the foregoing Discourse of prosecuting, and more particularly explaining the way of ranging Observations and Experiments, so as to make them more convenient for Use, as occasion offers, was I believe never performed: For I never heard or met with any of that Subject, and as to the reasoning part of his Philosophick Algebra, that likewise was not wrote, only there is something to that purpose in several of his Geometrick Lectures read Anno 1680. *wherein he shews the Excellency of the Method observed by* Euclid *in his Elements, which he enlarges upon; shewing how from a few self evident Axiomes and Definitions, and* Postulata *easy to be granted, a vast Structure of undeniable Truths have been raised, and that from the Method of not leaving any thing undemonstrated behind, but still proceeding on, steadily and firmly a* Notioribus ad minus nota; *which Method, if exactly observed in Philosophical Inquiries, the whole Pile would be founded and built upon so sure a Foundation as never to be shaken. And in order to this, he prefers generally the* Synthetick *Method as the most instructive and perfective of the Understanding and Reason, tho' he sometimes proceeds by the* Analytick, *Specimens of each of which will be seen in several of the following Lectures, wherefore I shall forbear to enlarge upon them in this place, since the Prefaces to the particular Lectures will with more Benefit inform the Reader what use he made of them: And likewise of what Use, if not Necessity,* Theories *and pre-conceived* Hypotheses *are (contrary to the Opinion of some Learned Persons) in order to the making more proper Observations, contriving and ordering more convenient Experiments, and inventing more fit Instruments for that purpose, the more accurately and nicely to determine whether the suppos'd Theory be true or false; all which Observations without such a preconceived Supposition, would either have been past by unheeded, and several material Particulars unobserved, and Experiments wanderingly made; or as Chance offered them, and not made with so much Care and Circumspection, and Instruments and other necessary Apparatus not well contrived for determining the Enquiry; yet he still asserts all should be done with great Candor, and without Fondness for any* Theory, *which should be taken up only to discover Truth, and as easily laid down again if found not agreeable to Truth. For a farther Account of his Opinion in this Matter, I refer the inquisitive Reader to the several places where this Subject happens to be discoursed of, and more particularly to a Lecture about determining the Oval Figure of the Terraqueous Globe, and Encompassing Atmosphere, whether it be an Oblong or a Prolated Spheroeid, and of determining the Question whether the* Axis *of the Earth's Rotation has or does successively, tho' very slowly alter, which Lectures were read the beginning of the Year 1687. and follow in their proper place.*

I shall only as a Specimen of these Geometrick Lectures above-mentioned, give the Reader some few Abstracts of some of our Author's Explications: Since I judge it needless to publish his Lectures on that Subject at large, the Elements of Geometry having been already illustrated and set forth by several eminent Persons and that in different Methods, and the first I shall offer is what our Author has delivered concerning the Definition of a Point, viz. R. W.

A Point is that which hath no part. This which some would deem the most inconsiderable thing in the World, seems yet the most difficult to be understood;

ſtood; no Senſe, or Imagination, or Fant'cy, can reach it, nor words deſcribe it, but by a Negative, to tell you what it is not: For it is not to be taken in the Senſe, that the whole Earth is called a Point in reſpect of the Univerſe, nor in the Senſe that the End of a tapering thing is called a Point, as of a Pin or Needle, tho' they ſeem to be the ſmalleſt things we know, becauſe theſe later may be ſaid to have as many parts as the fore-mentioned; for ſince all Quantity is diviſible *in infinitum*, the leaſt Quantity may be divided as often as the greateſt, and therefore whatever is diviſible muſt have Parts, and therefore none of theſe can be properly called a Point, in the Senſe here named, unleſs this Point be underſtood to be the *Apex* of a Mathematical Cone or Pyramid, where the Superficies of it is determined, for that will be a Mathematical Point: But it cannot be ſuppoſed of a Phyſical Point, or Material Cone, or Pyramid, for that will have Extenſion and Bluntneſs. And we find that Microſcopes will make thoſe Points diviſible even to Senſe, nay even almoſt to diſcover a new World in a Point, nay there is one now that affirms he has ſeen more than 10000 Living Creatures in the Bigneſs of a very ſmall Sand, which it ſelf indeed is but a viſible Point to the naked Eye, and each of thoſe 10000 may have Worlds within them. We know not the Limits of Quantity, Matter, and Body as to its Diviſibility or Extenſion, no Imagination can comprehend the *Maximum* or the *Minimum Naturæ*, our Faculties are finite and limited, and we muſt content our ſelves within the Orb and Sphere of their Activity. And acquieſce in a Negative Definition, and underſtand if we can ſomewhat that is ſmaller than the ſmalleſt, though that be alſo improper; for in that which is not Quantity, there is neither ſmaller nor bigger, we muſt endeavour to underſtand ſomewhat infinitely little, leſs than which there cannot be, ſomewhat that has no Bigneſs or Extenſion, or Quantity, but only Poſition and Reſpect to Quantities circumjacent: From which, to this or that Body, there is a determinate Length and Diſtance; and upon this account, wherever we endeavour to underſtand this Notion, our Imagination will repreſent to us the ſmalleſt viſible Body, as an exceeding fine Sand, or a Mite, or the Point of a Needle, or the ſmalleſt viſible Body we have ever ſeen on Paper, or the like; which we muſt be content with ſince the Fantcy forms nothing but what is firſt in the Senſe, though it be none of theſe. And in truth it can have no true Definition that will reach its Eſſence. Analogous to this Point, Sign or nothing in Quantity is the *Nought* Cifer, or *Zero* in Number, the never in time. The Reſt or Quiet in Motion: For as no Aggregate of Points will ever produce a Line or a Quantity, ſo the Multiplication of Noughts or Cifers will never produce a Number, and as the Addition of Nevers cannot make time, ſo the Aggregate of Reſts cannot produce a Motion. So that all theſe may not improperly be called the *Terminus* or Bound, from which they all begin, ſo Quantity may be ſaid to begin from a Point or nothing. Number may be ſaid to beigin from Nought Cifer or Zero; Time may be ſaid to begin from Never, and Motion to begin from Reſt: And as the *Minimum Naturæ* may be ſaid to be the firſt Quantity, if at leaſt there be a *Minimum* in Nature, ſo a Unite may expreſs it in Numbers, Inſtant in Time, and Moment in Velocity. It may poſſibly be thought I have ſaid too much of nothing, but yet it ſeems to be of the greateſt Conſideration in Nature; for it ſeems to be the beginning of every Creature, even the greateſt Creatures having been traced to begin from an Atom or Point, no Eye or Senſe can reach it, nor any Underſtanding limit it, that the beginning of a very large Animal hath been ſeen alive 10000 times ſmaller than a Mite may be proved, and yet how much ſmaller it may have been is not determined.

Now as theſe expreſs Incomprehenſibles one way, as to their Beginning or Centrality, ſo the Incomprehenſibles the other way which may be called Circumferential, may be expreſſed by Infinity, Abyſs or Immenſity for Quantity or Extenſion, Innumerability for Number, Eternity for Time, and Inſtantaneous for Motion: But thoſe are beyond our Reach, and yet even of thoſe there is a neceſſary Uſe in Geometry; and without which ſeveral of the moſt conſiderable Demonſtrations both in that and Arithmetick cannot be performed, but of theſe elſewhere. When I come to conſider Infinity and Innumerability, when I ſhall ſhow that innumerable Points do make a Mathematical Line, innumerable Lines

do

do make a Mathematical Superficies, innumerable Superficies do make a Mathematical Body, innumerable Moments make a Velocity, innumerable Instants make Mathematical Time, by supposing Motion joyn'd to them: For a Point moved makes a Line in a Mathematical Sense, a Line moved makes a Plain, a Plain moved that makes a Body, and contrary Motion reduce them back again, which is exprest or perform'd by Multiplication and Division.

I shall beg the Candid Readers Patience to add one Remark more of the Doctors on the Method of Euclid, *and that is of his Method of Demonstration, and that in two very easy Problems,* viz. *the Prop.* 1. *and* 2. *Lib.* 1. *which I hope for some Observations and Hints, particularly as to the Analyticks of the Ancients will not be altogether unacceptable.*

Euclid having premis'd his Principles, he begins his Method of Demonstration, in which he takes no more for granted than what he hath already laid down as easy and self-evident. His first Proposition then is upon a right Line, given to make an Equilateral Triangle. He hath defined in the 4th Definition what he means by a right Line, namely, that which lieth straight between the two Extremes of it which are Points, and what he means by an Equilateral Triangle, namely, such a one which hath all its three Sides equal to one another.

This first Proposition is a Problem, which explains a way how to do and perform the thing required, as well as shews how to manifest the Truth and Certainty of the thing done: It contains therefore and shews a double Invention, without which, or some such other thing, the Proposition can neither be done, nor demonstrated; which Inventions are called Mediums or Means by which we attain to the end propounded or desired. The end here sought is how from the ends of a Linen give to draw two other Lines each equal to the given Line, which shall meet in one and the same Point: It is certain that these Lines must begin from the ends of the first Line given, but which of these to draw first, and which way, with what Inclination to the former Line, that is, with what Angle, that is not yet known, and some Invention must be thought of how to direct our Ruler to draw it. Well, how shall this be done, since there may be infinite of Lines drawn from each of those Points which shall every one of them be equal to this Line given? How then shall we among those Infinite or Indefinite Number chuse out the right? 'tis impossible, without some Invention. Our Author therefore helps you to one, and one which you have already granted to be feasable in the third Petition upon the Center a, and Distance, a b, draw a Circle, says he, b g c h f b, what then? To what purpose? Why this Circle then will give you a Line in which are contain'd all the Points or Ends of the infinite Lines, which may be drawn from the Point a any ways that shall be equal to a b How so? Why by the 15th Definition you are taught, that a Circle is a plain Figure bounded by or contain'd within one Curve Line, which is called the Circumference, to which every right Line drawn from a Point in the middle, which is called the Center, are equal to one another: But what are we yet the wiser? How do we know which of these infinite Lines we are to draw? To which of these infinite Points that are in this Circumference? To know this, you must do the same thing upon the Point b, that is, upon the Point b and Distance b a. Draw or describe the Circle a d c e f a, which will give you all the possible infinite Points in that Plain; to which the from the Point b right Lines may be drawn equal to b a. Now then since these Circles contain all the possible Points of the Lines equal to a b or b a, that can be drawn from a or b. It follows, that where those Circles intersect there only must be the Point to which those Lines may be drawn; namely, at c and at f and no where else soever: Drawing therefore Lines from a and from b to either of those Points c or f as a c, b c, or a f, b f, you have done the thing that was propounded, namely, upon the Line a b, given you have made an Equilateral Triangle a b c or a b f, which was desired. This is the first part of the Problem, and indeed the difficultest to find out; namely, how to do the thing required, and in this part lie the greatest Difficulties of Mathematical Knowledge, to wit, in the finding out the proper and true Mediums or Means to perform the Problems requir'd to be done, which for the most part are of the same Nature with this, and consist in the

Plate 1*st. Fig.* 2 *d.*

the finding out the Position of a Point; for this Problem might have been thus worded. A right Line being given as a b, to find a Point as c or f, to which Lines being drawn from the Points a and b, they shall each of them be equal to one another, and to the Line a b which is given; or two Points a and b being given to find a third Point, as c or f, which shall have the same Distance from a and from b that they have from one another. But our Author not having given any Definition of Distance or Equality, otherwise than may be collected from Equality of the sides of some Figure, or of the Rays or Lines drawn from the Center to the Circumference of a Circle, he chuses rather to make use of an Equilateral Triangle to find out that Propriety of a Point so posited. What ways the Ancients had for finding out these Mediums or Means of performing or doing the thing required, we are much in the dark: Nor do any of them shew the way, or so much as relate that they had such a one; yet 'tis be-
" lieved they were not ignorant of some kind of Algebra, by which they had a
" certain way to help themselves in their Inquiries, though that we now use
" be much confined and limited to a few Media. But I do rather conceive,
" that they had another kind of Analyticks, which went backwards through
" almost the same Steps by which their Demonstrations went forwards, though
" of this we have no certain Account, their Writings being altogether silent
" in that particular. However, that such a way is practicable, I may here-
" after upon some other Occasion shew by some Examples: Whereby it will
" plainly appear how much more useful it is for the finding out the ways for
" Solutions of Problems, than that which is now generally known and pra-
" ctised by Species. But this only here by the by, our present Business being to go through all the parts of this first Problem of our Author. The second part then of the Proposition is the Demonstrative part thereof, namely, to prove from the Principles already laid down and granted and assented unto for true and certain, by a clear Chain of Reasoning and Deduction, that these Lines a c and b c or a f and b f, are each of them equal to a b, and so equal to one another; and consequently that the Figure a b c bounded and limited by them is an Equilateral Triangle, according to the Description of their Figure in the 24 Definition. The next thing then to be invented or found out is the Medium or Means of demonstrating it to be such, for this we have two. First, the Definition of the Proprieties of the Lines from the Center of a Circle to the Circumference in the 15 Definition, that they are all equal to one another: And Secondly, We have the first Axiome, those which are equal to one other are equal to one another. First, a b is equal to a c, because they are right Lines drawn from the Center a to the Circumference b g c h; for by the 15 Definition, as I said, all such Lines must be equal next b a, and b c must upon the same account be equal to one another, because they also are Lines drawn from the Center b to the Circumference a d c e: Therefore both a c and b c are equal to a b, but by the first Axiome those which are equal to one other are equal to one another, therefore a c and b c are also equal to one another. Therefore the three sides of the Figure a b c, namely, a b, a c, and b c, are equal to one another, and consequently bound an Equilateral Triangle according to the 24 Definition, therefore upon the Line a b given an Equilateral Triangle is made, which was the thing to be done and proved.

I do not any where find that this was ever done by Dr. Hooke, *and leave the Usefulness thereof to be considered by the Learned.*

The second Proposition is also a Problem.

From a Point given to draw a right Line, which shall be equal to another right Line, given. For the performing of this Proposition, it being a Problem, there is need of two Mediums to be invented or found out; the first is for the doing of the thing required, and the second for the Demonstration of it, and both these are to be fetcht out of the Principles already agreed to, or from the Truth evidenced in the preceding Proposition: For we are not to suppose any thing further known in this Science, and therefore much less are we to make use of it. Searching therefore our Store, we have no other Medium to make a Line equal to a Line, than first by the Help of a Circle, defined Definition the 15. which by the third *Postulatum* is granted to be describable upon any Center, and at any Distance: Or 2dly, by an Equilateral

Triangle

Triangle described Definition 24, which we learnt how to make by the preceding Problem: For as to the equal sides of an Equilateral Triangle, Definition 25, or the equal sides of a Square, a Parallelogram or oblong Square, *Rhombus* or *Romboeides* described Definition the 30, 31, 32, and 33. Though their Proprieties are there defined, yet we are not taught how to make them as yet, and consequently can make no use of them, as *Media* to perform the thing required to be done by this Problem: Nor are we to suppose, that the length of the Line given may be taken by the help of a Measure or a pair of Compasses, and transferred to the Point given; because those are first not mentioned in the Principles laid down there which you are to make use of, and of no other, till they be accepted for Principles undeniable: For 'tis not yet granted, that you can with Compasses, take a true Length of a Line, much less that you can transfer it and set it in another Place. But you have granted that 'tis possible, upon a Point given at any Distance, to describe a Circle, or suppose it so done; which is sufficient for the Demonstration, that being the principal thing aim'd at by our Author; Namely, to lay open to the Understanding, the Reasons and Grounds of the Proprieties of Quantities so and so qualify'd, that you may plainly see how and for what Cause things are thus or thus and cannot be otherwise: For as to the most practicable and expedite ways of doing those things Mechanically, and for other Uses, that belongs to another part of Mathematicks; namely, to the practical Part thereof, which is called Practical Geometry or Mechanical Geometry, which ought not to be Learned till this be first known, but this which our Author treats of is Speculative Geometry, and principally aims at Demonstrations or explaining the Proprieties of Quantities to the Understanding. You saw clearly by the former Proposition why a b c was as equilateral Triangle, and why there could be but two such made upon the Line a b in the same Plain; there being but two Points wherein those Circles cut each other, those Circles determining all the Lines equal to a b that can be drawn from the Points a and b. His way then of performing this Problem is this, Let the Right Line given be a b in the third Figure, and the Point given be c, from which Point a right Line is to be drawn equal to the Line a b. *Plate 1st. Fig.* 3. First draw a Line from b to c, which is granted possible by the first Postulatum, then by the former Proposition upon this Line, b c make an equilateral Triangle b c d, then upon the Center b and Distance a b describe a Circle, as a g by the third Postulatum; then by the second Postulatum produce d b to the Circumference e, then upon the Center d and Distance d e, draw the Circle e h; then as before, produce the Line d c to the Circumference f, then shall c f be the Line required to be drawn from the Point c equal to the Line given a b. This is the Construction of the Problem, or the preparing of the Proposition fit for Demonstration, by which you may clearly understand the Reasons of it, deduced from the few Principles already laid down: For first, that a b is equal to e b is clear from the 15 Definition, which determines the Propriety of Equality of the Rays of a Circle. Next that d b e is equal to d c f, is as clear from the same Definition, they being both Rays or Lines drawn from the Center d to the Circumference e h by the Construction premised. Thirdly, That d b is equal to d c, is clear from the Construction; for d b c is an Equilateral Triangle, two of whose sides d b and d c are. Now by the third Axiom or common Notion, if from equal Quantities you take equal Quantities, the Remainders shall be equal; if from d f you take d c, and from d e d b the Remainder c f shall be equal to the Remainder b e; but a b is also by the Construction equal to b e, therefore since by the first Axiom these two Quantities which are equal to one other Quantity are equal to one another; therefore a b and c f, being equal to b e, are equal also to one another, therefore from the Point c the Line c f is drawn equal to the Line a b, which was the thing to be done and proved.

Now though this way of Demonstration and Reasoning may seem tedious and too long to detain the Mind and Attention in the finding out the Proprieties of Quantities, yet 'twas the way made use of by the Ancients. And 'tis altogether necessary, especially in the beginning of this Study, to accustom the Mind to Attention and Circumspection, that it may receive nothing for Truth, but what it sees clearly by the Reasons and Causes of it, that thereby the

Mind may acquire an Habit of Intention, and of examining the whole Chain of Consequents from the first Principles to the Truth evidenced. For the want of which, some small Error perhaps may slip into the Mind under the Appearance of Truth, and thereby make all the subsequent Reasonings and Deductions unsound; and 'tis very much harder to clear and free the Mind from it when once received, than to prevent the Reception thereof. There cannot therefore (in this Study especially, not now to mention any other, where it is possible it may be altogether as convenient, nay necessary) there cannot, I say, therefore be as I conceive too much Circumspection and Caution used in admitting Principles, and furnishing the Mind with the true grounds of Knowledge; because for the most part we are too prone to take up every thing we hear upon Trust: Without Examination, we are too apt to run away with a thing, and think we know it and see it clearly before we are sure we do, and are impatient of Delay in examining and considering, whereas if the Mind be a little at first accustomed to this leisurely and strict way of reasoning, after it has got a habit it will make as much Dispatch in receiving things with sufficient Examination, as another shall without it. And the Patience only is needful for the most part, at first, to beget Attention: Nor is it peculiar to this Acquisition alone, but we see it necessary, and practised in many other things where a good habit is to be acquired; as in Reading, Writing, Musick, Drawing, and most other Manual Operations. The Roots and Beginnings of Knowledge and Practice too are bitter and tedious, but the Fruits are sweet and pleasant; and whosoever attains the end, will never repent the time they spent in the beginning.

Possibly some Readers may think these Abstracts, out of some of our Authors Geometrical Lectures, too prolixe; but I hope they will not by all be judg'd wholly unnecessary, and useless, at least I thought it not amiss to give this Specimen of our Author's Niceness, as to the admitting of things unproved, for real Truths: But if this be a fault, I hope what follows in the subsequent Discourses of the Nature of Light, and other no less curious Subjects, will make sufficient amends. R. W.

Lectures

LECTURES of LIGHT,

EXPLICATING ITS

Nature, Properties, and Effects, &c.

SECT. I.

Containing those read about the beginning of 1680.

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1. I Intend, God willing, this Term to treat of *mixt Geometry*, as it is made use of for the Explanation and clearing of some Subject to which it is applyed, and by Example therein to shew of what Use it may be in any other Matter that falls within its Reach. And the Subject I have pitched upon as the first and most obvious, though yet the most abstruse of all others is *Light*: None that has Eyes can be ignorant of it, and yet there have been *The Difficulty of the Subject.*

been very few, if any, in the World that have hitherto underſtood and explained the true Nature and Cauſe of it. And though it was the very firſt thing in the World to which the Almighty Creator gave his *Fiat*, when he made the World, *fiat Lux*, Let there be Light; yet it may be poſſibly the laſt and moſt difficult of all ſenſible things, that may be thoroughly underſtood. And this Subject I have the rather begun withal, becauſe from a clear Explanation of this, ſeveral other Subjects, as thoſe of *Gravity*, *Magnetiſm*, *Rarefaction*, *Condenſation*, *Solidity*, *Fluidity*, and the like, will be demonſtrably evidenced: Now though Nature hath not furniſht us with diſtinct and appropriate Organs of Senſe, whereby we may immediately be made ſenſible of all thoſe Operations and Workings of Nature, as no Senſe informs us immediately of the Emanations of the *Magnetical* Vertue, no Senſe immediately informs us of the Inſtruments or Powers imployed for driving Bodies towards the Center of the Earth; no Senſe informs us of the *Gravitation* or continual Preſſure of the *Air*; no Senſe informs us immediately of the means of the Conveyance of Light, yet an inquiſitive and obſerving Man may find Helps enough to aſſiſt thoſe Senſes which the Creator has furniſht him with, to diſcover all thoſe ways and means made uſe of, and to demonſtrate their Proprieties and Powers as clearly, as if the Inſtruments and manner of working were viſible and obvious immediately to ſome of our Organs of Senſe.

To repeat to you all the Definitions and Deſcriptions thereof in *Authors* that have treated of it would be endleſs, and inſtead of making the Nature of it more perſpicuous, would quite darken and put it out: For the moſt part of them have only ſpoken of it as it were Metaphorically and by Smilitudes, ſeeming not to have underſtood at all themſelves what they endeavoured to explain to others: Or at leaſt have treated of it in ſuch general Terms, that inſtead of making it more intelligible, they have made it incomprehenſible. Such therefore I ſhall omit to mention, the Science that they deliver being only uſeful for Allegories and Similitudes, and Rhetorical Embelliſhments, and no way tending to the Phyſical Explanation of its Effects and Proprieties.

Certain it is, that the Nature of it ſeems to be the moſt abſtruſe of any thing we yet know in the Univerſe, and though moſt ſeeing People do believe they thoroughly underſtand it, yet if they ſhall conſider more attentively what their Knowledge of it is, they will begin to think themſelves a little in the dark, and to want ſome further enlightning to diſcover that which before they thought ſo evident, which will now ſeem to differ from all other things in Nature.

The Opinions of the Ancients.

2. But before I come to theſe, I ſhall determine the Opinions of ſome of the moſt eminent Philoſophers and Mathematicians, which we find either in ancient or Modern Writings, to ſee how far they have agreed, and in what they have been deficient in explaining the true Nature of Light.

Amongſt theſe I ſhall begin with the moſt ancient, as *Anaximander*, *Anagoras*, *Leucippus*. *Heraclitus*, *Empedocles*, *Zeno*, and the *Stoicks*, *Plato* and his Followers. All which make Light to be Fire, or a certain Flame iſſuing from the Lucid Body, as the Sun, which they ſuppoſe the Fountain of Light, and to be all Fire, Flame, or pure Light: And there *Anaxagoras* call'd it μύδον διαπυρόν a fiery Maſs, and καθαρώτατον πῦρ moſt pure Fire, and πυρὸς ἄθροισμα μέγα a vaſt Maſs of Fire. And wherefoever there was Light, there they ſuppoſe Fire, which produced the Effects of Fire if it were denſe enough; but if it were not denſe, it only made things viſible, and produced the Effect that we call Light. This was their Opinion in general, but how they did more particularly explain the Nature of Light do not now appear; ſo that in effect we are as much to ſeek as to the Knowledge of the true Nature of Light as before: But 'tis but giving of it another Name, and calling Light by the Name of Fire or Flame, without telling us what that other thing is which they name. For who underſtands what they meant by Fire or Flame, whether the ordinary Fire of Wood, Coles, *&c.* or an Elementary Fire, ſuch as the Peripateticks afterwards ſuppoſe; or a third kind, ſuch as the Maſs of the Sun and fixed Stars, or neither of all theſe: Becauſe they granted the Moon riſes to participate of it, and yet hath none of its own.

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In truth we have no Information from it that is pertinent to this Inquiry I am now about: For call it Light, or call it Fire, or call it Flame, unless we knew the Proprieties and Causes of it, it comes all to one thing, it instructs us not; for how come we thereby to know how this passes from the Sun? For instance, or from the fixed Stars, some Thousands of times further than the Sun to our Eye here placed upon the Earth, in an instant? Which Light really doth (as I shall afterwards endeavour to show.) How comes the Sun, or any one, nay all the fixt Stars, continually to give out so great a Quantity of Flame, as every moment to fill the whole Universe; which is an Extension or Space Millions of Millions of Millions of times bigger than the whole Globe of the Earth and Sea, and indeed incomprehensible in Greatness, and yet at the same time the Body of it not sensibly wasted; nay, thus it hath done ever since the beginning of the World, in every moment of time, and yet by the best Observations we can find recorded in Natural Historians and Astronomers, we cannot learn that the Sun is diminished in Quantity: So that let the Flame be never so much rarify'd, yet considering it must fill so infinitely vast a Space every Moment, certainly it must have long before this have rarify'd this Body all away, this therefore cannot be a true Explication of the Nature of Light. Besides, we are yet to seek the true Nature of Flame, how that comes to make it self sensible at a Distance: For though we see a Stick of Wood, for instance, or a Candle, by means of Heat to be turned into Flame and to be consumed thereby, so that the whole Substance thereof by degrees is all converted into a successive Body of Flame, yet how this comes to affect our Sight at so many Miles distance in an instant, so that at the very Moment the Flame is kindled, or extinguished; or discovered, or covered, though at 10, 20, or more Miles Distance, the Eye at the same instant is sensible of these Varieties. Now who can imagine, that the Body of Flame, which appears at one instant in the top of the Candle, should at the same instant fill a Hemisphere of the Atmosphere 10, 20, or more Miles in Diameter, and yet it must be concluded so to do if this be the cause of Light: For there is no Point in all that Hemisphere, in which if the Eye be placed, the Candle cannot be seen at the very instant 'tis lighted. This Explication therefore is to me, I confess, wholly inconceivable, and is complicated with such Difficulties as no true reasoning can make it possible and intelligible, and therefore as an Absurdity or Impossibility, I must reject it.

Nothing is to be allowed in Natural Philosophy but what is solid.

For as in pure Geometry nothing is to be let pass for a Truth, whose Cause and Principles are not clearly shown by the Progress of Reasoning, and the Process of Demonstration: So in Physicks Geometrically handled, nothing is to be taken for granted, nor any thing admitted for a true Conclusion, that is not plainly deduced from self-evident Principles, and those founded upon the immediate Objects of Sense disintangled from all the Fallacies of the Medium and Organ. To avoid then in part this unintelligible Expansion of Flame, so as to fill the whole Sphere of the true Medium incompassing the Lucid Object. Some later Authors have added, that this Expansion is only superficial, and not solid, and that the whole Medium is not at the same Moment compleatly fill'd with this rarify'd Flame, but that the Momentary Emanation of Flame from the Lucid Point makes a Spherical Superficies, which Spherical Superficies by an almost instantaneous Motion expands it self every way *in Orbem*, and successively becomes the Superficies of greater and greater Spheres, till it attain the Extremities of the Universe, or be at length lost in the Profundities of the Abyss of Matter. For Explanation of which, they bring the Similitude of the Rings or Circular Waves upon a stagnating Pond of Water, for as in that (say they) the Wave made by a Stone, or the like Body falling into the Water makes a Wave, which very Wave you see expands it self and moves from that place where the Stone fell, in a Circle that continually grows bigger till it touch the Extremities of the Pond, or *Stagnum* of Water; so that very Flame which is emitted from the Lucid Body, does by successive Motion, but yet very rapid, move it self from the Lucid Point to all the Extremities of the Material World in a Spherical Superficies, which does continually grow bigger and bigger, and that 'tis only a Superficies as it were that is at once fill'd by it, and not the whole Sphere; from which Cause, say they, the Eye can be

no where plac'd in the ambient Sphere of Matter, but this increaſing Sphere will affect it and move againſt it, and thereby make on it an Impreſſion which we call Light. Now the Body ſo long as it burns continually emitting ſuch Spherical Superficies of Flame, which continually follow one another, with the ſame, though it be an infinitely rapid Motion and ſwiftneſs.

Semper enim nova ſe radiorum Lumina fundunt,
Primaq; diſpereunt.

Says *Lucretius.*

And again in another Place of his Books he adds,

Suppeditatur enim confeſſim Lumine Lumen,
Et quaſi pro telo ſtimulatur fulgure fulgur;
Qua propter ſimulacra pari ratione neceſſe eſt
Immemorabile per Spatium tranſcurrere poſſe,
Temporis in puncto.

It follows therefore, that the whole Sphere muſt alſo be fill'd with them. This ſeems to be the Theory which *Epicurus* and the *Atomiſts* maintain, which is at large explained by *Gaſſandus*, and our Learned Dr. *Charleton.*

The Insufficiency of the Ancient Opinions.

3. But the Difficulties in it are very great; for firſt, *Epicurus* ſuppoſed that all the Space between the viſible Cœleſtial Bodies was a perfect Vacuity, and only made for the way of theſe Orbicular Superficies of Light, or Paſſage of thoſe Troops of Atomes of which theſe Orbs conſiſted; for ſo *Lucretius* in his Second Book explains it, ſpeaking of Atomes.

Quæ porro magnum per Inane vagantur
Et cita diſſiliunt longe; longeq; recurſant
In magnis Intervallis. Hæc aera rarum
Sufficiunt nobis, & ſplendida Lumina ſolis.

Now 'tis hard to conceive how ſuch infinitely ſmall Bodies, ſhould with ſo rapid a Motion paſs ſo vaſt a Space in an inſtant almoſt, and yet muſt continually in the way through every Point of Diſtance meet with croſſing Spherical Surfaces of Light from infinite other Lucid Points, and yet the Paſſage of them not to be at all impeded or ſtopt.

2*dly*, 'Tis not yet proved, that there is any ſuch thing as a *vacuum* in Nature; and *Deſcartes* ſuppoſes that Extenſion and Body is one and the ſame thing, and that there is no where Extenſion but there is Body, and no Body but is extended; for which he brings ſeveral Arguments, not eaſy to be fully anſwered, which I ſhall not now inſiſt upon.

3*dly*, Though it might be granted, that there were an Extenſion without a Body to fill it, and a perfect Vacuity; and ſo the Atomes or Bodies moved through it, will paſs without any Impediment from this Medium or Space, yet ſince we ſee that Light paſſes the moſt ſolid Bodies alſo inſtantaneouſly, or in a Velocity rapid beyond Imagination, here certainly it ſhould meet with Impediments to ſtop it: For we find it paſs through the hardeſt Body in the World, namely, a Diamond; and ſeems to paſs more freely through it than through the Air or Water, or the moſt Fluid Body, as may be gathered from the greater Refraction of the Rays from the perpendicular in the more ſolid Body: Nor can I conceive how the Vacuity of the Pores of the Bodies can ſolve this Difficulty, ſince it will be hard to conceive how thoſe Pores can be alike open every way to the Paſſages of the Atomes of Light.

4*thly*, Suppoſing there ſuch a Vacuity or Medium not reſiſting Motion, and there were ſuch Bodies as Atomes to be moved in it, yet 'tis difficult to conceive how they ſhould receive ſo rapid a Motion from the Luminous Body:

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For no ſuch rapid Motion is there in being. Now 'tis a Rule, *Nil dat quod non habet*, that which hath no ſuch rapid Motion cannot give it to the Atomes that proceed from it. Now that 'tis not neceſſary a Luminous Body ſhould have ſo rapid a Motion, may be argued from the ſhining of a Diamond in the dark, only by gently ſtriking it with the end of ones Nail, as I have often experimented, upon a large Diamond that had that Quality: Or from the ſhining of rotten Wood, or ſuch other cold Subſtances which ſeem not to have any ſuch kind of rapid Motion, and yet produce Light, which might be farther inſtanced in the new *Phoſphori*.

5*thly*, If ſuch a rapid Motion of fiery Atomes ſhould be the cauſe of Light; it would be very difficult to conceive, how ſo tender a part as the Eye ſhould continually receive them concentrated in the *Tunica Retina*, and yet not be deſtroyed and batter'd in pieces by ſuch continual Volleys of Atomes.

6*thly*, If there were ſuch a conſtant Emanation of Atomes, and that it has continued ever ſince the Creation of Light: Certainly this ſuppoſed *Inane*, or void Space between the Cœleſtial Bodies, muſt needs have been filled quite full long before this, and then the free and iſtantaneous Motion of the ſucceeding Emanations muſt have ceaſed, becauſe they muſt find their way all ſtopt up by others, and conſequently by this time we ſhould have had no Light at all communicated from the Sun.

I could inſtance in many other Difficulties, as that of conveying the *Species* of things, and the like; that this *Hypotheſis* of the *Epicureans* or *Atomiſts*, who did not underſtand the Reaſon of Viſion is encumbred with, which ſeem to make it impoſſible, and unfit for the Genuine Explication of their admirable Proprieties of Light; but that theſe, I ſuppoſe, may ſuffice at preſent for this purpoſe, though on the other ſide there are many things that may be ſaid for it, that have not been hitherto urged by any I have met with. Some of which I ſhall have occaſion hereafter to mention.

4. *Ariſtotle* was aware of theſe Difficulties, and therefore goes ſomewhat more craftily to work in his Definition of Light: Giving you a Notion of it in ſuch general Terms without particular Explication, that you make almoſt what you will of it, φῶς ὅ ἐστιν ἡ ἐνεργεία τοῦ διαφανοῦς ᾗ διαφανές. Light is an Act of a perſpicuous Body, in as much as it is perſpicuous. He affirms Colour to be the Cauſe why a coloured Body is ſeen, and this Colour, ſays he, does effectually move the Pellucid Body: But this Colour is not ſeen but with Light, therefore ſays he, Colour in the Light does effectually move the Pellucid Body, but Colour without the Light, though it be congenit with the Pellucid, yet it doth not actually move the Pellucid Body; therefore, ſays he, the Body muſt be actually Pellucid that Colour may move it. Now it cannot be *actu* Pellucid without Light, therefore Light is that which *actu* by its Action makes a Pellucid Body: And therefore the Act of that pellucid Body is Light. Now ſays he, this Light is not Fire nor any other Body, nor the *Effluvium* of another Body, for ſo it would ſtill be a Body; but 'tis the Preſence of Fire, or ſome ſuch like, in the Pellucid, and the Abſence or Privation of it Darkneſs: From which his Definition of Light, I cannot I confeſs, well judge what his Theory of Light was; for this Definition is only made upon one Effect of Light, and doth not at all tell us under what *Genus* Light is put, nor what are its Differences, nor what are the many Proprieties of it. So that theſe are to be ſought elſewhere. And when we have ſeen all he has ſaid of Light, we ſhall find our ſelves as much in the dark as before, as to the Knowledge of the Nature of Light, he here conſiders Light only as it is in the *Medium* that conveys it, namely, in a Pellucid or Tranſparent Body, and ſo calls it the Act of the perſpicuous Body; but what this Act is, or how it comes into the Pellucid he tells not, that you muſt ſeek for elſewhere. However, though he has not ſo particularly and poſitively explained what he means by this Expreſſion of his; nor did perhaps underſtand any plauſible or intelligible *Theory* of it, yet to me he ſeems to have light upon ſuch an Expreſſion as may poſſibly being

Ariſtotle's Definition of Light.

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Mechanically and Geometrically explained, more naturally and truly make out the *Theory* of *Light* than any other Expreſſion or Explanation of any other, either Ancient or Modern Naturaliſt, Φῶς ἐστὶν ἡ ἐνεργεία τοῦ διαφανοῦς. Light is the in-working of the Tranſparent Body or *Medium*; that is, the internal Action of the Pellucid or Tranſparent Body, is that which is the Light of which we are ſenſible, or that Light which moves the Eye, And this ἐνεργεία is nothing but Motion, and this Motion is impreſſed by the Motion of the Lucid Body, and that Body is Lucid that has ſuch a Motion in it: So that Light in the ſhining Body is a peculiar Motion of it, which can communicate it to the tranſparent Medium, that is, to ſuch a Body as is fit to propagate it, and Light in the Eye is this Motion impreſſed on the Eye, by which the Brain or *Anima* becomes ſenſible of it. For if we conſider all the Appearances thereof, we ſhall at length be neceſſitated to come to ſome ſuch Concluſion: Nor can I conceive how the Phœnomena thereof, can be by any other Hypotheſis but this of a propagated Motion, be comprehended. And though even this be not without its Difficulties, nor is it well conceivable how it ſhould be, if we conſider the almoſt infinite Difference between the Propagations of Light, and the Motion of any other ſenſible Body: Yet when we more attentively conſider and weigh all the Effects and Proprieties thereof, and compare them with the other Effects, and Proprieties of more groſs, tangible and ſenſible Bodies, we ſhall find that the *Lex Naturæ* is the very ſame, by which both the one and the other Motions are governed; and that there is here the ſame *Regimen in Specie*, though they differ in Degrees.

A new Theory explained.

5. The firſt and moſt difficult Propriety of this Motion of all the reſt, is the almoſt incomprehenſible and unconceivable Extenſion thereof; which is as boundleſs and unlimited as the Univerſe it ſelf, or the *Expanſum* of all Material Beings: The Vaſtneſs of which is ſo great, that it exceeds the Comprehenſions of Man's Underſtanding. Inſomuch that very many have aſſerted it abſolutely infinite, and without any Limits or Bounds, there being no bound ſet; but it may be conceived, that Matter may ſtill extend farther and farther continually, being as infinite as Quantity, which is by all concluded to be ſo, both as to its Greatneſs and Smallneſs: The Limits of which, cannot be either conceived or expreſſed; for whatever can be conceived, may be expreſſed and computed by Meaſure and Number. Now here no Number can be aſſigned, but there may be given both a greater and a leſs: As Unity, let it ſignify never ſo great a Quantity, as a Foot, a Yard, a Mile, a Diameter of the Earth or of its Orb, may continually be increaſed by Multiplication or Addition, ſo as to repreſent Tens, Hundreds, Thouſands, Millions, and ſo onwards of its Quantity. So be a Unity taken for never ſo ſmall a Quantity, as a Foot, an Inch, a Line, an Atome, its Quantity may be ſtill ſuppos'd diminiſhable, either by Subſtraction or Diviſion; and ſo a Tenth, a Centeſme, a Thouſandth, a Millionth part of it may be conceived and computed. Now the Propagation of this Motion is coextent with it, as I ſhall afterwards prove.

To avoid the Incomprehenſibleneſs therefore of this infinite Extenſion of the Univerſe, and yet to make it as extenſive as Quantity it ſelf, *Des Cartes* has found out a new Term or Expreſſion for it, which he calls indefinite; which Notion differs only from infinite in this, that the one has abſolutely no Bounds or End, and the other that it can have none aſſigned. But in truth, they have one and the ſame Signification, and that is that Quantity neither hath any Bound, nor can have any Bounds aſſigned to it by Humane Reaſon. And if Quantity can have no Bounds, then Body and Matter can have none, according to the aforeſaid Author *Des Cartes* Opinion, Body and Extenſion, or Quantity being the ſame thing: So that wherever Extenſion can be ſuppoſed, there alſo muſt be ſuppoſed a Body, and where there is no Body there can be no Extenſion, and conſequently no ſuch thing as a Vacuum or Space devoid of Body.

Quantity boundleſs, or can have no Bounds ſet to it.

But whether his Notion be true or not, 'tis not much to our preſent purpoſe: For moſt certain it is, whether it be finite or infinite, the Vaſtneſs of it is ſo great that it exceeds our Imagination, to conceive of it truly as it is, and whoſoever has a finite and limited Conception of it, has a falſe one not grounded on Reaſon, but ſome precarious Opinion; for if we conſider firſt the vaſt

Diſtance

Diſtance between us and the Sun, which from the beſt and lateſt Obſervations in Aſtronomy, is judged to be about 10000 Diameters of the Earth, each of which is about 7925 *Engliſh* Miles, therefore the Sun's Diſtance is 79250000 Miles; and if we conſider that according to the Obſervation, which I publiſhed to prove the Motion of the Earth, the whole Diameter of this Orb, *viz.* 20000 made the Subtenſe but of one Minute to one of the fixt Stars, which cannot therefore be leſs diſtant than 3438 Diameters of this great Orb, and conſequently 68760000 Diameters of the Earth: And if this Star be one of the neareſt, and that the Stars that are of one Degree leſſer in Magnitude, I mean not of the ſecond, becauſe there may be many Degrees between the firſt and ſecond, be as much farther, and another ſort yet ſmaller be three times as far, and a fourth four times as far, and ſo onward; poſſibly to ſome Hundred Degrees of Magnitude, ſuch as may really be diſcovered by longer and longer Teleſcopes, that they may be 100 times as far, then certainly this Material *Expanſum*; a part of which we are, muſt be ſo great that 'twill infinitely exceed our ſhallow Conception to imagine. Now by what I laſt mentioned, it is evident, that Light extends it ſelf to the utmoſt imaginable Parts; and by the help of Teleſcopes, we collect the Rays, and make them ſenſible to the Eye, which are emitted from ſome of the almoſt inconceivably remote Objects: And ſince we find, that ſtill longer and better Teleſcopes do diſcover to us ſmaller and ſmaller fixt Stars, which in Probability are farther and farther removed from us, and that we cannot ſet Bounds to the Extent of it; it follows, I ſay, that the Extenſion of the Propagation of Light is indefinite, immenſe, and beyond our reach to conceive, yet nevertheleſs we ſee by clear Induction that ſo it muſt be, though we do not preſently well conceive how. Nor is it only the great Body of the Sun, or the vaſt Bodies of the fixed Stars, that are thus able to diſperſe their Light through the vaſt *Expanſum* of the Univerſe: But the ſmalleſt Spark of a Lucid Body muſt do the very ſame thing, even the ſmalleſt Globule, ſtruck from a Steel by a Flint, which is as ſmall as the Point of a Pin. For that produces as real Light as the other; and all Light propagating *in Orbem*, that Point muſt do the ſame thing with every Point of the Superficies of the Sun. Now that every Point of the Luminous Superficies does emit Light *in Orbem* through the Diaphanous Medium, is evident from this, that there is no Point of the Ambient Tranſparent Medium in which the Eye being placed, does not ſee every Point of the Lucid Surface, and conſequently every ſenſible Point of the Superficies of the ſhining Body, does really propagate its Light thus *in Orbem*. Nor is this to be limited to a Point big enough to be ſenſible to the naked Eye; for by the Help of Microſcopes viewing a Lucid and ſhining Body, as a burning Cole, or a red hot Iron, or the like; one is able to diſtinguiſh Parts that ſhine 1000 ſmaller than we can diſtinguiſh with the naked Eye, and yet theſe may be diſcover'd and are viſible, and conſequently muſt radiate *in Orbem*, as the bigger and more ſenſible Parts: So that hereby we are aſcertained by our Senſe, that the leaſt ſenſible Point of Body is able to affect the greateſt *Expanſum* of Nature. So it appears both to our Senſe and our Reaſon, and therefore we cannot doubt it, but ſet it down as an undoubted Principle.

The Diſtance of the Stars inconceivable.

6. But then ſecondly, In the next place, this Propagation of Light which is immenſe, is (in all Probability, and as far as Experiments, Obſervations and Reaſons can aſſiſt us) infinitely ſwift: Or we may ſay, that the Propagation thereof through the whole vaſt or immenſe *Expanſum*, as far as we can yet find, is made in a Point or Inſtant of time; and at the very Inſtant that the remoteſt Star does emit Light, in that very Inſtant does the Eye upon the Earth receive it, though it be many Millions of Millions of Miles diſtant, ſo that in Probability no time is ſpent between the emitting and the Reception; for with this agrees all the Experiments that have been thought of for this purpoſe, and no one has yet proved it temporary, though many ways have been thought of for that purpoſe: And though the ingenious Monſieur *Romer* pretends to have found a way, by which he hath experimentally proved, that this Propagation is not inſtantaneous but temporary, and ſo there is ſomewhat of time ſpent in the Paſſage of Light, from the illuminating Object to the Eye or Body enlighted

The Motion of Light infinitely ſwift.

Romer's Experiment doubted whether ſufficient.

lightned, yet if we examine his Experiment a little more consideratelyy we may find reason to doubt, whether he hath from these grounds sufficient to make such a Conclusion. Certain it is, whether by it he proves the matter he aims at, or not: His Ingenuity in the inventing the way was not less to be esteemed and valued, than if it had succeeded; nay, it is altogether as valuable, if by it we could prove that no space of time were spent whilst the Light is propagated such a determinate Space, as if it proved it to be momentary and measurable. For in all Inquiries of this Nature Truth is the thing sought after, and the finding of that is the Reward of our Endeavours: And therefore I would not be thought to examine this Observation of this ingenious Man, with any design to detract any thing from the Credit of the Observation, or the deserved Reputation of the Author. But that I may first explain it to such perhaps as have not heard of it; Secondly, that I may put some in mind of it, that perhaps may have forgot it; and Thirdly, That I may excite both, or either, to be mindful to make some farther Observations of their own of that kind, to see if by any means they can thereby determine this Question, whether the Propagation of Light for such a determinate Distance, or Length, be instantaneous or temporary: For till that be proved positively, the true Theory cannot be proved; as we shall afterwards shew. His Way then which is printed in the Journal *des Scavans* at *Paris*, and since in *English* in the 136*th* Philosophical Transaction, is by the Light of the Sun reflected from the Satellit of ♃, both when it enters and when it emergies out of the Shadow of the Body of ♃, by which he endeavours to demonstrate, that the time that Light spends in passing about 3000 *French* Leagues, or 7925$\frac{19}{33}$ *English* Miles, of 5280 *English* Feet to a Mile, that is, in passing a whole Diameter of the Globe of the Earth, is less than one single second, or the 60th part of a Minute of an Hour.

But to consider a little further this ingenious Way of Monsieur *Romer*, I do very much doubt, that we are as much to seek for a true Theory of this Satellit of ♃, as we are of our own Satellit the Moon, if not somewhat more, by reason that the Anomaly thereof may be complicated with more different Motions than even this of the Moon, which is affected only by two Bodies, *viz.* the Sun and the Earth; whereas I am of Opinion, that the Motion of this inmost Satellit may be acted on also by the other three exteriour Satellits, and consequently there will need other Equations and Allowances to be made in the Calculation of its true Place, besides the Allowances for the Influences of the Sun, and the Body of *Jupiter*, which whether he did conceive or take any Cognizance of, I know not: And therefore unless we are assured of the true intermediate times between the Eclipses of it, we cannot make a certain Conclusion.

But supposing this may prove it to be temporary, and not instantaneous, yet we find that 'tis so exceeding swift that 'tis beyond Imagination; for so far he thinks indubitable, that it moves a Space equal to the Diameter of the Earth, or near 8000 Miles, in less than one single Second of the time, which is in as short time as one can well pronounce 1, 2, 3, 4: And if so, why it may not be as well instantaneous I know no reason, unless it may be said 'tis inconceivable any Body can be infinitely fluid; which yet how it can be denied, I know not, unless we will allow a Vacuity, which the great Asserter of the Instantaneous Propagation of Light, Monsieur *Descartes* will by no means admit. Now that either there must be a Vacuity, or an infinite Fluid, or else no Motion can be made, every way, will necessarily follow from Geometrical Demonstrations of the Proprieties of Figure: And therefore either infinite Fluidity must be allowed in Matter, or a Vacuity. Nor can this infinite Fluidity be evaded, by saying, that there is a Matter indefinitely fluid, because if indefinitely signifies any thing less than infinite, the Demonstrations holds good against it, as well as if it signify'd finite. There is a necessity therefore of admitting in Nature, either first a Vacuity, which impugns the very ground of the *Cartesian* Principles, *viz.* that Body and Extension are the same thing; or secondly, a Penetration of Dimensions, which is likewise contradictory both to his and the Opinion of most eminent Philosophers in the World; or thirdly, a perfect *Plenum* but infinitely fluid, which I conceive cannot be disproved. But being proved, I shall afterwards

wards ſhew all the ſtrange and unconceivable Phenomena of Light will be moſt clearly and evidently, and moſt demonſtrably made out; and not only the reaſon ſhown why its Extenſion is ſo vaſt, but why its Propagation is ſo inſtantaneous. Now though I cannot now ſtand to ſhew the Reaſons of theſe Concluſions, yet by a Methodical and clear Proceſs of Demonſtration they will be ſhewn to be as neceſſary Conſequences from undeniable Principles, as any Concluſion made by *Euclid* in his Geometry, of which I ſhall have occaſion to ſpeak more largely.

This being that we call Light, ſure if any thing may be call'd the *Anima Mundi*: Its Action being ſo near of Kin to that of a Spirit, the whole Maſs being in an inſtant acted by it, and made ſenſible as I may ſo ſpeak, of what is done in any one Point: So that Light may be ſaid to be *tota in toto & tota in qualibet parte*, poſſibly with ſome kind of Plauſibleneſs. And yet after all this we may prove it to be purely corporeal, and ſubjected to the ſame Laws that bulky, tangible, and groſs Bodies are ſubject to. This may inform us alſo, how even the very remoteſt Star, and every one of thoſe indefinite Number of Stars may have an Influence every Moment upon this Ball of the Earth on which we tread, and every one upon every other, and all in Proportion Meaſure and Harmony, ſo they were made, and ſo they are preſerved, Θεὸς γὰρ ἀεὶ γεωμέτρει.

7. We come then in the third place to note, that this Propagation of Light, whether it be inſtantaneous, as moſt probably it is, or temporaneous, and requires a time ſomeway proportion'd to its Diſtance, is not the Action of a Spirit but of a Body, and that it is ſubjected to the ſame Laws that other corporeal Actions or Motions are ſubjected to, and conſequently is a Subject that falls under the Laws of Quantity, and there its Proprieties may be a fit Subject for Geometrical Exercitation. *Propagation of Light the Action of a Body.*

And this appears firſt, for that its Power or Action is always proportionable to its Expanſion; now this Expanſion in a free Pellucid Medium, is in a Duplicate Proportion to the Diſtance it acts reciprocally taken.

The Actions of Light are firſt, that effect it cauſes in the Eye, where it creates a Paſſion which makes us ſenſible of Light, which Effect or Action of Light is ſometimes ſo very ſmall and curious, that we ſhould no way have been ſenſible of it had not the Creator given us an Organ Paſſive by it, and ſo fit to diſcover it, and had Mankind not had that Organ of Sight, no other part of our Body could have been ſenſible of that Effect, nor could it ever have entred into our Imagination to conceive what way it were poſſible the Mind or Underſtanding of Man ſhould be informed of an Action a thouſand thouſand Miles off, at the ſame Inſtant that it was there done, nor though it were a ſhorter way that this Information came, *viz.* 8000 Miles which Monſieur *Romer* ſays he has proved, is paſſed in leſs than a ſecond of time: We could have had, I ſay, no Imagination concerning it, nor any Conception of the Poſſibility of the Appearance of Light or Colours. Hence, To hint this only by the by, we cannot conclude but that poſſibly there may be many other Motions and Operations of Bodies at a diſtance, and ſeveral other ways by which the Bodies of the World may influence one another, though it has pleas'd God not to give us Organs or Senſes to diſcover them, and thereby many things that are accounted Sympathetick or Magical may be done by Natural Cauſes and Powers, of which we have no Organs to make us ſenſible. Now from divers late Diſcoveries about the influencing Powers of Gravity and Magnetiſm, to name no other at preſent, of which we have no Senſe that does immediately inform us; but we become knowing and aſſur'd of them by other means, than immediately by peculiar Organs of Senſe.

Now this Propagation of Light doth act duplicately proportionate to the Diſtance from the Lucid reciprocally; that is, the Strength of the Light at one Foot diſtance from the Lucid Body, is to the Strength of the Light at two Foot as four to one, and to that at three as nine to one, and ſo forwards. So that the farther this Action is propagated, the more is it expanded, rarify'd, or weakned. To explain this, Let us conceive all the Medium incompaſſing the Lucid Body within the Compaſs of a Sphere of a Foot *Radius*, to be by the *The Propagation acts in a Duplicate Proportion to the diſtance.*

Power

Power of Light in the Lucid Point, thrown out and opened into a hollow Orb, which shall incompass this emptied Globe of a Foot Diameter, possessed by the shining Body. The Thickness then of this incompassing Orb will be $\sqrt{c\,2}$ — $\sqrt{c\,1}$. the Expansion of this Orb causes the fluid Matter that was in its place before to expand into a bigger Orb: The Thickness of which will be $\sqrt{c\,3}$—$\sqrt{c\,2}$. and so onward. So that the Rarefaction or weakening of the Power of Light increases in Duplicate Proportion to the Distance, and that this is so does plainly appear by Multitudes of Experiments, which I shall have occasion to make use of hereafter.

The Action of light carries with it a certain degree of Heat.

Next, Though so small a Degree of this Power or Action as does affect the Eye, doth not move or affect the other Senses of our Body, yet is it not without its effect upon other Bodies, besides that which it works on the acutely sensible Parts of the *Retina* of the Eye; for we find, that it also doth produce Heat, and every the least degree of it carries along with it some, though it be a small degree of Heat: Which degrees, if they are collected and concentred, do produce very sensible Effects both upon the touch, and also upon most other Bodies, whether fluid or solid: For we find it to rarify Fluids, and to melt, burn, and shatter to pieces the most solid Bodies: And therefore though the rarify'd, and smallest Degree of Light does not actually produce sensible Effects, yet since the Constipation, Multiplication, or collecting of many of those together. It follows, that the least Degree of Light has somewhat of Heat; and that the reason why it is not sensible, is only because of its Smalness, and that it is beneath those Degrees which are before actually in the Ambient, even as in the Day-time we are insensible of the Stars, because the Light of the Sun hath already fill'd the Air with a greater Light: Not that they do then less shine upon us than they do in the Night, for as I many Years since here shewed many of them may be seen at Noon day, by the help of Telescopes. And (as I shall afterwards prove more at large) there is no degree of Light, but has its degree of Heat proportion'd to those degrees of Light, which are concomitant to the degrees of the Light of the Sun. To this many have objected, that the Light of the Moon is so far from being actually hot, that it is actually cold, and the more those Rays are condensed the more is the Cold augmented: And to this purpose *Wepferus*, in his Treatise *De Apoplexia*, relates a Story how by the collecting the Rays of the Moon there was produced an actual Cold, which was very sensible to the hand held in the *Focus*. But this he relates not as tried by himself, but by another Person; but upon Inquiry further concerning this Matter, I cannot find there was any such Matter certainly observed. So that the Observation is suspected to have proceeded from some Mistake, and the Person said to have made this Observation, would not maintain any such Assertion, and therefore though it might well suit with the Relator's Theory, yet till we have some more positive Proof of Matter of Fact, and of the Curiosity and Circumstances of the Observation, I hope we may be dispensed with, though we are not of his Opinion.

Why the Rays of the Moon have no sensible Heat.

Besides, I have this to answer, That by divers Experiments purposely made, both by my self and divers others, we could not find that the Rays of Light from the Moon had any such Power of Cold as is pretended; nor indeed could we find, that they had any sensible degree of Heat, for having made the Tryals with reflecting Concaves, which collected a great Quantity of the Rays, and concentred them upon a Thermoscrope (which would be moved sensibly by a very little Alteration of Heat or Cold) I could not certainly perceive any sensible Variation, though the little accidental Changes of Heat or Cold in the Ambient Air, were very sensible by it; so that whatsoever may be pretended, I am sufficiently assured there is no such cooling Quality in the Light of the Moon.

Now that the degree of Heat, if proportion'd to the degree of Light, as in the Sun must be very small, and consequently wholly insensible to us will plainly appear, if we consider what Rarefaction of Light is caused by the Reflection from the Body of the Moon. And how small a Quantity of the Light of the Sun, which falls upon the Moon is reflected to us: For if we consider, that when the Moon is full, and so all the Hemisphere of it visible to us, is inlightned by the Sun, that the Quantity of Light which falls upon that Hemisphere

miſphere of the Moon is rarified into a Sphere about 228 times bigger in Diameter than the Moon before it arrive to us, and conſequently that the Light of the Moon is 104368 times weaker than the Light of the Sun; and conſequently, that there muſt be 104268 full Moons to reflect a Light as ſtrong upon the Earth at Midnight as the Sun doth at Noon day: And therefore 'tis no great Wonder, if a 104368th part of the Heat of the Suns Rays is not felt by us. This would be the greateſt Strength of the Moon's Rays, ſuppoſing no part of the Sun's Light were loſt in the Body of the Moon, but that all were reflected; but then if a part of it be there loſt, it will make the Diſproportion conſiderable greater, and conſequently leſs ſenſible: Though therefore we are not ſenſible of the Heat of that Light, yet we are not to conclude it without its due Proportion of Heat.

The ſame Reaſon may be valid, why the Light of Gloworms, rotten Wood, Fiſh, and the Late invented *Phoſphorus*, do not at all affect the touch with their Warmth: For though that degree of Heat be proportion'd to their degree of Light, yet their Proportion of Light is ſo ſmall, that 'tis not to be imagin'd it ſhould produce any degree equivalent to that which is in the Air that incompaſſes our Body.

The Propagation of Light in ſtrait Lines in an homogeneous Medium.

8. This Inſtantaneous Propagation of Light is in the next place in ſtraight Lines, every way from the Radiating Lucid Point, through a uniform pellucid Medium. With this agrees the Judgment and Conſent of all, both Ancient and Modern Authors, that have written of this Subject, all conclude it to radiate every way in ſtraight Lines from the Luminous Point, whether they ſuppoſed it a Flame, as divers of the Ancients; or whether they ſuppoſed it a Flux of Atomes, as the *Epicureans*, or Species, as the *Peripateticks*, or the Motion of a ſtagnant Body, as the *Carteſians*, and our Country-man Mr. *Hobbs*; they all ſuppoſed it to paſs in ſtraight Lines, though ſome of them ſuppoſed thoſe Lines to be but Phyſically ſuch, that is, ſo that the whole made a ſtraight Line, though the imperceptible parts thereof might be a little bended by the Poſition of the Pores, as the Atomiſts ſuppos'd, or by the Form of the conſtituent Parts of the pellucid *Medium*; as the *Carteſians*, who imagined the ſaid *Medium* to conſiſt of ſmall Globules contiguous to each other. And with this alſo agree all Obſervations both in the Heavens, and on the Earth, nor have any Experiments or Obſervations hitherto contradicted it. Now though the Propagation of Light at a great Diſtance ſhould be temporaneous, and ſo be ſome conſiderable time in coming from the Luminous Body to the Eye, and thence that the Morning Object ſhould not be in the ſame place that it appears to the Eye, yet this hinders not but that; that temporaneous Propagation may ſtill be made in a ſtraight Line, there being no Cauſe aſſignable in a uniform ſtagnant Medium why it ſhould be otherwiſe.

But then this hinders not, but that this ſtraight Line may be bent by a Difform Medium.

In the next place therefore, the Propagation of Light is various ways affected, and ſo the Straightneſs of the Rays is changed and diverted another way.

By a Difform Medium the Ray is bent into a Curve.

1*ſt*. By a Medium not uniform and homogeneous, the Ray is bent from a ſtraight Line into a Curve, which I have long ſince proved by many Obſervations and Experiments, and publiſhed in the Year 1664. This Paſſion of Light from a difform *Medium*, I have called *Inflection*; and ſhall hereafter have occaſion more fully to treat of it.

2*ly*, The Straightneſs of the way of Propagation is broken, ſhort as it were, and diverted another way by its paſſing out of one uniform Medium into another uniform *Medium*. This is call'd *Refraction* of the Ray, whereby the ſtraight Line of Propagation is at the Superficies of the two contiguous tranſparent *Mediums* diverted ſome other way within the ſecond *Medium*, which makes an Angle at the Superficies w the former Rays contiuued.

3*ly*, The Ray is broken and diverted another way by its meeting with a *Medium* unfit for admitting the Propagation of Light through it ſelf, and thereby the Ray is kept within the firſt Medium, but at the *Superficies* is with an Angle diverted and bent ſhort another way, this is called Reflection.

4*ly*, The Ray is impeded, ſtopp'd, deaded, or abſorpt by meeting with a Body unfit either to propagate it through it ſelf, or reflect it into the firſt *Medium*, which may be called Mortification or Extinction, of this kind are blank Bodies, and divers others which retain and keep it for a long time, and do not whilſt they keep that Form, return or communicate it to any other.

5*ly*, The Ray is diſperſed, ſplit, and opened by its Refraction at the Superficies of a ſecond Medium, and from a Line is opened into a diverging Superficies, and ſo obliquated, whereby the Appearances of Colours are produced.

6*ly*, The Rays of Light are imbib'd into, and receiv'd by a ſecond Medium, and thence returned again by degrees after they have remain'd a conſiderable time in the recipient Medium, as in the *Bononia* Stone, and ſome of our late invented *Phoſphori*.

Of each of theſe, I ſhall more at large diſcourſe, and explain the particular Cauſes and Reaſons of theſe Affections, and the Rules, Laws, and Limits of their ſeveral Powers.

SECT.

SECT. II.

Containing the Lectures of Light read about Michaelmas, 1680.

The CONTENTS.

1. *The true Method of acquiring Knowledge, is first by examining the* ὅτι *that it is so, and then the* διότι *why it is so.* 2. *The Bodies from whence Light proceeds, as first the Sun; its vast Bigness and Distance from the Earth, emits Rays every way equally* in Orbem, *is subject to Changes from its Spots which are at large described; with their Motions and Nature, and of the Sun's Rotation.* 3. *That the Rays of the Sun carry Heat as well as Light, that the Sun has Heat really, and that it is not produced by the Reflexion of the Rays from the Earth; why the upper Air colder.* 4. *That the Sun is incompassed with an Atmosphere, or something analogous to it, the Limb which appears to us is that of the Atmosphere, more of the Spots: The Sun agrees with the Earth in most Particulars except Light, why the Light of the Sun is most insisted on.* 5. *Farther Reasons that there must be a fluid Body incompassing the Sun, with a farther Explication of the Spots, that they are not Planets like the Body of* Venus *or* Mercury in Sole, *tho' there may possibly be Planets nearer the Sun than them which the Author sees no reason to believe, these Spots are within the Atmosphere of the Sun, and much of the Nature of Meteors, a farther Confirmation that there is a small transparent Shell or Atmosphere about the Sun.* 6. *That within this Shell is a solid Opaque Body, solid from its Rotation, Fixedness of its Axis, and its Power of Gravitation, Opaque from the Spots not appearing thro' it.* 7. *Eight Particulars, wherein the Sun and Earth agree, and three wherein they differ.* 8. *Supposing the Sun composed of Nitrous and Sulphureous Particles, and set on Fire, all the Phenomena thereof may be explained, the Proportion of the Diminution of the Action of Light in Proportion to the Distance from the Luminous Body demonstrated, and that the Light of the Sun is from an actual Fire, or Dissolution of the Superficial Parts thereof, with an Objection against it answered.* R. W.

1. I Have begun in my former Lectures to enumerate and explain to you some of the Proprieties of Light, and to observe to you what it effects and performs, which I have done in order to shew how, and by what means they are performed, and from what Causes those Effects proceed. First, to explain to you the ὅτι, and shew you that so and so it is, and then the διότι, how and why it is so.

This is the true Method of coming to the Knowledge of all the Operations of Nature, and therefore whoever goes the other way to work, and begins *a priori* to this first of the Cause, and then to deduce the Effects from it, as a great *The true Method of acquiring Knowledge.*

great Man has done, or at least would be thought so to have done; begins at the wrong end, and at length when he came to the ultimate and most visible Effects, he found himself, or at least most Men have found it for him, that he was much at a loss and unable to get out, and extricate himself.

The Works of Nature are a great Labyrinth, which is already built and perfected, their ways are determined and bounded by impenetrable Walls; and there are no new Passages to be made, other than what are already fixt: He therefore that shall think immediately to fly and transport himself over these Walls, and set himself in the very middle and inmost Recess of it, and thence think himself able to know all the Meanders and Turnings, and Passages back again to get out; will find himself hugely mistaken and puzled in finding his way out again.

Whereas he, that would march secure, must first find some open and visible Entry, and there enter with his Clew and his Instruments, and take notice of what Turnings and Passages he finds, and see how far he can proceed in this and that way, before he finds a *ne plus ultra*; then setting down and protracting all the ways he has there gone, and what he has there met withal, he must return by the help of his Clew and try another Passage, and do as much there, and so a third and a fourth, and so onward, setting down still and protracting his several Essays; by comparing of all which together, he will at last be able to give you the true Ground-plat of the whole Labyrinth, and thereby to tell you which is the right and which is the wrong way to find the middle or Center: Which is the nearest and which is the fartheſt way about, which is the plainest and easiest, and which the ruggedest and the most difficultest, which the lightest, and which the darkest Passage, and all the Occurences you will meet withal in the ways.

The most of our Philosophers that have hitherto written, have gone the other way to work. They have begun from some inward part of the Labyrinth, having made some small Entrance, and have thence thought they knew the whole Fabrick, and to have found the way out again by the help of their Memories, neglecting or despising the Clew, the Compass, the Circumferenter, and the Chain, whereby to observe Measure, and set down all they observed in their way: And have thereupon feigned a way, and have made to themselves a Labyrinth, and have presently given you a Design of the whole. But alas, this Labyrinth was in their own Mind, and not of Nature's making, and how perfect soever they are in their own Method, they are altogether to seek in that of Nature.

Thus the *Pythagoreans* were puzled with their Numbers; the *Peripateticks* with their Four Elements; the *Epicureans* with their Atoms; the *Chymists* with their three Principles, Salt, Sulphur, Mercury; *Ptolomy* with his Orbs and Epicycles; *Kepler* with his Harmonicks; *Guilbert* with his Magnetisms; not to name many of the Ancients, some whereof would reduce all from Fire, others from Air, and others from Water, some from Heat and Cold, others from Light and Darkness, others from Good and Evil, but all fell short of the true Explication of Nature.

He therefore that would make a thorough Discovery, must begin from the most sensible, obvious and plain Effects of Nature; of these he must make a diligent Inquiry, first what is done, and then as near as may be how 'tis done.

Our present Inquiry therefore being after the Nature of Light: To proceed according to the Method I have now been speaking of to you, we must first inquire and search on the outside of this Labyrinth, and see what Entrances or Inlets there are by which we penetrate into it; that is, we must inquire what are the most obvious and sensible Effects of it: These must be all, if possible, found out, enumerated, and set down. Secondly, Every one of these again must be more strictly examined, determined, and stated, and the Limits set, its *Maximum* and *Minimum* demonstrated; its comparative Likeness and Unlikeness to the Proprieties of other Subjects taken notice of, and recorded; its Congruents or Opponents, or its Promoters or Retarders; its Contraries and Destroyers; and the like must also be examined, and all these must be Methodically Disposed and Registred into fit Tables, that so out of these found Materials

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chosen with Judgment, examined with Strictness, cleansed and fitted with great Sedulity and Reasonings, we may raise a sound and lasting Structure that no Age or right Reason shall overthrow or destroy.

Such are the Fabricks raised by Geometry, thus *Euclid*'s and *Archimede*'s Demonstrations, none since have been able to disprove. This Learning which was said to have been brought first out of *Egypt*, was possibly known before the Pyramids were built, and may last when not a Dust of those massy Piles may be left undevoured by Time; for Truth always was, is, and ever will be the same.

2. To find the Nature of Light we must examine first, what it is in the Luminous Body that is the Fountain, and emits or causes it; Secondly, what it is in the Medium that propagates and conveys it; and Thirdly, what it is in the Eye, or the subject that receives it, and is affected or acted by it. *The Bodies from whence Light proceeds.*

The first thing then I shall take notice of, is of the Bodies from which Light proceeds, as from the Fountains, whence it has its Original and first Spring. Namely, of such as we have no sense that informs us, that 'tis brought into them from any other place, but seems to be there generated and produced.

These Bodies are very many, and very differing in their Constitutions; and therefore the Enumeration of them, and some of their Proprieties may be a great help to us to judge of the Nature of Light.

The greatest and most remarkable of all (at least *quoad nos*) is the most glorious Body of the Sun; which from the glorious, great, and powerful Effects of it upon this World or Earth, on which Mankind is placed, was by the Heathens, *Romans*, *Greeks*, *Persians*, &c. esteemed a God, and so worshipped and adored; but under various Names, as *Jupiter*, *Apollo*, *Phœbus*, *Phaeton*, and several other Names, all of which signified the Sun. As *Juno*, *Venus*, *Cynthia*, *Diana*, &c. signified the Moon. The things observable in this Body, besides its Light, are first, that 'tis the greatest Body we yet know in the World, of whose Magnitude we can have any tolerable Certainty: It being very much bigger than all the Planets together, *viz.* ♄, ♃, ♂, the Earth, ♀, ☿, and their Satellits, *viz.* those of ♄, ♃, and the Earth, and may be possibly bigger than any fixt Star, of which by and by. *The vast Bigness of the Sun and Distance from the Earth.*

The Bigness of it is collected from its Distance, and the Angle, under which it is seen. The Distance is by some of our late Astronomers, who have been more than ordinarily curious in their Observations, judged to be about 10000 Diameters of the Earth distant from us, and the Angle under which it is seen about half a Degree: Its Diameter therefore must be about $\frac{1}{174}$ part of its Distance, and consequently about 87 times bigger than the Diameter of the Earth, its Body therefore being Spherical, as I shall shew by and by, must be 87 times 87 times 87, that is, 658503 times bigger in Bulk than the Body or Globe of the Earth: And therefore the Surface of it, which is the part that gives Light, is 7569 greater than the whole Superficies of the Globe of the Earth. Now almost half this Superficies is seen at once, and therefore that part is near $3784\frac{1}{2}$ times bigger than the whole Superficies of the Earth. Now every part of the whole Superficies of the Sun does shine, and emit Light every way *in Orbem*, which will be probable from this, that a very large Zone of the Sun doth so; and therefore since all parts of the Sun seem to give Light alike, it is more than probable, that every other part of the Sun's Surface doth the same thing. Now before I demonstrate this, I must note to you another Propriety observed in the Body of the Sun, which is necessary for proving both the real Bulk of its Body, and the radiating every way of the Superficial parts of it. It is observed then, that there sometimes happen to be several dark and dusky Spots visible upon its Surface, whose Passage over the Sun have been by Telescopes and other Instruments curiously traced and calculated, by which it plainly appears, 1st, That this Body we see, which appears only as a Plain, is a Globous and Spherical Body; and this because the said Spots are observed to pass over its Face with a Motion proportion to a double Line of Sines, or as they must appear, supposing they were placed upon a Globe appearing under that Angle, and equally turning round upon an *Axis*. This is yet farther confirmed by the Alteration of the Shape of the Spots, when they are nearer the

Limb, and so are posited obliquely from what they appeared in the middle, and so directly faceing us; which Alteration perfectly answers to the Shape of such a Spot, made upon the Face of a Globe, and by turning the Globe, altering the Position of it to the Eye. These tell us further, that this vast Globe makes a Revolution in 25 Days, or thereabouts, upon an Axis obliquely posited to the Ecliptick; whence it is plain, as I noted before, that all parts of the Sun's Surface do shine, for that they are sometime or other seen. 2dly, There being no part of the Sun's Surface lying between the two Tropicks of the Earth upon it, but is sometime or other seen in all the Positions of a Hemisphere, and yet continually seeming as far as we can discover, equally giving Light; it follows, that all those parts at least do emit Rays of Light *in Orbem* the like may with all manner of Probability, be concluded of all the rest.

The Sun subject to Changes and of the Spots seen in it.

The next thing then I shall observe is, that this great Body is subject to as great Changes in its superficial parts, as any that happen to the superficial parts of the Earth, and consequently may have Generations and Corruptions, or Alterations, as do happen here upon the Earth. This is evident by those great Spots which, as I have noted to you, do often appear upon the Face of the Sun, and move along with it.

These are of no certain Figure, nor of any certain Bigness, but sometimes bigger, sometimes less, sometimes more appear, sometimes fewer: Sometimes darker, sometimes dusky, sometimes brighter. Most of the dark have about them a Duskiness at a certain Distance, which does sometimes remain after the dark one be quite wasted, as they are found sometimes before the dark appear. Some of these Spots have been observed to turn into Spots brighter than the rest of the Sun's Surface, but especially when they approach the Limb of the Sun, where also many of the dusky ones appear, and more than usually upon the middle parts of the Sun. Both the dusky, and especially the brighter parts, are observed to stay some of them considerably longer in the Limb of the Sun than they ought to do, according to the Theory of moving upon and along with the *Superficies* of the Globe: But they are never seen to appear without the Limb, but within the edge or in the very edge of the Sun, without making any Protuberance. The brighter Spots are observed to appear brighter towards the Limb, and sometimes to appear in it very bright.

They are observed always to pass over the Face of the Sun, from the East-side towards the West, sometimes in a straight Line, and sometimes in an Ellipsis when they move regularly, but they are also sometimes observed to decline out of those Lines, and swerve sometimes towards the North, and sometimes towards the South, but never to go the contrary way.

Sometimes one of these Spots divides into many, which separate from one another, and sometimes many of them coalesc, and joyn together in one.

From all which Appearances, it is very evident, First, That these Spots are Bodies moved upon, or in some fluid Body somewhat of the Nature of those we have upon the Earth, as to Fluidity, *viz.* Air or Water, though possibly the fluid, may differ from these Earthly Bodies in other Qualities.

Secondly, That these Bodies are either opaque, and so hinder the Light of the Sun to pass through them, or else they are incombustible and dark Bodies, which will afford no Light at all for a certain time, and do as it were quench and deaden that part of the Sun where they rise.

An Account of the Spots in the Sun.

So that though the Face of the Sun be the most glorious and vivid Light that we are sensible of in the World, yet since the Discovery and Use of Perspective Glasses it has been observed, not to be free from some parts that are dusky, and some perfectly dark, and some other parts that are observed to give a brighter Light than even the clear Face of the Sun it self: The former are called *Nebulæ* or Clouds, the second *Maculæ* or Spots, and the third *Faculæ* or Blazes. These have been observed by *Schiner*, *Galileo*, and others, to be generated up and down in various parts of the Sun's Face, and to increase and grow bigger sometimes, and sometimes to grow less, decay and vanish: Their Increase is sometimes from a small Cloudiness, to increase larger and larger, and then in the middle sometimes, and sometimes in various parts of it, to have perfect dark Spots, which also continue to increase sometimes so big as to co-

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ver a part of the Sun equal to all *Europe*, and ſometimes to be bigger than all the Superficies of the Earth, thoſe Spots do ſometimes coaleſs and joyn all into one, and ſometimes divide and ſeparate into divers, and part aſunder conſiderably: And again, at other times many of thoſe Spots which are generated ſeparately, do meet together and make one great one. Theſe appear ſometimes of a dusky Red, ſometimes Yellowiſh, ſometimes of a dusky Blew, and various other Colours; their Shape is very irregular, and ſcarce any two alike, not unlike the upper ſides or edges of the great white Clouds we uſually ſee here in the Summer-time: Yet generally the edges of the *Maculæ* or darkeſt Spots, are very defined, and this Spot is perfectly Black to the very edges; but always about theſe edges to a certain Diſtance, which is much the ſame, be the Spot bigger or leſs there is a dusky bordering, which is likewiſe ſhaped according to the edges of the Spot, and is all of an even Darkneſs or Duskineſs. The *Faculæ* are not defined but uneven, and uſually appear brighteſt towards the middle. The Shape of theſe Spots ſometimes continue much the ſame for ſome Days, but yet ſeldom without ſome Alteration: So that indeed they ſeem to be always in a State of Alteration, but ſometimes quicker ſometimes ſlower. From the Obſervation of them in ſeveral parts of the Sun, it is moſt demonſtrably evident, that they have ſome kind of Thickneſs, but very ſmall in compariſon to their Breadth; for as they approach towards the Limb, they keep their extent toward the North and South, but diminiſh towards the Eaſt and Weſt, in the ſame manner as a broad flat Body would do if variouſly poſited to the Eye: Inſomuch as ſuch as are towards a round appear by degrees to turn to a longer Oval, almoſt all in the edge appear a Line bended circularly, which is an evident Proof that the Motion of them is on a Spherial Surface, and not a plain, for if it were on a plain the Shape of them would receive no other Alteration at the Limb of the Sun than it would at the middle. And from hence alſo we have a good Argument, that the Body of the Sun is a Globe, and not a plain flat round Superficies, as ſome of the ancient Philoſophers are ſaid to have aſſerted it; nor a round Hole bored through the dark Shell of the Univerſe, to let through the Light of the *Cælum Empyreum*, which ſome others of them are ſaid to have aſſerted, ſuppoſing alſo the fixt Stars to be nothing elſe but ſmaller Holes through this dark Shell. But theſe Conceptions as too rude, groſs, and ſavouring of vulgar Conceptions, I paſs over and proceed to obſerve to you further, that theſe Spots of the Sun are obſerved to move generally all from Eaſt to Weſt, and over the Face of the Sun, ſometimes coming in at the Eaſt Limb, and in 12, 13, 14, or 15 Days to move to the Weſt Limb, and to perform this Motion regularly for the moſt part, according to an order of Sins, the Radius of the Sun being for the Radius, and the Order beginning from the Center, which is another Demonſtration that their Motion is on the *Superficies* of a Sphere, and that they move on it almoſt equal Spaces in equal times, I ſay almoſt equal; becauſe they have a kind of Motion of their own, whereby they are ſometimes as it were promoted and ſometimes hindered, ſometimes carried a little towards the North, and ſometimes a little towards the South. This Motion of theirs from Eaſt to Weſt, over the Face of the Sun, ſometimes appears to us to be made in a ſtraight Line, which happens when the Earth is in that part of the plain of the Ecliptick, which cuts the Plain of the Equinoctial of the Sun's turbinated Motion, which is twice a Year, *viz.* in the beginning of *June* and *December*: At other times the Line of the Motion of them is incurvated and bent into an Ellipſe, which is greateſt when the Earth happens to be in thoſe parts of the Ecliptick, which are the extream Limits of it, compar'd to the Plain of the Sun's Equinoctial, which is alſo twice a Year, *viz.* in the middle, between the Nodes, both Plains paſſing through the Center of the Sun, that is, about the beginning of *March* and *September*. From whence alſo is deduced another undeniable Demonſtration, that the Sun's *Superficies* is Globular, and that it moves round upon its *Axis* from Weſt to Eaſt, as the Earth and *Jupiter* alſo are proved to do. And another Remark is likewiſe evidenced, that this *Axis* of the Sun's turbinated Motion, remains fixt and directed toward the ſame parts of the Heavens. In the ſame manner as the *Axis* of the Earth is obſerved to do, and likewiſe the *Axis* of ♃ and ♄, ſo far as we can yet diſcover by the Spots, Ring, and the Satellits of

those Bodies. So that the Method of Nature in most things agrees both in our and other Globous Bodies of the Universe. There is yet one Observation more concerning these Spots, which further confirms this Deduction, and that is that there is a certain torrid Zone, as I may call it from its Similitude to the torrid Zone of the Earth, *viz.* a certain Space or Breadth on each side of the Æquator of the Sun towards the North and South Poles, in which these Clouds, Smokes, Blazes, or Spots are observed to appear most: Whereas without those Limits, or in the two temperate Zones, they appear more seldom, and those which do are only *Nebulæ* or Clouds; but in the two Polar Zones there appear none at all.

How great a Similitude there appears in this with the Globe of the Earth, I need not now insist on, only I shall make this Remark by the by from this Similitude, that though all that have hitherto spoken concerning this Subject, have concluded that the time of the Revolution of the Sun's Body upon its *Axis*, is to be deduced from the Revolution of some Spots that have lasted more than quite round the Body of the Sun, and come to the same Place again, in which they were 29 Days before or thereabouts. I must upon this occasion, I say, remark that here upon the Earth, between and near the Tropicks, we always have a continual Brieze of Air, which moves from East to West; which upon very good Reason is concluded by *Galileo*, and most of our Modern Naturalists, to proceed from the Earths moving from West to East, and so leaving the Air behind, which lagging of the Air is yet much more considerably felt and perceived in the higher Parts of it by the Clouds, and by the Passage of it over the tops of high Hills. So that if these Spots be Clouds or Smoke, or somewhat Analogous to them, rais'd into the Air, Atmosphere, or some Fluid Analogous to the Earth's Atmosphere, as I shall observe by and by, then may the Motion of the solid Globe of the Sun be considerably swifter than those Clouds appear to be carried, and instead of being 25 Days, possibly may make a Revolution in 20 Days or sooner.

These Particulars I have here mentioned, I could have more largely demonstrated to you by Schemes and Figures, whereby every Particular I have asserted of this Matter might have been more fully shewn and explained. But I do rather avoid it; First, because in Demonstrations of that kind very few Auditors are able to go along with the Description and Quotations of Lines and Letters in the Schemes; and Secondly, because it spends more time with much less Advantage to the Auditory.

The Suns Rays carry Heat as well as Light.

3. I shall then in the next Place remark to you, That the Rays of the Sun are observed to carry with them Heat, or to produce it in the Bodies upon which they fall, especially if they be collected by the help of a reflecting or a refracting Burning glass: Insomuch that by those means it is easy to set Bodies into an actual Flame and Fire; nay, not only to set Bodies on fire and consume them, but even to melt the most stubborn Bodies. Insomuch that none of the Metals, as Tin, Lead, Silver, Brass, Copper, Iron, Gold, are able to indure it without being in a Moment almost melted, and nor only these, but Stones, Clay, Flints, Bricks, and almost all other Bodies that will not burn, will by the Power of the Sun's Rays, collected with a Burning-glass, be melted and turned into Glass to Admiration. Nay, 'tis possible by this means to augment the Heat to almost any assigned Degree, and possibly some hundreds times more than 'tis possible to perform by all the Artificial Fires that can be made with any combustible Materials we yet know: Of which Effects, and the Causes and Proprieties thereof, more hereafter. Now after all this, there have not been wanting divers Men who would needs perswade us, that notwithstanding all these Observations the Body of the Sea has no Heat, nor have the Rays themselves, but that they produce Heat and Fire only by agitating the Body upon which they fall, and are reflected; and this is the Reason (say they) why the upper Parts of the Air are so very cold, and the under Parts next the Ground are so very hot, for the Rays of the Sun, say they, being in themselves perfectly cold in passing thorough the upper Air; and being not reflected, they cause no Agitation or Heat, but being reflected from the Earth in the under Parts of the Air, the cross Agitation causeth the Parts of the Air to beat one

against

against another, and this causeth Heat much in the same manner as a Flint and Steel being struck one against another, though neither of them be hot before they meet together; yet when they meet, produce both Heat, Fire, and Light, though there were no sensible Signs of any of these before, and so a piece of cold Iron may by being hammer'd on a cold Anvil with a cold Hammer, very nimbly and stongly, be not only heated so as to burn ones Fingers, and to fire Gunpowder, but to be visibly red hot: So that though the Hammer and the Anvil were both in themselves devoid of Heat, yet their Motion does produce it on the Iron. To this it may be answered, that as to the Warmth of the Air at the bottom, and the Coldness at the top of the Mountains, or high Towers, the reason is plain from this, that the Air near the Earth is warmed by the Heat of the Earth, and being not so swiftly moved and changed for cold Air, as that which is at the tops of Mountains, or of very high Towers, which is also further removed from the warm Surface of the Earth: But that the Rays of the Sun will do the same thing as to burning of any Body by the help of a refracting burning Glass at the top of a Hill or Tower, there is no manner of reason to doubt. 'Tis, I think, sufficiently evident to all the World, that Heat is convey'd by the Sun Beams as well as Light, and that those Beams both of Light and Heat are emitted by the Sun, and therefore we have no more reason to believe, that the Sun has no Light than that it has no Heat.

Why the upper Air is colder.

4. All these Circumstances consider'd, it seems very reasonable to conclude, that the Superficies of this great Body of the Sun is incompassed with an Air or Atmosphere, or some other fluid Body or Menstruum, even as this Body of the Earth; and that this Atmosphere, though possibly 80 times thicker than the Thickness and Height of the Atmosphere about the Earth, yet compared to the Vastness of the Diameter of the Body, it becomes wholly invisible to us, though assisted with our best Telescopes: And besides, 'tis not to be doubted, but that being very near the Body, and having reflective Parts in it, it must of it self look as bright as the very Body it self, and consequently that the Limb thereof which appears to us is really the Shell of the Atmosphere, Air, or fluid Menstruum about the Sun, and not the very solid Body it self that shines. Hence all the Phænomena of the *Maculæ* and *Faculæ* of the Sun observed will be solved, and these Spots of the Sun will be no other than our Clouds or Smokes, which rise into the Atmosphere; this I say, will plainly make out all their Appearances to be much the same as those of Clouds are here with us: For 'tis not to be doubted, but that we have sometimes Clouds big enough to hinder the Sun from shining upon as great a part of the Earth's Surface, as those Clouds of the Sun do hinder us from seeing of the Sun's Surface.

That the Sun has an Atmosphere, or something like it.

Hence 'twill be easy to know why they sometimes move a little Northwards, and sometimes a little Southwards, but still follow the general Course of the Sun's Body, why the black Spots generally vary their Shape, regularly as on a Spherical Surface, but that the bright ones do not, but seem to grow otherwise; why the bright ones appear most near the Limb of the Sun, and not so often in the middle; namely, where we come to see the Light reflected from the under sides of the Spot, or Cloud: This gives a clear reason why they stay so long about the Limb, and why they grow bigger, whereas the dark grow less and sooner vanish. And in short, there is no Observation of these Spots in the Face of the Sun that I have ever yet made my self or seen of others, but will hereby be clearly made out.

So that upon all that has been thus far said concerning the Body of the Sun, it plainly appears, that it agrees with the Terraqueo-Aerial Globe in divers of its Proprieties, and I shall another time prove to you several other Particulars, by which it will plainly appear, that they perfectly agree in most other Proprieties except Light, and wherein that difference consists I shall likewise show.

The Sun in most Proprieties agrees with the Earth except that of Light.

I am the more particular (upon this occasion) in my Description of the Sun, because as it is the very Fountain of all visible Light, and the most considerable Body in the World: So the Proprieties of this being explain'd, it will the more clearly discover to us what are the most considerable Proprieties of Light in

other Luminous Bodies, and thence we may be able fully to explain this Subject, which is the most operative and most considerable Ingredient of the Universe.

There must be a fluid Body encompassing a more solid in the Sun, with more concerning the Spots.

5. Having thus shewn you that it is necessary there must be a fluid Body incompassing the solid Body of the Sun, for otherwise those irregular Motions of the Spots cannot be made out, and with the supposal of it, may be made out and explained very rationally, I shall now more particularly shew you the Reasons thereof. All that have hitherto made accurate Observations concerning these Spots in the Sun, amongst which, I think, none has been more diligent and curious than the Learned and Ingenious Jesuite *Shinar*, in his *Rosa Ursina*, that the *Phænomena* of the *Maculæ*, *Nebulæ* and *Faculæ*, are much what I have already given you an account of: And though there be one or two who from some superficial and slight Observations, and from much of Fantcy have pretended some other Motions of these Spots, and would thence conclude, that they are not Clouds but some smaller Planets, so near the Body of the Sun, as that they can never be seen, but when they are in their Perigean Conjunctions, and so come between the Sun and our Eye; yet since they are disallowed of by the most diligent and curious Inquirers into these Matters, and since I could never meet with any such my self, I have good reason to suspend my Assent to their Conclusion, till by manifest Observations it shall be made out to the contrary. Certain it is, that the Bodies of *Venus* and *Mercury* when they have appeared in the Face of the Sun, have been very differing in their form from those of the usual Spots: For First, they appear round, which few or none of these Spots are observed to do. Secondly, They have not been observed to have any *Nebulæ* about them, which all the Spots that ever I have seen have always had. And Thirdly, Their Motions have been so swift as to pass over the whole Face of the Sun in a very short time, as in some few Hours; whereas these Spots are at least 12 days, and sometimes longer. Fourthly, They are observed to pass over in a straight Line, whereas these are very often observed to pass in an Ellipse, *quam proxime*, and but twice a Year in a straight Line. Fifthly, They pass over the Sun with an equal swiftness as to Sense, whereas these pass with very unequal, as I noted to you before, and according to the Proportions of Sins. Sixthly, They make no stay in the Limb, which these Spots oft-times are observed to do. It plainly follows therefore, that these Spots are very near the Surface of the Sun, if not upon it.

I do not deny but that it is possible there may be the Bodies of other Planets about the Sun, nearer than that of ☿, which by reason of their nearness to its Body, may never appear but only at such time as they happen to be observed whilst they pass under the Sun: But I never yet met with any certain Observation from which I saw a necessity for making such a Conclusion; for the Possibility thereof is no ways a sufficient Argument for its Necessity, or so much as a Probability; for all the Observations that have been made of these Spots at the Limb make their stay rather longer than shorter than they ought to do, supposing them upon the very Superficies of the Sun, and therefore they are so far from being without the shining and bright Limb of the Sun, that 'tis manifest that they are within it, that is, within the Superficies of the Atmosphere that incompasses the Body of the Sun.

Now the supposing of such an Atmosphere or fluid Body to incompass the solid Body of the Sun (for there is as great a necessity of a solid Body of the Sun as there is of a fluid about it to make out the reason and cause of divers other Proprieties of it, as I shall afterwards shew) will plainly and intelligibly make out all the *Phænomena* of the Spots, and make it almost demonstrable that these *Maculæ*, *Nebulæ* and *Faculæ* of the Body of the Sun, are much of the Nature of the Meteors raised up into our Atmosphere from the Earth, and, as I shall by and by make appear, will plainly shew unto us from what cause the Light of the Body proceeds. I have mentioned to you already, that the Spots are observed to stay considerably longer in the Limb of the Sun than they ought, according to the Rule of moving upon the Superficies of an opacous Globe, for it has been found that they appear, when according to that Rule they should disappear; it follows therefore, that either they must lose their

Regularity

Regularity when they come to the apparent Limb of the Sun *quoad nos*, or elſe that the edge of the Limb is *aliquatenus* tranſparent; for the former there can be no imaginary Reaſon, there being no difference in that part of the Superficies of the Sun from any other; becauſe every part of the Sun ſucceſſively is in the Limb, and Spots ariſe promiſcuouſly in any Part of its middle Zone: It muſt therefore of neceſſity be from the Tranſparency of ſome ſmall Shell, about the ſolid ſhining Body, and therefore probably of an Atmoſphere. But ſecondly, 'Tis manifeſt that this Atmoſphere is moved much as our Atmoſphere is; for by many Obſervations it has been certainly found, that theſe Spots which riſe in the middle Zone of the Sun have been obſerved to be longer in paſſing over the Sun's Disk, than thoſe which happened in the Intermediate, which perfectly agrees with the Motion of the Atmoſphere about the Earth, for the Air between and near the Tropicks is obſerved to lag and fall more behind the Motion of the Earth than the Air in the temperate Zones; for in the Torrid Zone the Air or Wind almoſt continually ſeems to blow from the Eaſt, or from ſome Point of it, which is generally now concluded to proceed from that Cauſe, I ſay for the moſt part from the Eaſt, or ſome Point of it, as Eaſt South-Eaſt, or South-Eaſt, Eaſt-North-Eaſt or North-Eaſt, or the like, which explains alſo why thoſe Spots of the Sun are obſerved to move ſometimes toward the North-Weſt, and ſometimes towards the South-Weſt: But then thoſe in the intermediate Zones follow the Courſe of the Sun's Body more eaſily, as with us, where the Winds ſometimes blow from the Weſtwards, and ſeem to be moved faſter than the Earth it ſelf.

That the Sun is a ſolid and opacous Body.

6. Having therefore as far as the thing is capable of Demonſtration ſhew'd, that the Superficies of the Sun is fluid and ſomewhat tranſparent, and has Motions in it analogous and very like to the Motions of our Atmoſphere: I come in the next place to obſerve to you, that the Body of the Sun it ſelf within this Shell is a ſolid Body and opacous. Its Solidity I prove from three Proprieties here obſervable, and thoſe are Firſt, the Conſtancy of its Rotation; Secondly, The Fixtneſs of its Axis; And thirdly, the Power of its Gravitation or Attraction to its Center. Firſt, I ſay, from the Conſtancy of its Rotation; this is an Argument ſo plain, as nothing can be more, for we need go no further than the Earth on which we tread, whoſe Rotation we find very certain and conſtant, and none can yet prove but that it is always equal and uniform; in that Motion whereas we ſee the fluid Bodies about it, as the Air, nothing is more uncertain and unconſtant than them, nay though it be guided by the Superficies of the Earth, nay the very Water which is contain'd in the Capacity of the Earth, and ſo has much more reaſon to move round, than if all fluid: Yet we ſee that this has great Varieties of Currents, Ebbings and Flowings, and the like; eſpecially in the great Ocean, though it be leſs in Seas incloſed, the ſame we ſhall find if we make tryal with Water in a Diſh, or Water about a Diſh, and the like, which will preſently confound a circular Motion that ſhall be impreſs'd upon it, and ſo muſt quickly ſtand ſtill, whereas we find it quite otherwiſe, and to continue the ſame as it was firſt obſerved to do.

Why ſolid.

But then ſecondly, by reaſon of the Fixedneſs of the Axis of its Revolution, this is a ſtronger Argument than the former for its Solidity; for there is no body that we yet know that is fluid, has any ſuch Propriety as Magnetiſm or Direction, and all that have a Magnetiſm are ſolid as the Earth, ♄, ♃, and the Moon, the Magnet and Steel; nay, Steel being either melted or diſſolved in *Aqua Fortis*, and ſo made fluid loſeth its Virtue [And Iron heated red hot does no more attract till cold, as having ſomewhat of Fluidity] and if it would loſe the Regularity of its turbinated Motion, then certainly much rather would it loſe the Direction of its Axis, if it were not a Solid: It follows therefore that ſince 'tis evident from Obſervation, that this Axis keeps its Poſition and Direction, therefore that the Body of the Sun muſt be a ſolid and not a fluid Body. The third Argument drawn from its attractive or gravitating Power, to prove its Solidity, I cannot here ſtay to inſiſt upon the Explication of, becauſe the reaſon thereof cannot ſo plainly appear without the Explication of a whole Theory of Gravity, which will come in more properly under another Head, and therefore I can only tell you, that the Explication of the

Cauſe

Cause of Gravity will clearly prove that the Body that has Gravitation strictly so called, must have also Solidity. Now that it has such an Attraction or Gravitation, I shall prove first from its Spherical Figure; 2dly, From the Motion of these Spots; and 3dly, From the Motions of all the other primary Planets, whose Motions as I have many Years since shewed in this Place, are all influenced and modulated by the attractive Power of this great Body. This also as the former, I must for the present refer to that Head to be more fully explained and demonstrated, and only name it at present.

Why Opaque. In the next place, that the Body within the Atmosphere or transparent Shell, is opacous, I argue from the disappearing of the Spots in the Limb, and their not returning backwards as they would seem to do if the Body were transparent as the Atmosphere is, or the Flame of a Candle, or the Radiations, or hazy Light about the Nucleus of a Comet, through which as through its Beard, I have seen small fixt Stars.

Eight Particulars in which the Sun and Earth agree. Three wherein they differ. 7. We find then, that thus far the Proprieties of the Body of the Sun do seem to agree with the Proprieties of the Body of the Earth: As first, in its Globular Figure; 2dly, In its Rotation; 3dly, In its Gravity; 4thly, In its Polar Directions; 5thly, In its Atmosphere; 6thly, In the Motions of that Atmosphere; 7thly, In attracting Planetary Bodies; 8thly, In the Fixtness of its Axis or Polarity, *&c.*

But then in the next Place they differ, first in Magnitude, the comparative Quantities of each I shew'd you before. 2dly, In the Make of the Surface, that of the Earth being rugged and unequal, but that of the Sun as far as yet can be discovered, very equal and smooth. 3dly, In their Qualities, the Sun's Surface being both hot and light, and that of the Earth dark and cold; that therefore which would afford these Proprieties to the Body of the Earth would make the Earth on which we tread a Sun. These two Proprieties then we find Fire to supply, if therefore the Surface of the Earth were made and compounded of Nitrous and Sulphureous Particles, or such like combustible Substances, and that they were once set on fire, I see no reason why the Earth should not be in all respects the same to the Moon as the Sun is to the Earth: Nor is there any reason why all the other Proprieties of the Earth that it now hath, excepting those of Coldness and Opacity, should not remain much the same. If therefore we further suppose (I say suppose for I do not now intend in this Place to prove that 'tis really and positively so, and not otherwise, though I shall afterwards from other Arguments demonstrably prove it) that the solid Body of the Sun is made or compounded of such Materials as will really work one upon another, and dissolve or burn each other, as we find Sulphur and Nitre do, or any Sulphureous Body, and the Air when rightly joyned. From this Hypothesis, I say, for I will not presume to call it more at present, I conceive all the Phænomena of the Sun will be made very easily intelligible, and be shew'd to be perfectly consonant with the other Processes of Nature, which is a very probable Argument at least that really it is even so done and not otherwise.

The Phænomena of the Sun explained. 1. First then I say, supposing the Superficies of a Body as big as the Sun to consist of such Materials as would really work upon each other, and consequently burn, as violently as some Materials which are here upon the Earth would do if once set on Fire, I say the Surface of such a Body at such a Distance so burning, must give to the Earth a very considerable Light and Heat.

First for Light, It is evident by Experiment that Nitre and Sulphur burning each other, make a very bright Light; insomuch, that few Eyes can indure to look upon it, and is as intolerable almost as the Light of the Sun. Now 'tis very probable, that the Materials that maintain the Fire of the Sun are yet much more adapted for that purpose, and therefore that this Light and Heat may much exceed it, but still this doth not make the Action of it differ, nor make it really differ in *Specie* from a Fire made with Earthy Materials but only in degrees, and therefore still supposing the whole Superficies of the Sun to afford as much Light in every visible part of it, as these Bodies so burning do, according to the Bigness of their Surface; it must necessarily very strongly affect the

Earth.

Earth, though placed at this Diſtance; for all Light in the firſt place propagates *in infinitum* in an Inſtant. Now the *Medium* between the Sun and us being perfectly tranſparent, and ſo nothing of the Light being loſt but only rarify'd, it follows, that we muſt receive the ſame Proportion of the Light of ſuch a Body as we do now of the Light of the Body of the Sun as now it is: So that thence the only Difference muſt conſiſt in the Proportion of the Light of the Bodies; that is, whether the Light of any one part of the Sun equal to an Artificial Fire ſo made, be any thing brighter: For if they be equal, as 'tis very poſſible they may, then the ſame Effects will follow. Now the Queſtion will be, how ſhall this be proved or tried, whether this be ſo or not? We cannot go to the Sun, nor fetch Fire from Heaven, as *Prometheus* is ſaid to have done: Nor can we ſet or remove our Fire ſo far diſtant from us, as to make an equal Compariſon of the one with the other. I grant it, we cannot; but yet Art may help us to a way, by which we may be able to aſcend thither by Reaſon, and be as much aſſured of it as if we actually did it: And that is, by knowing in what Proportion the Quantity of Light does diminiſh, according to the diſtance it is propagated from the Luminous Body; for by that means, we may meaſure *Hercules* by his Foot, from exact Obſervations made of the Power of Luminous Bodies in propagating Light here with us, we may calculate the Power of Luminous Bodies, though never ſo far diſtant. Light then, as I formerly hinted, doth decreaſe in Duplicate Proportion to its diſtance of Propagation from the Luminous Body, that is in the ſame Proportion with the Superficies of the Spheres of Diſtance.

The Proportion of the Diminution of Light. Fig. 4. Plate 1.

For ſuppoſe A the Luminous Point, that emits a Quantity of Light to fill the Space A B B; this Light in the next Space fills B B c c, then c c d d, then d d E E: And at E E it is arrived at twice the Diſtance of B B from A. The Power therefore of this Ray of Light which at B B was all contained within the circular Baſe of the Cone A B B, is by that it acts at the Diſtance E E expanded into the circular Baſe of the Cone A E E; Namely, into the Circle E E, which Circle being twice the Bigneſs of B B in Diameter, muſt have its Area Quadruple to the Area of B B. And ſo of F F, which is at treble the Diſtance, the Area of the circular Baſe of the Cone A F F will be Nine times the Area of B B, and ſo onward the Areas increaſe in a Duplicate Proportion of the Diſtance of them, from the Apex of the Cone, or which is the ſame from the Luminous Point A.

The Power therefore of Light thus propagated will be diminiſhed or rarified, ſo that at twice the Diſtance it will have but a Quarter of the Power at thrice the Diſtance, but one Ninth at Four times the Diſtance, but $\frac{1}{16}$ at five times the Diſtance, but $\frac{1}{25}$ part of the Power which it had at one Space of Diſtance: And conſequently the Proportion of the Power of Light at any one Diſtance, to the Power of the Light at any other Diſtance, will be reciprocally Duplicate to the reſpective Diſtances, as the Power of Light at five Spaces Diſtance to that at ſix Spaces Diſtance, will be as $\frac{1}{25}$ to $\frac{1}{36}$, that is as 36 to 25; for as $\frac{1}{25}$, $\frac{1}{36}$: : 36. 25. which are the Squares of the Diſtances reciprocally taken. This, I ſay, is the Expanſion of Light according to the various Diſtances of its Action from the Luminous Body, and according to this Rule all Light is found to act and diminiſh its Power in Proportion to its greater Diſtance. So that the Power of any Artificial Light, as Fire, Flame, *&c.* being found at any meaſurable Diſtance, the Power of it may be eaſily found for any aſſignable Diſtance be it never ſo great: And on the contrary, the Power of Natural Light, as that of the Sun, Moon, Planet, or Stars, being found by Experiment at an aſſigned Diſtance, though never ſo great, the Power of it may be found by Calculation at any aſſigned Diſtance, though never ſo near, and conſequently we have a means of truly calculating the comparative Power of Natural and Artificial Lights from Experiments made on each of them. But then ſecondly, We have another thing to be taken notice of in our Calculation, to make the Compariſon compleat and exact, and that is of the Area of the Luminous Body, for 'tis not enough to calculate the Power of one

Point only, but the Power of an Aggregate of them muſt alſo be taken notice of. And this is of the Cone inverted, and turned the other way, where the Apex of the Cone is the Eye, or the Point of the Subject inlightned, and the Baſe is in the Luminous Body, as the Disk of the Sun, and this by ſuppoſing the Ray in all Degrees of Diſtance equally ſtrong, does diminiſh the Power of inlightning in Proportion to the viſible Angle, under which it appears at greater or greater Diſtances. This therefore will alſo be in Duplicate Proportion to the Diſtance reciprocally taken; for the Area of Light muſt ſubtend equal Angles or Cones to make an equal Light, and therefore at double Diſtance there muſt be Four times the Area of Light to make the ſame Effect, and at treble Diſtance Nine times the Light, and at Quadruple Diſtance Sixteen times the Luminous Area to produce the ſame Effect upon the Subject. A circular Area therefore of as bright a Light, or ſhining Body as the Sun, being placed at ſuch a Diſtance as that it may appear under much ſame Conical Angle as the Sun doth, *viz.* of ½ a Degree, muſt give as Light to the Subject as the Sun it ſelf.

From theſe two Conſiderations, 'twill be eaſy to calculate the comparative Power of naturally Luminous Bodies to the Power of ſuch as are artificially, or to compare the Light of the Sun with the Light of Coles, Flame, *&c.* and to ſee their Differences.

The Light from the Sun caused by an actual Fire.

From which I queſtion not, but that there may be very cogent Arguments drawn to prove, that the Light of this Body of the Sun may be cauſed by an actual Fire, or Diſſolution of the ſuperficial Parts thereof; partly by the Atmoſphere or Air incompaſſing it, and partly alſo by the Conſtituents of it mixed together into one Maſs, which have Analogy with our Sulphur and Nitre, which do work upon and burn each other, and ſo the Sun will be found to be a vaſt Globular Body, whoſe whole Superficies is in a continual Diſſolution or Fire; partly by the working of its conſtituent Parts one upon another, and partly alſo by the Aſſiſtance of the Atmoſphere, Air, or Fluid Body, incompaſſing it. And thence we may deduce, that the Phyſical or Natural Cauſe of its Light, is the actual Fire or burning of its ſuperficial Parts; which being proved, or ſuppoſed ſo, all the Appearances that have been hitherto taken notice of concerning Clouds, Spots, and Blazes, will be very naturally and clearly ſolved; and there is no one Obſervation I have yet made, or met with in other Authors, that do any way ſeem to croſs or thwart it. Matters of Fact none can deny, that ſuch Changes and Alterations do happen, and I conceive it will be as eaſily granted, that they have their Natural Cauſes. And therefore that which doth with moſt likelihood ſolve them, is at leaſt the moſt probable Cauſe.

An Objection anſwered.

But ſome may object and ſay, that if this were ſo, certainly the Body of the Sun in ſo many Thouſand Years would have been all conſumed, at leaſt would have grown ſenſibly leſs. Suppoſe this were granted and ſaid, that it has grown ſome Minutes leſs ſince it firſt began to give Light, none could contradict it by any Obſervations we have upon Record; for we have no Aſtronomical Obſervations of that kind 2000 Years at leaſt, that could evidence the contrary. But ſuppoſing we had Obſervations of 4000 Years ſtanding, and that they had found the Diameter of the Sun to be as many Minutes as 'tis now, yet that would have been no Argument but that the Sun might have every Year been a Mile leſs in Diameter than it was the preceding Year, and conſequently been 4000 Miles leſs in Diameter than it was 4000 Years ago. No Obſervation never ſo carefully made, either then or now, could have contradricted it: For if the Sun's Diameter be near 87 times bigger than the Diameter of the Earth, and the Earths Diameter be near 8000 Miles, the Diameter of the Sun muſt be near 696000 Miles, and 4000 is but a 174 part of the Diameter, and conſequently could have diminiſht it but about ¼ of a Minute, which is a much leſs Quantity than the Ancients pretended to obſerve to. But ſuppoſing they could have obſerved even to Seconds, yet that could

could not have contradicted it, since as I shall upon occasion shew a Reason, why the Sun may have approacht as much as to recompence that Defect. But I have not now time to explain it: And shall only add, that this being so, it will thence very rationally follow, that the Stars also being very probably Bodies in most Proprieties the same with the Sun, will be Bodies also whose Superficies do actually burn consonant to which the Observation of the Noble *Tycho*, and others of the Stars that appear'd in *Cassiopeia*, in the Year 1572 will be judged to be all fir'd together, and so quite burnt out in one Year; for it lasted no longer, and did never appear before, nor has since that I can hear of. Consonant to this Theory, will be the Appearances of Comets, of which kind I this Week observed one in the Sign of *Scorpio*. But of this Matter I have elsewhere discoursed somewhat already, and shall add more hereafter upon another Opportunity, when I come to explain what the Cause of Light is in Fire, and other Luminous Bodies here below within our reach; the Explanation of which will manifestly demonstrate to us what 'tis in all other Bodies whatsoever that are out of our Reach.

SECT.

SECT. III.

Containing the Lectures read in January *and* February, 168$\frac{0}{1}$. *being a Continuation of the same Subject of Light.*

The CONTENTS.

1. *Light the most admirable Effect of Nature, one of the principal Powers by which every part of the great Existence of Material Beings is united and made one. The Infiniteness or Indefiniteness of the active Power of Light already explained; the smaller the Stars appear, the greater is their Distance; the reason why some before invisible are made visible by Telescopes, because few Eyes can be affected by any Object under a less Angle than a Minute; thence several small Stars coalesce into one, and why some of the fixt Stars, though less than a Minute, as but of a second, are yet visible; an Objection against the use of Telescopes in Astronomical Observations answered, and why the Stars appear less through a Telescope than to the naked Eye.* 2. *An Explication and Confirmation of* Des Cartes *Hypothesis of Vision, and that the fixt Stars are really at different Distances, though they may be also of different Magnitudes, a farther Reason that the Propagation of Light must be instantaneous.* 3. *The innate Light of all Celestial Luminous Bodies proceeds from an actual and real Fire something like that on the Earth, though not altogether the same, the Fuel being possibly different.* 4. *By this the Subject of the Inquiry is brought nearer,* viz. *on combustible Substances, whereon we may exercise our Scrutinies with more Power, to find the Cause of Light and Fire, and by Analogy, what it is in the Sun: Which therefore is to be the Subject of future Discourses.* 5. *Of the Nature of Comets, which are another sort of Celestial Fire, which ought to be examined before the treating of Terrestrial and Culinary Fires, and whose Light is different from that of the Sun, Stars or Planets, their different Appearances have caused great difference in Writers of them. The three Opinions mention'd by* Seneca *in his Natural Questions enumerated, with those of other Ancient and Modern Philosophers.*

Light the most admirable Effect in Nature.

1. I Began the last Term to explain to you several of the Proprieties of Light, as being one of the most admirable Effects of Nature which are subjected to our Senses, and consequently to our Speculation and Contemplation, as being one of the first and principal of the Powers of the great System of the World, by which the whole is united and made one; and every one part of that unconceivably great Existence of Material Beings is affected by every other, which may thence not improperly be called one Body, or the only Material or Corporeal Being, distinct from which no other Corporeal being is.

This

This by *Moses*, in the History of the Creation, is comprehended under the double Name of Heaven and Earth, denoting both, one material Being; but considered in its parts, Namely, fluid and solid Matter. After the Creation of which God said, Let there be Light and there was Light, so that the first active Power was Light.

Some of the Proprieties of this active Power I have already explained: Namely, first its indefinite Extension to every part of the whole of Matter, which because our Imagination can set no Bounds or Limits to; I therefore call infinite or indefinite, not as supposing it to be really so, but for that, as our Senses inform us of no such Bound, so neither can our Imagination fix the *ne plus ultra*, beyond which no Material Being can exist. For wherever we put it, we presently suppose Space and Extension beyond it, and that at least if it be not Body, as *Des Cartes* would have it; yet it has the inseparable Propriety of Body and Matter, namely, Extension: And no one has yet told us, what Body is distinct from Extension, or what is the true Essence of Body or Material Being, besides Extension; and 'tis as easy to conceive indefinite Body, as indefinite Extension. Nor indeed can Extension be well conceived without the Notion of Body, no more than Body can without the Notion of Extension: for Extension is nothing but the abstracted Notion of somewhat extended: And therefore if there be Extension, there must be somewhat extended. Now if it be not the Propriety of Spirits, as all Divines and Philosophers conclude, but only of Body, then wherever there is Extension, there is really a Body extended; and therefore since our Imagination can never limit Extension, so neither can they set Bounds to Matter or Material Being.

Now I told you, that our Eyes assisted by the help of Glasses inform us that Light is propagated or communicated to us from utmost inconceivable Distances, at least if we believe, the vast Distances the Stars are placed from us, and that the smaller the Stars are the greater is their Distance: For still the longer and better our Telescopes are the more are there discovered of small Stars which were before, and without that Help invisible; not for that they did not affect the Eye with Light without, as well as with the help of the Telescope, but because the Power of the Eye is limited to a certain Magnitude of Appearance, under which nothing can be distinctly perceived: Whatsoever Object therefore affects the Eye under a less Angle than that Eye can distinguish, becomes invisible or not seen. Now whereas most Eyes distinguish not a less Angle than a Minute, or the 60th part of a Degree, or the 21600 part of a Circle, therefore whatever is sensated or seen by it, is seen of that Bigness or under that Angle: And so if there be 2 or 3, or 10 or 100 small Stars so near together as that they are all comprised within the Angle of one Minute, the Eye has a Sensation of them all, as if they were one Star, and distinguishes them not one from another; so likewise is it, that if the Light be strong and powerful so as to affect the Eye, it always appears of the Bigness of a Minute, though possibly its real Angle be not a second. Thence every Star that such an Eye discovers, appears to be of the Bigness of a Minute at least, and so it is conceived really to be, though yet when we come to examine its Diameter by the help of Telescopes, we really find it to be but some few seconds or sixtieth Parts of such an Angle; and hence it is, that it is told as a very great Wonder, and is indeed as a great Argument objected against the Use of Telescopes, that there can be no Truth in the Discoveries made by them: For that though they are found to magnify and increase the Appearance of all other Objects except the Stars; yet when they are viewed through them they appear to be rather lessened than increased in Bulk, whence they conclude of that Instrument that does sometimes magnify and sometimes not, and indeed both at the same time (as when one looks on two Stars 10 Minutes distant from each other, their Distance is really augmented though their apparent Diameters seem not to be at all) they conclude, I say, that all the Appearances through such an Instrument are uncertain and imperfect, and real Misinformations, and consequently nothing but Phantomes and false Representations; and this Consideration or indeed Inconsideration hath been the occasion why several otherwise very ingenious and knowing Men have been prejudiced against the making use of Telescopes, and other Optick Glasses, for the Discovery of Nature, for not

knowing how to anſwer to themſelves theſe and ſome ſuch other Objections as eaſily anſwerable, if well conſidered, they have fallen into a Disbelief of the whole Information theſe Helps afford us; and will therefore in all Obſervations on which they build any thing; only make uſe of the naked Eye: Whereas had they made uſe of theſe Helps, they would have been able to have made much greater Advances in their Diſcoveries and Obſervations.

An Objection againſt the uſe of Teleſcopes anſwered.

To anſwer this Objection therefore againſt the Truth of the Diſcoveries of Teleſcopes, and thoſe of Microſcopes, I ſay, that theſe Inſtruments do equally magnify the real Angle, under which any Object appears to the naked Eye, and ſo doe equally magnify the real Angle of the Stars, as well as of any other Object, and that the Fallacy lies in the Eye and not in the Inſtrument: For as I ſaid, ſuch is the make of the ſenſible part of the Eye, *viz.* of the *Tunica Retina*, that it cannot diſtinguiſh in moſt Eyes an Angle leſs than a Minute (though there be ſome that can to the third of a Minute, but theſe are very few) whence if there be any ſtrong ſhining Object that does very powerfully operate on the Eye, ſo as to create a Senſation, and yet does really act under an Angle only of ſome few ſeconds; yet becauſe the Eye cannot diſtinguiſh a leſs Angle than a Minute, the Object is ſuppoſed to be a Minute in Bigneſs: And ſo if the Teleſcope do not ſo far increaſe the real Diameter of the Object as to make it more than a Minute, it does ſeem indeed not at all to magnify it; becauſe it is ſtill made to appear, but under the Angle of a Minute. *Des Cartes* has a very ingenious Explication of the *Tunica Retina*, or the way of Viſion, which does very intelligibly make out the reaſon of this Propriety in the Eye: Which poſſibly it may not be amiſs now a little to explain, that ſome Prejudices may be removed, againſt Arguments that are deduced from Obſervations made with Teleſcopes, and ſome other Optical Glaſſes.

Des Cartes Hypotheſis of Viſion.

2. " He explains then (as *Porta*, *Kepler*, *Shinar*, *Galileo*, and many others " that had treated of that Subject before him do) the Organ of Viſion the " Eye, by the Similitude of it to a dark Room, into which no other Light is " admitted but what enters by one round Hole, in which a convenient Con- " vex refracting *Lens* is placed ſo, as to collect all the Rays from Objects " without, and to unite them in their diſtinct and proper places upon a Wall " or Sheet of Paper at a covenient Diſtance within; whereby the Picture of " all thoſe Objects that are without the Room, is made as it were and placed " upon the Wall or Sheet within: This Sheet ſays he in the Eye, is the *Tunica* " *Retina*, on which the Picture of all Objects without the Eye are as it were " painted and deſcribed. Now this Picture on the *Tunica Retina* is nothing " but the Impreſſion of the ſeveral Rays from the Objects without, collected " by the help of the *Cornea* and *Cryſtalline*, as by the Convex Glaſs in the dark " Room. And the *Retina* being like a piece of Pluſh, with the ends of the " Threads turn'd towards the *Cryſtalline*, all the other ends of them being termi- " nated in the *Brain*, there can be no more diſtinct Senſations than there are " diſtinct Threads to convey the Impreſſion on them: So that if the whole Pi- " cture of the Object be ſmaller than one ſingle Thread of this Pluſh, it can- " not affect or move a leſs part than one of thoſe ſmall Threads or Filaments " of the *Retina*, and therefore the Senſation is the ſame as if the Object did " take up or cover the whole end of the Thread or Filament, though it affect " but a tenth part of it provided it be ſtrong.

I have been the more particular in the Explication of this, becauſe ſince my former explaining of the indefinite extenſive Power of Light, I have met with ſome that have objected againſt the Reality of the Appearances through Teleſcopes, as if no Arguments drawn from Obſervation, made by the Help of ſuch were to be eſteemed of any force, whereas indeed all ſuch Objections do only proceed from an Ignorance of the Grounds of Opticks and of Viſion, we being equally as certain of the Appearances we diſcover by them, as of thoſe things which are diſcovered and ſeen by the naked Eye. It was by ſome of the Ancients conjectur'd, that the *Galaxia* or Milky Way was nothing elſe but a great number of Stars, ſo ſmall as that they could not be diſtinguiſh'd: Teleſcopes have diſcovered the Truth of that Conjecture, and manifeſted it to be ſo, and

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we have henceforth no more reason to doubt that it is so, than we have to doubt whether there are any Stars at all in the Heavens.

Others again I find to object, that though there really be such a great Variety of Magnitudes in the Appearances of the fixt Stars, yet it is uncertain whether those Magnitudes do wholly proceed from the Distances of them, and not rather from a real Difference in their Magnitudes, and if so, then all those Stars both great and small may be at equal or very near equal Distances from the Earth; and if so, then the Extensions of the Heavens need not be supposed so vastly big, as if their appearing Magnitudes proceeded only from their Remoteness from the Earth: To which I say as I did before explain, that I do suppose their appearing Magnitude to be caused by both; that is, First by their real Difference in Magnitude and in Brightness; and secondly, by their differing Distance from us. The Visibleness of some proceeds from their extraordinary Vividness of Light, as that of the Great Dog-star, which though it be the most conspicuous Star in the Heavens, is yet found by the Telescopes to be less in Diameter than several others which appear not so conspicuous: As that of the Bull's Eye. *That the fixt Stars are at different Distances.*

And this by the way seems to be the reason of the Appearance of the New Star in *Cassiopea*, observed by *Ticho Brahe*, and by divers other eminent Astronomers of that time, which from a Star of the third Magnitude increased to be of the Bigness of *Venus*, and more conspicuous than any other fixt Star in the Heaven, and yet in less than a Year it diminished by degrees and went out wholly, and hath not since appeared; all which time of its Appearance it perfectly kept the same place without any Variation, so that in Probability it was a fixt Star before of a very dull Light, and so invisible till by some Constitution in its make, as some more combustible Shell or Orb of its Body, it then burnt or shined out more conspicuously, which Shell being once consumed, it again disappeared, and has since that time been no more seen.

Others again, that to the naked Eye appear one Star, and that very conspicuous, by the Telescope are discover'd to be two or more Stars, so near together as that the Eye cannot distinguish between them, both the Images of them falling upon one single Filament of the *Tunica Retina*, and so both of them making but one Impression on the Brain; of this kind the most remarkable is the Star in the Left Horn of *Aries*, which whilst I was observing the Comet which appeared in the Year 1664. and followed till he past by this Star, I took notice that it consisted of two small Stars very near together: A like Instance to which I have not else met with in all the Heaven, they seeming to be both of them very near of equal Bigness, and yet so very near together, that you will need a Telescope of a considerable Length to see them both distinct and separate.

Others, I conceive, may be of equal Distance, and may yet appear of differing Magnitudes from their real Difference of Magnitude, the Body of the one being so much bigger than the other as they appear.

But after all this, I conceive it very probable, that the greatest Number of the small Stars appear such, not from any of these fore-mentioned Reasons, but only because they are further distant from us: It may be objected perhaps, that 'twill be very hard to prove, whether that be the Cause or not of such their Appearance: But to this I answer, that though it hath not yet been positively proved, yet as I mentioned in my Attempt to prove the Motion of the Earth by Observations, I there hinted somewhat to this purpose, and it shall not be long before I acquaint the World with what I have done in that kind. So that for the present I shall say, that upon the whole there is no reason to doubt, but that the extent of the Heavens is vastly beyond what we have hitherto imagined, and consequently that the extent of the Propagation of Light is equal with it, and therefore, notwithstanding these Objections that I formerly laid down, remains without any solid Reason against it.

I proceeded next to shew that this Propagation of Light was to all imaginable Distance in a Moment or Instant of Time, insomuch that every one part of the Universe might by this means be affected by every other part of it, and though I then related some considerable Objections against it, and to prove its Propagation Temporaneous, that is to spend some considerable time in passing from *Of the instantaneous Motion of Light.*

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the Lucid to the enlightned Body, if at a great Diſtance, yet as I ſhall afterwards prove by the Effects of Light, the Propagation muſt be inſtantaneous.

After this I explained what Light was in the Lucid Body: And for that end more particularly deſcribed the Conſtitution and Make of the Body of the Sun, as the principal and moſt conſiderable Body for Light as to us, and ſhewed many Arguments to prove, that it is no other than a Body actually burning or on Fire, that it has an Atmoſphere that incompaſſes it, which may poſſibly be the *Menſtruum* that diſſolves it, as the Air or Atmoſphere about the Earth is the *Menſtruum* of burning Bodies here upon the Earth, that it did ſometime produce dark Spots or Clouds, which ſeem'd Analogous to our Smoke, and ſometimes brighter, which ſeem'd Analogous to our Flames. So that upon the whole, I concluded it a ſolid Globous Body actually on fire in its ſuperficial Parts, and that from that Fire its Light and Heat proceeded.

The Light of the Moon and other Planets, both Secundary and Primary, Teleſcopes do plainly evidence to proceed from the Reflection of the Sun's Light, and therefore none of thoſe can be properly ſaid to be Luminous Bodies. But the fixt Stars, as I have already mentioned, ſeem to be of the ſame Nature with the Body of the Sun, and therefore the ſame Explanation that was given of the Light in the Sun, will ſerve alſo for the Light of the Bodies of theſe Stars. And thence, as I juſt now mentioned, a clear Reaſon will be given of divers new Stars that have appeared and diſappeared.

The Light of the Stars from an actual Fire.

3. So that in Probability the Light of all the Celeſtial Bodies proceeds from an actual Fire, much of the ſame Nature with the Fires we here have burning upon the Earth; and therefore if we find out what is the Nature of our Fire here with us, we may from that explain how it is generated and how it operates in the Heavens.

Not that I ſuppoſe, that the Fuel of the Celeſtial Fires is the ſame with our Fuel here upon the Earth, as Sulphur, Bitumen, Stone-Cole, or other combuſtible Mineral Subſtances; or Woods, Reſins, Oyls, or other Vegetable Subſtances, or Fat, Bones, or ſuch like Animal Subſtances; but that it may be of Variety of other Subſtances very differing from any of theſe; for as all thoſe I have named are much different from one another, ſo may there be a Hundred other Subſtances diſtinct from any one of theſe, and diſtinct alſo one from another, all of which may notwithſtanding be of a Subſtance fit for the Diſſolution of that fluid *Menſtruum* in which they ſwim, in the ſame manner as theſe I have named are for the Diſſolution of the *Menſtruum* of the Air, and ſo may be fit Fuel to maintain that Celeſtial Fire.

Of the Nature of Fire.

4. We have therefore, brought our Inquiry into Subjects much nearer to us than either the Sun or fixt Stars, and into ſuch as are within our Command and Reach, into ſuch as on which we may with more Power exerciſe our Scrutinies and Examinations; in which, if by our Tryals and Examinations we can find out what the efficient Cauſe of Fire and Light are, we ſhall by Analogy eaſily find out what is alſo the Cauſe of the Light in the Sun, and in the fixt Stars, which Examination and Scrutiny into the Cauſe of Fire, and the Light thereof, ſhall therefore be the Subject of ſome of our following Diſcourſes.

Of Comets.

5. But before we leave the Contemplation of the Celeſtial Bodies, and begin our *Examination* of Terreſtrial or Culinary Fires, the late appearing Comet puts me in mind of another kind of Light, which is thought by moſt to be of a quite differing Nature from thoſe of the Sun, Stars, or Planets, and not to be at all Analogous to them.

The great Variety of Form there has been amongſt thoſe that have appeared at ſeveral Times, and in ſeveral Ages of the World, and the great Alterations there have happened almoſt in every one that appeared before it diſappear, has ſo much confounded Mens Judgments concerning them, that you ſhall hardly find two Men agreeing in all things, to the ſame Opinion.

Seneca

Seneca in the Nineteenth Chapter of his ſeventh Book of Natural Queſtions, recites three Opinions concerning *Comets*. Some, ſays he, think that no Comet does really exiſt, but that the Appearance thereof is made only by the Conjunction of the Rays of ſeveral Stars or Celeſtial Bodys into one Point, and a Repercuſſion or ſpreading of them from thence: *Quidam nullos eſſe Cometas exiſtimant, ſed ſpecies illorum per repercuſſionem vicinorum ſiderum, aut per Conjunctionem vicinorum reddi.* *The Opinions concerning them.*

2. Some indeed do ſuppoſe them to have a real Exiſtence, but to have peculiar and proper Courſes of their own. And that after a certain time, the ſame Comets return again, and appear to us: *Quidam aiunt, eſſe quidem, ſed habere curſus ſuos & poſt certa Luſtra in conſpectum mortalium exire.*

3. Some do alſo ſuppoſe them to have a real Being, but not ſuch a durable one as may deſerve the name of a Star, but of ſuch a ſubſtance as does waſt, and is diſperſed and conſumed after a certain time; namely, The time they appear which is but ſhort. *Quidam, eſſe quidem, ſed non quibus ſiderum nomen imponas quia dilabuntur, nec diu durant & exigui temporis mora diſſipantur.*

So that the firſt of theſe Opinions did ſeem to ſuppoſe that they were either an Union of ſeveral ſmall Stars which did really before exiſt, but being ſeparate, made no Appearance 'till united; or elſe that the Rays of theſe meeting together in one Point by Repercuſſion or Reflection, did ſeem to make this Appearance. This might well enough agree with the Opinion of the Peripateticks, and thoſe that ſuppoſed the Planets and Stars fixt in ſolid Orbs, whoſe Motions carried them round, and thence poſſibly they might allude to the Focus of a Burning-Glaſs, as if this Appearance were nothing elſe but the Rays of ſome Celeſtial Body, whether Sun, Planet, or fixed Star, which being collected into one Point, by Reflection, from the middle parts of the Concave of ſome of the ſolid Cryſtalline Orbs, might there make a bright Appearance, and then the Tail would be nothing elſe but the union of other Rays which fell further from the Middle or Axis of the Concave, which unite at ſeveral Diſtances from it; or elſe that ſome of theſe Spheres might have ſome parts of them of greater Refraction then others, and ſo by that Refraction, might collect a great Quantity of Rays diffuſed from that Luminous Body which was its cauſe, as moſt probably the Sun, as the moſt conſiderable Light of this part of the Univerſe; and unite the greateſt Quantity in the Head of the Comet, and others in the Tail: And according to theſe Hypotheſes, the Comet would really be nothing elſe but a Phantaſm or Appearance, and not have any real Exiſtence in Nature, and ſo would not be much differing from the appearing Meteors, ſuch as Rainbows. The *Parhelii*, and the *Paraſelenæ*, the Mock-Suns and Mock-Moons, and the like; all which have no other Exiſtence than the Repreſentation of a Body in a Looking-Glaſs; they being indeed nothing but a Reflection or Refraction of thoſe Luminous Bodies which they repreſent, or are attributed to. As a Rainbow is nothing elſe but the Reflection and Refraction of the Rays of the Sun from the round Drops of Rain which fall from the Cloud, which at certain Poſitions to the Eye and Sun, do by Refraction and Reflection return an extraordinary bright and coloured Ray to the Eye, which very Drops ſo ſoon as ever they are out of that Poſture return not at all; this is Geometrically demonſtrated by *Maurolicus*, *Des Cartes*, and divers others, and may Experimentally be verified by an artificial Fountain, caſting up and diſperſing Water into the Air in a Miſt, which will in the Sunſhine make a Rainbow. The ſame may be Geometrically demonſtrated of the *Parhelii* and *Paraſelenæ*. That all theſe are nothing but the Phantoms or Appearances of ſome other Luminous Body, made by an extraordinary Collection and Repercuſſion of the Rays from ſome other place, than that Luminous Body ſhould appear in, and ſo the Cauſes of them may be moſt certainly aſſigned and ſhewn, which being all Atmoſpherical and Aerial, and placed in the lower Region near the Earth, they become of no long continuance, but quickly vaniſh. Now if theſe Refracting and Reflecting Subſtances that may be ſuppoſed the cauſe of the Comets this way, be ſuppoſed to be Ætherial Subſtances, and ſo not ſubject to any ſuddain Change (as the Atmoſphere is) the Cauſe re-

maining longer; the Effect alſo may have a longer Exiſtence, and ſo a Comet may be ſuppoſed to laſt ſix Months or more.

Several have been the Opinions concerning this way, and thoſe very differing; ſome have ſuppoſed the Head to be the Point where all theſe Rays concentred and met together, and there produced a kind of combuſtive Focus; through which the Rays of the Sun penetrating, did afterward refract various ways, and ſtrike forth to a vaſt length, and from that Penetration of the fiery Focus of the Head, acquired ſuch a Quality, as made them to become viſible; by which means, according as this burning Point or Focus did refract more on one ſide than on the other; did the Stream or Tail of the Comet appear to bend from the ſtrait Line continued from the Sun through the middle of this Focus. This they reſembled to the Radiation of the Sun between dark Clouds upon a thick and foggy Air, which does indeed very much reſemble the Appearance of the Blaze, or rather like the Rays of the Sun let in by one ſingle Hole, or through a Glaſs into a dark Room.

I have only this more to add, That if ſuch Reflecting or Refracting Bodies could be ſuppoſed, or that we had any other Argument to prove them than only the Appearance of the Comet it ſelf, there would be ſome pretty Congruities in the Theory that would be of ſome cogency to perſwade the Belief of this Opinion: As, Firſt, That from the Geometrical Laws both of Refraction and Reflection, this Phantom would have a form much like that of a Comet; that is, it would have a Head brighter than the reſt, it would have a Tail or Blaze ſpreading from it, it would have this Tail always pretty near, oppoſite to the Sun; that is, not always directly, but ſometimes a little varying from the direct Line, though it would ſometime alſo be directly oppoſite; it would ſometime be ſtrait, but ſometime alſo be bended, ſometimes clear, ſometimes a little coloured, and the like; which I cannot now ſtay to inſiſt upon, but may ſome other time more fully explain. And this the rather, becauſe I do not find that any one that has hitherto written of Comets, has in the leaſt mentioned any Explication like this; nor does *Seneca* at all explain what the Opinion really was: But upon conſidering of various ways how to ſolve the Phænomena, and how alſo to explain the Words of *Seneca*, amongſt others, I pitch'd on this, of which I ſhall upon another Occaſion ſpeak more fully, and ſhew wherein alſo the Objections lie againſt it.

Hevelius's *Opinion examined.*

Mr. *Hevelius* ſeems to give another kind of Solution of the Tail or Blaze of Comets, which though it does, *toto Cœlo*, differ from this I have now explained; yet it may not improperly be made uſe of to explain this firſt Opinion mentioned by *Seneca*. He then ſuppoſes that the Tail or Blaze, is really nothing elſe but the Rays of the Sun, which in paſſing through a nebulous Body, ſuch as he conceives the Head to be, are refracted, and reflected by the *Nucleus* or *Nuclei*, if it have more than one, by which Condenſation, Decuſſation and Collection of thoſe Rays he ſuppoſes the Blaze to be formed; now though, indeed, he does ſuppoſe the Head of the Comet to be a diſtinct Subſtance, and ſo falls in or agrees with the Third Opinion; yet as to the Tail, he ſuppoſes it a meer Phantom, and to have no real Exiſtence in Nature.

This ſuppoſition concerning Comets refuted.

But againſt this Suppoſition there are many Objections; as firſt, though the Blaze of the Comet does ſometime reſemble the Radiation of the Sun between the Clouds, upon a thick Air below thoſe Clouds, as it did in this preſent Comet, when the Blaze appeared brighteſt and longeſt, yet 'twill be very hard to make out the Similitude well in a Comet; for theſe Radiations under the Clouds appear brighter than the reſt of the Air, becauſe all the reſt of this thick Air under them is ſhadowed and darkned by the interpoſition of the Clouds, and thoſe that appear bright, do ſo, becauſe the Sun ſhines clearly upon them between thoſe Clouds. But in the Comet we want, firſt the Cloud, or ſomewhat that ſhould darken the *Æther* round about the Blaze; I ſay the *Æther*, becauſe, as I ſhall afterwards ſhew, all Comets that have been accurately obſerved, and thence, in probability, all Comets whatſoever have appeared, to be very far removed above the Air, then in probability this dark Body would hinder the view of ſome part of the Blaze. Secondly, We find that theſe Radiations between the Clouds never happen but when the Air underneath the Clouds is thick and ſomewhat opacous, without which they cannot appear; but when

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ſhall we find ſuch an opacous Air to reflect the Light into the Heavens. It would be much more difficult to ſuppoſe ſuch a vaſt ſpace of the *Æther* to be thickned (as muſt neceſſarily be) to make out this Appearance; than to ſuppoſe only ſo much Matter as may juſt ſerve to make the Bigneſs of the Blaze itſelf, which though it be prodigiouſly long, as ſome thouſands of the Earths Diameters, yet ſtill 'tis eaſier to conceive how there may be matter enough to make a Cylinder, than to make ſo vaſt a Body as an Orb of the *Æther* of that thickneſs. But then, Thirdly, There is nothing in the ſhape of the Head of the Comet that does any ways reſemble the perforation of a Body that ſhould ſhadow the reſt of the *Æther* about the Blaze. For as I ſhall afterwards ſhew you, Comets do generally appear to have a brighter Body in the middle, about which there is a kind of White Cloud, from which the Blaze does ſeem to iſſue. So that, in truth, they have no reaſon at all for this Suppoſition or Opinion, and it has in probability ſprung, and had its firſt riſe from thoſe who ſuppoſed Comets to be nothing elſe but ſome ſmall Appearance here in the Air below: But ſince, as I ſaid before, It has been by ſo many and ſo exact Aſtronomical Obſervations found, that ſome of theſe Comets are very high in the Heavens, and far removed beyond the Bounds of the Air, that groundleſs Opinion may alſo be diſcharged, and yet I find moſt of our Aſtronomerrs and Philoſophers do incline to be of that Opinion, as particularly *Des Cartes*, *Fromundus*, *Kepler*, *Cyſatus*, *Riccioius*, *Gremaldi*, &c. who though they do all aſſign the real Body to the Comet, yet as to the Blaze, that they ſuppoſe to be made by the tranſit of the Suns Rays through the Cloudy part of the Head. And *Hevelius* alſo, the lateſt Writer of Comets, is of this Opinion, not as if it were made by the paſſing of the Rays through a Hole, as in a dark Room, but by the Refraction and Collection of the Rays in the Cloudy, and yet tranſparent Body or Head of the Comet. Now this Body or Head he does not ſuppoſe Spherical or Globular, and to collect the Rays of the Sun beyond it into a Focus, as a Glaſs Globe full of Water would do; but to be of the form of a Diſh or Boat, and to conſiſt of various ſorts of Bodies, ſome Round, and ſome Angular, which do variouſly Reflect and Refract the Rays of the Sun, and ſo make them unite and croſs each other in various Ways on that ſide of the Comet which is oppoſite to the Sun, but becauſe he could not well conceive how theſe Rays ſhould come to be conſpicuous, unleſs there were ſome opacous reflecting Body behind the Comet, as there is in the Air when the Radiations before mentioned are ſeen below the Clouds, therefore he has ſuppoſed a vaſt Collection of Vapours or halituous Subſtances, proceeding partly from the Sun, and partly from the reſt of the Planets, as ♄, ♃, ♂, *&c.* to be made beyond the Body of the Comet, that is on that ſide that is oppoſite to the Sun, and theſe he ſuppoſes to be very much more thin than the Air or Atmoſphere about the Earth; and therefore, that a little quantity of Matter will go a great way in that Collection: Upon this halituous Matter the Radiations falling, he ſuppoſes, are Reflected, and ſo the appearance of the Blaze is generated. *Kepler* was aware that there was a neceſſity of ſuch a kind of halituous Subſtance as this mentioned by *Hevelius*; but yet, conſidering the vaſt extent of the Blaze of ſome Comets, namely, to 40, 50, 60, nay 90; and if we may believe —— to 110 Degrees in length; and that this Angle muſt be ſubtended by the Tail, as a ſtrait Line, which in ſome Caſes will run it out to a vaſter length than if it were only a Circular Extent, he could not conceive whence all that matter ſhould be brought. But *Hevelius* has found out whence to fetch it; namely, from the Orbs and Bodies of the Planets; for ſince, ſays he, we are aſſured, *Quod tam immenſa materiarum Congeries, umbrarum ſcilicet primariarum circa maculas & circa ipſum Solem ſecundariarum in longe adhuc majori quantitate quandoq; reperiatur, utiq; non abſurdum quoq; eſt etiam tales expirationes tenuiores etiam circa Cometas dari. Nam dum non raro pene omnium Planetarum Orbes trajiciunt, multum ubiq; materiæ attrahunt averruntq; ſecum, adeo ut breviſſimo temporis Spatio cum motu velociſſimo gaudent vaſtiſſimum ſubtiliſſimarum iſtarum exhalationum cumulum, ad caudam refringendam convenientem coacervare poſſint.* But to this Opinion of his, it may be objected, that, firſt, as to the Collection of halituous Subſtances, if ſuch were made in its Paſſage then in probabiliy this would be in that part of it which came behind it in its Motion, and ſo conſequently the Tail ſhould always appear in that Line which the Comet has paſt; as we may often obſerve in the ſmall Meteors to

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be ſeen in a clear Night called Star-ſhootings, many of which do leave a kind of Glade of Light behind them in the way through which they have paſt. So he gives no manner of Reaſon why it ſhould be oppoſite to the Sun, nor indeed is his Explication at all natural, but altogether forced, and Extraneous from any other Method or Operation in Nature, nor is it built upon the Appearances, for as I ſhall afterwards ſhew, had he well heeded thoſe, they would have hinted ſome other ways of explicating theſe *Phænomena.*

Anthelme's *Opinion examined.*

I ſhould have here left this Opinion, but that I was this Week informed from *France* of a Perſon *D. Anthelme*, a *Carthuſian* of *Dijon*, who pretends to have a true Theory of Comets, and to be able to predict them; and accordingly hath put out an Ephemerides of this preſent Comet, therein not only ſetting down what he had obſerved before the Publication, but what ſhould happen afterwards 'till the time of its diſappearing. This Man I mention not for his predicting of the Way and Motion of the Comet, for that I think may be much more exactly done than what he has, by the way I have publiſhed in my *Cometa*, which was invented by Sir *Chriſtopher Wren*; by which, from any four Obſervations truly made, one may certainly find the Line, Diſtance, Motion, Inclination to the Ecliptick, its place among the fixt Stars, the length of its Tail, Brightneſs, *&c.* ſo long as it ſhall appear to the naked Eye; for ſo long that Theory will hold pretty near; I do not therefore mention this *French* Author for that, but to ſhew that he that is far out of the way in his Conjectures about the form of the Comet, which he ſuppoſes alſo to be made by the Refraction of the Sun's Rays, the Opinion we have now exploded, and ſhall hereafter more demonſtratively confute from undeniable Arguments; this Man, in probability, is as much out in his Theory, which is only this, that the Head or Body of the Comet is Tranſparent, and that the Tail is made by the Refraction of the Sunbeams through it, but does not ſeem to have conſidered the Difficulty which *Kepler*, *Hevelius*, and divers others had taken notice of, and provided for in this Hypotheſis.

I could relate to you the Opinions of many other Authors who have inclined to this Opinion, that the Blaze of the Comet is nothing but a Phantom or Appearance, but that as I find the very beſt of them that have imbraced this Opinion, to have been very dark and perplexed in their Explications; and as if they had not well underſtood it themſelves, ſo there are others who only give a bare Aſſertion without any Explication or Reaſon at all: The Authority of ſuch Men, I confeſs, weighs very little with me.

I ſhall therefore paſs on to the ſecond ſort of Opinions, and that was of ſuch as ſuppoſed them to be Aerial, Halituous and Sulphureous Bodies placed ſomewhere in or near the Atmoſphere, which was raiſed out of the Earth, and fired in the upper Regions of the Air, and there continued 'till they waſted away. Of this Opinion was the great Philoſoher *Ariſtotle*, and almoſt all his Followers; nay many of them, to this Day, who have not taken the Pains to be better inſtructed. Of this Opinion we find generally all the Stoicks, but that they ſuppoſe them elevated from the Air into the *Æther*; alſo the *Chaldeans* and all Hiſtorians, who have mentioned Comets in their Political Hiſtory: Of this Opinion are almoſt all the Illiterate and Ignorant People of the World, and almoſt ever have been, and ever will be; becauſe they are for the moſt part ruled by the moſt obvious Appearance to the Senſe, without taking Pains to make uſe of their Reaſon to examine things ſtrictly; ſo that if the majority of Votes be an Argument for the Truth of any Opinion, certainly this will carry it from all the reſt, at leaſt a Hundred Thouſand to One. And yet, after all this, *Ariſtotle*, his Commentators, his Followers, the greateſt number of Scholars, and particularly the Stoick Philoſophers, as well as Peripatetick, the Hiſtorians, Divines, many Phyſitians, and all the Illiterate *Vulgus* in the World, will be found quite miſtaken in their Opinion, and will eaſily be confuted by the Aſtronomers and modern Philoſophers, who have clearly and plainly demonſtrated their Miſtake and Error. And that is, by undeniably proving the vaſt diſtance thoſe Bodies are removed from the Earth by the Parallax, or rather want of Parallax, which they have been of later Ages certainly obſerved to have; for that does moſt certainly and infallibly ſhew that they are ſo far from being Aerial or Atmoſpherical, as *Ariſtotle* ſeems to ſuppoſe, that they are ſeldom,

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if ever so low as the Moon, many times as far off as the Sun, and sometimes perhaps much farther; I say perhaps, because the Evidence for that is not as yet so easily attainable, for no one has yet certainly proved the Parallax of the Sun; nor of *Mars* to any exactness; much less have they of the superior Bodies.

Johannes Regiomontanus, was the first among the Moderns, who began to elevate the Positions of Comets above the Air or Atmosphere; for by his Observations of that which appeared in the Year 1472, he found it by its Parallax, distant eight Semidiameters of the Earth at least, which is very far above the reach of the Air, which those, that with any probabilty judge of its Altitude, at most make, not above Twenty Miles Perpendicular, but in all probability is yet much less. But *Ticho Brahe*, and at the same time *Rothmannus* Mathematical Professor to the *Landgrave of Hassia*, *Michael Mestline*, *Cornelius Gemma*, *Maddeus Heggetius*, and many others (too many to be named at present) who had made Observations of the Comets that appeared in the Years, 1577, 1580, 1585, 1590, 1593. did all clearly find and prove that they had all of them less Parallax than the Moon, and consequently that they must be far above it; and with them agree almost all the Learned Astronomers since, only *Galileo* would seem to make it only a Phantom somewhat like a *Halo*, which changed its place according to the Position of the Eye that saw it, and thence would give a Reason why it could have no Parallax; for since its being or Position depended only upon the Refraction and Reflection of the Sun's Rays; according to him, its Distance or Angle with the Sun would appear the same where-ever the Eye were placed to time it; and, consequently, it would observe and keep the same Position amongst the fixt Stars in the Zenith, as in the Horizon; supposing it elevated so far only above the Earth, or at least, so posited, as not to fall in its Shadow. But this Explication of this great Wit, and most excellent Philosopher and Mathematician *Galileo*, though it be very subtil and curious, and has some seeming probability, yet the strict Examination of the Appearances by the known Laws of Refraction and Reflection, will sufficiently shew the Insufficiency of that Solution; and should the Examination of those not have been sufficient to have confuted this Supposition from the endeavouring to solve the common Appearances of Comets to the Naked Eye; yet the Impossibility to have solved the Appearances of them through the Telescope would have sufficiently confuted it. But setting him aside, all the considerable Astronomers who have since written of Comets, do conclude them not to be Sublunary, but far removed above the Moon, and Æthereal. Such were almost all those who writ of that great and very bright Comet which appeared to the World in the Year 1618. And such are those that have writ of Comets that have appeared since; and more particularly, of those two great ones which appeared in the End of 1664, and in the beginning of the Year 1665. Many of which are comprised in the *Theatrum Cometicum*, Printed in the Year 1667.

This is then the Third Opinion mentioned by *Seneca*, as the second to be held by divers of the Antients. Namely, That Comets were Æthereal Bodies, placed at a great Distance from the Earth, and there moved according to Rules peculiar to them only, and distinct from the fixt Stars, and constantly appearing Planets.

What Arguments the Antients had to make them of this Opinion, does not appear any more, than it doth why they held divers others; many of which have been with great Applause, and very good Reason taken up, and received by many of our late Philosophers: But certain it is, 'twas not without some very good Grounds; otherwise, 'tis not to be conceived how they should be able to hit upon them: As, Particularly that of *Aristarchus Samius* or *Philolaus*, who Asserted the Sun to be the Center of the Universe; and that all the Planets, and the Earth among the rest, which must therefore be esteemed one of them, moved round about it, that remaining fixt. Which Opinion was received by *Copernicus*, and has been since followed by the most knowing Astronomers. 'Tis not therefore to be doubted, but that the Antients might have some of the same Reasonings for them that we now have; and possibly many other, which length of time has devoured; and 'tis not Improbable what *Simon Steven* has indeavoured to prove, and the learned *Hugo Grotius* has helped him to many Arguments for it; that there was before any of the Histories now extant, of

Prophane Writers, a learned Age and Place of the World far exceeding that of *Ægypt*, or *Greece*; of which we have no manner of History conveyed down to us, but some few scraps and hints here and there scattered up and down in some of the Writings of the Antients. 'Tis not improbable, but some succeeding Ages and Sects of Men might industriously destroy them (which was no difficult thing to do before Printing was in use) as 'tis said of *Aristotle*. But whatever was the cause, is uncertain; It is therefore much easier to find out the Truth by new Inquiry into the Nature of the Things themselves, than to hunt for the Causes of things among the Worm-eaten Volumes of Antiquity. We shall therefore pass over the several Branches of Opinions under this Head, of the Æthereal Nature of the Comets, and come to the various Opinions that have been asserted and defended by the Moderns, whose Grounds and Reasons we may easily know.

There are then under this Head, great variety of Opinions, as to the Substance, Light, Magnitude, Distance, Motion, Duration, Generation, *&c.* of Celestial Comets. But they may be reduced to these.

The first was; That Comets were certain Planets or wandering Stars, the Laws or Rules of whose Motions were not yet known, and which were distant from the Seven Planets that were known. Of this Opinion were the *Chaldeans*, as also *Democritus*. And that thereupon, why they did but sometimes only appear, and then vanish; was by reason of their Approaching and Receding from the Earth in their proper Course, or by reason of their nearness to the Sun. *Plutarch*, also, says, that some of the *Pythagoreans* also, were of that Opinion: *Seneca*, also, held the same.

The second Opinion is, That the Body and Tail of the the Comet is made up only by the conflux of many small, and, before, imperceptible Stars; and that the Reason of their disappearing is, because those Stars are again dispersed.

The Third Opinion is, that the Comets are made *De novo*, out of the *Materia Cælestis*. Every of these are varied by several Suppositions about the Blaze, of which more hereafter.

N. B. *Here our Author breaks off, and leaves this Discourse of Comets imperfect, so that I was in some doubt whether I should publish it; but considering it contained a brief Explication of several Opinions of the Antients, and some of the Moderns, of the Nature of Comets; I thought it might not be unacceptable to the Reader. I shall in some following Sheets present you with a pretty large Treatise of Comets; containing his own Theory and Explication thereof, from Observations made on those in* 1680, *and* 1681.

What follows is the Continuation of his Lectures of Light, wherein he prosecutes his former Inquiries into the Nature thereof. R. W.

SECT.

SECT. IV.

Being a Continuation of the Lectures of Light interrupted for sometime by our Author's Observations on the Comets in 1680. *These were read about* May, 1681.

The CONTENTS.

1. *A Recapitulation of some former Particulars, as to the Three Properties of Light,* viz. *its incomprehensible Extension, prodigious Swiftness of its Motion, and yet the Limitation of its Power, so as to admit the Rules of Comparison, of Majority, Minority and Equality. Light falls under a threefold Consideration, as it is in the Luminous Body, as it is in the Medium, as it is in the Eye. Luminous Bodies are Celestial or Terrestrial; Celestial are such as shine by their own Light, as the Sun, and fixt Stars or Comets, all which are actual Fires: The Authors Theory of Comets, That the Planets except the Sun have no Light of their own.* 2. *The consideration of Bodies within our reach emitting Light, which are reduced to five Classes.* 1*st. All Sulphureous, Resinous and Spirituous Bodies. Here is a short Explication of Fire, and the Life of Animals.* 2*dly, Bodies not combustible, yet that will shine with a certain Degree of Heat.* 3*dly, Such as shine by an inward Fermentation without Heat.* 4*thly, Such as shine by an Impression of Light.* 5*thly, Such as shine by Motion.* 3. *These are to be the Guides into the Nature of Light. The Definition or Description of Light, what it is. The Proof and Confirmation thereof. That the* Medium *of it is perfectly Dense.* Bulialdus's *Notion of Light rejected. That Light is a Corporeal Substance, that it perfectly fills Extension or Quantity extended every Way, that it is susceptive and communicative of Motion.* 4. *The Motion of Light, in the Consideration of which are observable, The Quantity, Quality and Power thereof. These explained. The cause of Sound. Heat only an internal Motion of the Parts: A certain Degree of Heat or of this Internal Motion produces Light. Light in* objecto, *is a peculiar kind of this internal Motion, and the Propagation of this Motion is Light in the* Medium. *R. W.*

1. I Was the last Term diverted from proceeding with the Explication of Light I had begun to discourse of in some of my former Lectures, by the Appearance of the Comet, which seems to give a Light very differing from those of other Celestial Bodies: I was therefore the more willing upon that Occasion to discourse on the Light of that Body, having before discoursed of the Light of the Sun and Stars. But it was with a Design of Resuming the Discourse of Light in General; for that a clear Understanding and Explication of it, will very much facilitate the Knowledge and Science of many other abstruse and difficult Operations in Nature. For the doing of which as it ought, much

much uſe muſt be made of Geometry. And, indeed, without it little can be done, that will any ways intelligibly inform us concerning it. General and indefinite Aſſertions and Deſcriptions do but imperfectly inform, and the Deduction from ſuch Propoſitions muſt be uncertain, and of a dubious Senſe; and defective of Form, becauſe they want the neceſſary Limits and Boundaries. Whereas, on the other ſide, where the Definitions are ſtrict and exact, and the Deductions cloſe and neceſſary, the Science thence derived is Poſitive and Demonſtrative, and will admit of no manner of Heſitancy, or Contradiction.

The Proprieties I have taken notice of were,

A Recapitulation of the Three Proprieties of Light.

1. The Incomprehenſible Extenſion of its Propagation, boundleſs and unlimited as the Univerſe, and yet really affecting every Attom or Point of the Medium or Maſs of Created Body, and this not only of the tranſparent Medium, but as I conceive, and ſhall hereafter explain and ſhew my Reaſons for it, even every Atom and Point of Opacous Bodies alſo; ſo that no one Atom or Particle of created Body is free from its Power; and be the Extent thereof never ſo Immenſe (as whoſe Imagination can ſet Limits to Extenſion) yet the whole, and every part thereof is really affected by the Power of Light.

Secondly, The prodigious Swiftneſs, or rather Inſtantaneouſneſs of this Propagation; ſo that it ſeems to exert its Power to all imaginable Diſtance in an Inſtant of time; ſo that at the ſame Inſtant that the Lucid Body emits its Light, or exerts it Power, the Receptive Body though never ſo far diſtant is affected by it; and this without any reſpect to the vaſt ſpace interpoſed, ſo that a Body a Million of Millions of Miles diſtant, is affected as ſoon as a Body diſtant but a Span, ſo that it may be ſaid to outpaſs the quickneſs of our Thought; for that we muſt think of one thing after another. And though ſome ingenious Men, as Monſier *Romer*, have indeavoured to prove it to be temporaneous, and to ſpend ſome time in paſſing from the Illuminating to the Illuminated Body, thereby thinking to make it more Intelligible and Adequate to other Powers and Operations of the Univerſe; yet he ſuppoſing that time to be ſo incredibly ſhort, in compariſon to the length of the Space it paſſes, as he allows but one ſingle ſecond of time, or the ſixtyth part of a Minute of an Hour for the time in which it paſſes the Diſtance of about 20000 Miles; it makes it much more difficult to conceive ſo rapid a temporaneous Motion, than the Inſtantaneouſneſs of that other. For the Motion of a Cannon Bullet is as much ſlower than this of Light, as the Motion of a Snail is than that of a Cannon Bullet.

The Third Propriety of Light which I took notice of, was, that though its Expanſion ſeems to be indefinite, and its Motion Inſtantaneous, or infinitely ſwift; yet that its Power was finite, and limited and ſubjected to the Laws of Quantity, and admitted of the Rules of Compariſon, of Majority, of Minority, and Equality, which nothing that is infinite is ſubjected to; and upon this Account it is, that it falls under the Conſideration of Geometry.

1. I ſhall now begin with a more particular Conſideration of Light; and therein I ſhall conſider what Light is, that has theſe admirable Proprieties. Reſerving the explication of ſeveral other Proprieties of it altogether as wonderful, 'till I have a little further explained theſe, and ſhewn how theſe are produced by it.

Light then will fall under a Threefold Conſideration; Firſt, As it is in the Luminous Body. Secondly, As it is in the *Medium* that conveys it. And, Thirdly, As it affects the Eye, by means of which, we come to the Knowledge of all the reſt.

A Three-fold Conſideration of Light.

The Luminous Objects are either Celeſtial or Terreſtrial; of each of which, there are ſome that ſhine by their own Light, and ſome that ſhine by Light reflected from them, but derived from another Luminous Body.

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The Principal of the Celestial (at least as to us) is the Sun, which for ought we yet certainly know, is the Principal and Brightest Body in the World. I have already explained somewhat of the Nature of that Body as to its bigness, its turbinated Motion, its Atmosphere, its *Nebulæ*, *Maculæ* and *Faculæ*, and their Proprieties and Motions, and thence gave some probable Conjecture of the Constitution and Substance of it, and concerning the manner how it comes to give Light; and I shew'd you many Reasons why, in all likelyhood, the Light of the Sun might proceed from an actual Fire, somewhat Analogous to the Fire of Bodies burning with us; whence from an understanding of the Nature of Fire, Flame and Light here within our Reach and Command, we might the better be inabled to examine and judge of the nature of Light in general; for if the Celestial Lights are Analogous, and much of the same Nature with the Bodies that give Light with us, then the Knowledge of the one will explain the other. *Celestial Luminous Objects.*

Next, I began to shew some Reasons why in Probability the fixt Stars were of the same Nature with the Sun, as to this Propriety of Emitting Light: For, that first, they were Bodies some of them vastly Distant, as I have, I think, experimentally proved by the Observation I made of the passing of Stars near the *Zenith*; and consequently they must be vastly big. Thence, Thirdly, They must emit a very strong and vivid Light, since at so vast a Distance they do so sensibly almost Dazle the Eye; for the Power of Light, as I shew'd before, though it be instantaneous and indefinite in Extension, doth yet continually Diminish in its Power, the farther it acts from the Lucid Fountain; and this not in a Simple but Duplicate Proportion to the Distance; so that a Body a Hundred times further Distant, receives not a 10000 Part of the Light. But then, Secondly, 'Tis probable, that they are actual Fires, as I indeavoured to prove the same, from some remarkable Instances we have had of some of them that have, as it were, blazed out upon a suddain, and after a short space, quite burnt out, so as never to appear since; as that remarkable Star in 1572, which was so accurately observed by the Noble *Ticho Brahe*, and some others of that Nature; and by some others, which sometimes appear, and sometimes disappear again, as that in *Collo Ceti*.

Thirdly, I shew'd why also Comets were Bodies that shined by their own Light, and did not receive their Light from the Sun, but from a Principle of their own; and this I have shewn to be very much of the same Nature with our Fire. And by very many Observations I have made of the last Great Comet, I am confirmed that the Light of that vastly great Blaze, which at sometimes was extended to so great a length, as to subtend an Angle of almost Ninty Degrees, and to be of the breadth of near Three; was wholly from it self, and was not caused by the Reflections of the Light of the *Sun*; and that all that Stream issued from the Body or Head, much after the same manner, as the flame of a Candle does issue from the Weik; and therefore from all Circumstances I could observe of it, and from what I took notice of in the former Comets; I judge it to be a Body actually on Fire, or in a State of Dissolution, and that it consists of burning Materials, but much differing from the Substance of the Sun and fixt Stars, which afford a more pure, strong and defecated Light, whereas this is more blended with a kind of Smoke, or Hetrogeneous Vapours, which are consumed whilst they are in the Blaze, in the same manner, as the Smoke of a burning Body here with us is consumed by the kindling of it into Flame, as it ascends from the smoaking or steaming Body; as may be observed in the Burning of a Tallow or Wax Candle, or of Oyl, Spirit of Wine, or the like in a Lamp. These therefore are the Celestial Bodies that emit Light of their own; in all which, the Original or Cause of it seems to be nothing else but an actual Fire, and to be Analogous, or very much of kin to the Fires, that consume Terrestrial Bodies, and therefore our Inquiry for the cause of Light is brought somewhat nearer to us, and more within our reach, and therefore we may with the greater Ease and Certainty find out the true Cause and Nature of it.

For as to all the other Celestial Bodies, *viz.* the Moon, and the rest of the primary and secundary Planets, 'tis very evident that they do not shine by their own proper Light, but by the help of that of the Sun, which is reflected from

 them

them to us. For if we consider the Moon, 'tis very evident not only from the Increase and Decrease of Light, which make the Appearances and Phases of the Increasing and Decreasing of the Moon, and from the Eclipses both of the Sun and Moon, which have very long been Observed and Explained by this Theory, the Dark Body of the Moon eclipsing the Sun, and the Interposition of the Earth between the Sun and the Moon, eclipsing the Moon; but from the very Shadows of the Protuberant and Craggy Parts of the Moon upon the Surface of its Body; for those Shadows may, with a Telescope, be as plainly seen as the Shadow of the Stile of a Dial, and the Motion and Change thereof may be as plainly also seen, and the Progress of the Light of the Sun upon the Surface of that Body. But whereas some object that the secundary and faint Light of the Moon, which is sometimes remarkable in total Eclipses, seems to be a proper Light of the Body it self, 'tis now evident enough that, as *Kepler* well observed, that Light proceeds from the Refractions of the Sun's Light in the Atmosphere about the Earth, where it is refracted towards the *Axis* of the *Umbra* of the Earth; and as for that of the New Moon, that is caused by the Reflection of the Sun's Light from the Surface of the Earth; for that 'tis very plain, that as the Light of that Decreases, as it does when the Aspect is changed, and a less part of the inlightned Surface of the Earth reflects to the Moon, as from the first to the last Quadrature, that secundary or faint Light vanishes and is no more visible.

Next, As to the Light of the other Planets, 'tis very clear that they Receive what they Reflect, from the Sun; for 'tis plain, that *Mercury*, when it has passed between us and the *Sun*, has appeared a small Dark Spot, and some have affirmed to have seen the Phase of it through a Telescope, to appear Horned like a New Moon, though I never yet observed it so my self. But as for *Venus*, I have very often observed the Changes in her, and found her as sharp as the Moon, two days before or after the Conjunction, without the least Appearance of Light on the other part of her Body; and *Mars* I have observed a little wained, but as for *Jupiter*, I have divers times plainly seen the Shadow of one of the *Satellites* pass over its Disk, as well as the *Satellites* eclipsed by the Shadow of the Body of *Jupiter*; so that both the Body of *Jupiter* and the *Satellites* about it, do shine only from the Reflection of the Light of the *Sun*. We have no reason to doubt but that the Light of *Saturn* and its *Satellites* proceed from the same Cause, and that because as the Body of *Saturn* is so much further removed both from the *Sun* and us, so the Light is considerably more Dull and Weak. And besides, I have several times plainly seen the Shadow of the Ring upon *Saturn*, which could not be, if the cause of its Light did not proceed from the *Sun*. So that upon the whole, we have sufficient Grounds to conclude that the Light of all the Planets proceeds from the Light of the Sun reflected from them to us; and consequently, that the emitted Light of all Celestial Bodies is much of the Nature of the Lights of the Fires we have here upon the Earth.

Terrestrial Luminous Objects. 2. We come then in the next place to consider such Bodies as are within our reach, that emit a Light of their own; that so by a Scrutiny of them we may find out the Cause and Reason of Light.

Of these we have a vast Number of all Bodies almost, by some means or other affording us Instances of this Luciferous Nature, but they may all be reduced to a few general Classes or Heads, under which Classes they may be easily ranged in some respect or other.

1. Sulphureous Bodies, &c. The First and Principal, and the most general of all the rest, and which may most properly be said, of such Bodies as emit their own Light, or to produce Light from themselves, are all Sulphureous, Unctuous, Resinous or Spirituous Bodies, which will being first heated, be burnt or Dissolved by the Air, as a *Menstruum*; for all such Bodies, whilst they are thus Dissolved or Burnt, emit a considerable Light.

This Head therefore comprises all combustible Bodies, which are either Mineral, as *Sulphur*, *Cole*, *Asphaltum*, *Bitumen*, *Petroleum*, and the like; or Vegetable,

getable; almost all Parts of which, except the Watry, are Combustible and Dissoluble by the Air.

Or, Thirdly, Animal Substances; all the Oily or Fatty Parts of which are likewise Combustible, but the Watery and Earthy Parts are not.

Now all these Substances being first heated to a certain Degree, some more, some less, will by the Air be preyed upon and dissolved, in which Action of Dissolution or Burning, Light is produced: And 'tis very evident that that Action is necessary to the effect of Light, for that before the Consumption or Dissolution begins, and after it is finished, there is no Light produced, but only during the time of the Dissolution. And this may be farther argued from this, that the faster and quicker the Dissolution is made, the more strong and vivid is the Light; and the slower; the more weak and languid; and therefore, the more of the *Menstruum* of the Air is applied to the Dissolving Body, the more quick is the Dissolution performed, and the brighter is the Light, as is well known in the blowing of Fire with Bellows, whereby a quick supply of fresh Air, is brought to the burning Body, which is sufficiently known to all People, though not under this Notion: Most People suppose it to be only for blowing away the Ashes, and so by that means shewing or discovering the Fire that lies underneath them; but I have proved by divers Trials, that 'tis not the Motion of the Air by the Bellows, for removing the Ashes or driving off the burning Parts that does any thing in this Effect; because if the Air that is so blown be first satiated and then blown on it, it produces no other effect than to blow off the Ashes, and blow out the Fire; for the more you blow the more dead is the Light, and the sooner is the Fire quite extinct; insomuch that in a very short time the Coles all become perfectly Black, without emitting the least glimpse of Light or Shining, at which time if one blast of fresh Air be blown upon those seemingly dead extinct and black Coles, they all immediately begin to Glow, Burn, and Shine afresh, as if they had not been at all extinct; and the more fresh Air is blowed upon them, the more they shine, and the sooner are they Burnt out and Consumed. So that 'tis the fresh Air that is the Life of the Fire, and without a Constant supply of that it will go out and Die.

Somewhat like this is observable in the Life of Animals, who live no longer than they have a constant supply of fresh Air to breath, and, as it were, blow the Fire of Life; for so soon as that supply is wanting, the Fire goes out, and the Animal dies, and all the other vital Functions cease; as any one may presently see, if he puts a small Animal as a Bird, or the like, into a small Glass and covers it close; for in a short time the Air becomes satiated, and is no longer fit for Respiration; but though the Animal breath it as before, and Pant and move his Lungs as before; yet if the Air be not fresh, the Fire of Life will extinguish. Some Learned Philosophers and Physitians have been of the Opinion, that the use of Breathing was for nothing else, but that by the Motion of the Lungs the Blood might be kept circulating which past through them, or that the Steams of the Blood might be carried off, which it could not do when it was full of Steams; but by many Trials I have proved that neither of those are at all the Cause of the Death of the Creature, but only the want of fresh Air.

For whether the Lungs move or not move, if fresh Air be supplied, the Animal lives, if it be wanting, it dies. Again, If the Air be full of Steams or not full of Steams, it is all one, the Animal lives if it be fresh, but if it be not, it dies; nor does the heat or Cold of it do any thing. But this only by the by, being more proper to another Time and Discourse; my present Inquiry being after the Nature and Cause of Light. This then is one of the Classes of shining Bodies; namely, such as are Dissoluble or Burnable by the Air.

The next Class are all such Bodies as are not combustible, but are so fixt as to indure a great degree of Heat, without being subject to flie away or be dispersed into Vapours; such are all sorts of Metals, Stones, Earths, Clays, Salts, Sands, White Burnt Bones, Ashes of Vegetable and Animal Substances, and the like; Every one of which when heated to a certain Degree of Heat, will Shine or afford Light; but under a certain Degree will not shine at all. *2. Shining Bodies not Combustible, but heated.*

Now

Now there are great Varieties of these Degrees, for that some will not begin to shine till, 'they have a very intense and violent Heat, others with a small Degree, insomuch that I lately saw the Pouder of a Stone which laid upon a Plate of Metal, and held over a Chafingdish of Coles, would presently, and with a small Heat begin to shine, but so soon as the Plate cooled, would leave off shining, but the Plate being warmed again, it would again shine; and almost every Body has a peculiar Degree of Heat, at which it begins its shining; so that there are almost as many Varieties of Degrees of Heat to make Bodies shine, as there are to make Bodies flow and melt; some will shine before they melt, as almost all the harder Bodies; as Gold, Silver, Copper, Brass, Iron, Stones, Earths, *&c.* others will Melt before they Shine, as Tin, Lead, Saltpeter, Allum, Vitriol, Tallow, Gums, *&c.*

3. Bodies shining without Heat. In the Third Class are all such Bodies as shine without Heat, by an inward Fermentation, in which though their Light be but small, yet does it become visible enough in a darkned Room or in the Night; such are Glow-worms, *Scolopendra*, several kind of Flies, decaying Fish, as Whitings, Oysters, and many others, sometimes Flesh, as Veal; also rotten Wood, and some sorts of Putrifying Vegetables, also some Putrifying Urines; also the *Phosphorus* made out of the *Caput Mortuum*, or the Rob of Urine found out by Dr. *Kunkell*, and many others.

4. Bodies shining by an Impression of Light. In the Fourth Class are such as shine by the Impression of Light made upon them, by being exposed only to the Light of the Sun or the Day. Such are the Preparation of the *Bononian stone*, and the Preparation lately found out of common Chalk by Dr. *Baldwin*; these receive such a Power from the Influence of the Light, that being carried into a Dark Room after they have been exposed to the Light, they then appear to shine like a Cole of Fire, and continue so to do for a pretty while, but will by degrees lose their Light, and be extinct almost in the manner as a Piece of Red hot Iron; but being again exposed to the Light of the Sun, or a Window, they presently reassume their shining Quality.

5. Bodies shining by Motion. In the Fifth Class are all such as shine by Motion, Diamants, Sea-Water, some sort of Dews, Sugar, Black Silk, the Back of a Cat, and clean warmed Linnen, as has been lately experimented by Dr. *Crone*, and several other Substances which will shine with a degree of Motion or a little rubbing.

To this Head also, may be referred several others also which require a great Degree of Heating or Rubbing, as Iron and some other Metals which may be made Red Hot, or to shine with Hammering only, two hard Stones as Flints and the like, struck one against the other, two Pieces of Wood which with Rubbing will take fire, and the like.

3. These several sorts of Lights are to be the Guides which must conduct us in our search after the true Nature of Light, nor can the Truth of the Theory be fully Discover'd, 'till every one of these Witnesses and Testimonies are thoroughly examined, and that by comparing the Evidences that each of them shall bring distinctly, with those of every one of the other, there being such Axioms and Maxims founded, as will open a way to the clear Knowledge of this most abstruse and difficult Science of Light. From which as all the visible Appearances derive their Original, so the greatest part of the Knowledge and Information of Mankind; for the Explication of which, the Theory of Vision, and the structure of the Eye, the Organ of that Sense, and all the Powers and Modifications and effects of the Rays of Light: And so the Theory of *Opticks*, *Dioptricks*, *Catoptricks*, Perspective and Projections, and Cromatick, or the Theory of Position, Modification and Effect of the Rays of Light, whether Direct, Refracted, or Reflected, or Compounded on the various Superficies on which they are incident; every of which I design (God Willing) fully to explicate. So also the Velocity and Modification of all the Motions of the Celestial Bodies, *viz.* both the primary and secundary Planets, have their Original and Cause, as I shall hereafter plainly and fully demonstrate.

It

It would be too long here to recount to you the whole proceſs of the Examination of theſe Evidences, and the whole proceeding, with thoſe Evidences; by comparing every one, with every other, ſingly; and then, many together, with ſuch a peculiar Number of many others; whereby the Nature and Cauſe, and the Characteriſtick of Light in General is diſcovered; and then, to diſcover what is the peculiar cauſe of it in this, and that, and t'other particular Body, from whence it proceeds. It will ſuffice at this time to tell you the Reſult and Concluſion; for that the Proceſs is long and tedious, and not attained but by many Steps and Degrees. *Light then is nothing elſe but a peculiar Motion of the parts of the Luminous Body, which does affect a fluid Body that incompaſſes the Luminous Body, which is perfectly fluid, and perfectly Denſe, ſo as not to admit of any farther Condenſation; but that the Parts next the Luminous Body being moved, the whole Expanſum of that fluid is moved likewiſe.* So that any aſſignable Parts next the Luminous body being protruded a certain aſſignable Space, that protrudes all the vaſt *Expanſum* of the fluid, every way *in orbem*, at the ſame Inſtant an aſſignable Space: So that no one Atom, or Point of it, to all imaginable Diſtance, but is at the ſame time moved with it, or protruded forward: For Inſtance, When a Luminous Part of the Sun is moved with the Motion of Light, it does at the ſame Inſtant, move the Parts of the Incompaſſing fluid, which is the proper *Medium* of Light, with the Motion of Light; which part cannot ſo be moved, but that all the Parts of that *Medium*, to the extent of the World, muſt be moved at the ſame Inſtant, and protruded from the Luminous Point in a direct Line; ſo that at the ſame Inſtant, that the *Apex* of the Cone is moved, the ſpherical baſe of that Cone alſo is moved, and every imaginary Spherical Superficies, that is parallel to that baſe, is moved likewiſe.

Definition of Light, what it is.

This Conſequence will follow of neceſſity, from the Definition of the Nature of the *Medium*, that is proper for the conveyance of Light. And that is, that it is a *Medium perfectly Denſe*; that is, ſuch as will not be by any Power forced into leſs Dimenſions than it is contained in, but does compleatly fill and maintain that ſpace. And, Secondly, From its *perfect fluidity*, it does accommodate it ſelf to all manner of Forms, ſo as exactly to ſhape it ſelf into the new Form that is given to it, by the Motion of Light.

The Medium of Light is perfectly Denſe.

For Inſtance, If we imagine A B C to Repreſent an hollow Conical Body, Indefinitely extended from the Point A, which is the Apex towards B C, and at the ſame time imagine alſo this hollow Conical Body, fill'd with a Body perfectly fluid, and perfectly Denſe; that is, ſuch as will perfectly accommodate it ſelf to the Figure of that Cone, and intirely fill the Cavity of it, ſo as not to leave the leaſt Point of it unfilled; and that will not admit of any manner of Condenſation into a leſs Room: If then we imagine, that by the firſt ſtroke of the Motion of Light, the Parts of the fluid that fill th Apex *A d n*, be driven forward toward the baſe, into the ſpace *d n e o*, equal to it in quantity; it muſt at the ſame Inſtant drive that part of the fluid that fill'd the ſpace *d n e o*, into the ſpace *e o p f*, equal to it in quantity, and that which fill'd the ſpace *e o p f*, muſt at the ſame time be protruded into the ſpace *f p q g*, of the ſame quantity; and ſo onward *f p q g*, into *g q r h*, and *g q r h* into *h r ſ i*, *in Infinitum*, or to the utmoſt extent of the Cone, and filling fluid Matter; ſo that at the ſame time that the Parts that made the imaginary Spherical Baſe, *d n*, of the Cone *A d n* are moved into the imaginary Spherical Baſe *e o*, of the Cone *A e o*; will the imaginary Spherical Superficies, *l u*, of the Cone *A l u* be moved into the Place of the imaginary Spherical Baſe *m x*, of the Cone *A m x*, though never ſo far removed from the Apex *A*: So that a Body perfectly denſe, and perfectly fluid, muſt communicate ſuch a Motion begun, to all imaginable Diſtance in an Inſtant. It being impoſſible that the Apex of the Cone *A d n* can be moved into the ſpace *d n o e*, without moving at the ſame time, every part of all the reſt of ſuch a Cone, to the utmoſt Extenſion.

Fig. 5. Plate 1.

The further conſideration then of this Cone, will give us the Reaſons, and Grounds of the three I have already named, and of ſeveral other Proprieties of Light, and make them very intelligible and plain to be underſtood, and eaſy to be demonſtrated.

Reason of the Decrease of the Power of Light.

As, First, From hence we may understand the Reason of the Force and Power of Light, at several Distances from the Luminous Body; for according to the Increase of the imaginary Bases of the parts of the Cones, and according to the Decrease of the Thickness of the several Parts; so is the Decrease of the Power of Light at those several Distances. For, First, It is clear that the same Quantity of Motion, and consequently of Light, that there is is in the first Cone or Apex *A d n*, the same is there in the last part *l u x m*, and in every other intermediate Part, as *d n o e*, *e o p f*, *f p q g*, *g q r h*, and the rest; so that if we compute it first according to the Expansion of the Imaginary Base; we shall find that those increase in a Duplicate Proportion, that is, as the Squares of the several Distances, as at ten times the Distance, the Expansion is a Hundred times the space; and consequently the same quantity of Motion is expanded into a Hundred times the space, and therefore an equal space of the Superficies of that, at ten times the Distance, will have but $\frac{1}{100}$ Part of the Motion or Light that is upon the Superficies at once the Distance. This therefore will be represented by the Sections of a Conical Body, made by turning the Hyperbola round upon the Asymtot; for the Ordinates to the Asymtot being in reciprocal Proportion to the intercepted Parts of the Asymptot, the Squares or Circles of those Asymptots, must be in Duplicate Proportion of the intercepted Parts of the Asymptot Reciprocally. This is the Proportion that the ingenious *Kepler*, allows to the Decrease of Light, supposing it to be only in Duplicate Proportion of the Distance Reciprocal; and according to this, he founds the Proportion of the Power of the Sun in moving the Planetary Bodies at several Distances; but he ought to have considered also another Decrease of the Power of the Light, according to the Decrease of Thickness, of the base Parts of the Cone. For since in all the Imaginary equal Parts of the Cones, there is the same quantity of Matter, if the same be Expanded in Breadth, it must be diminished in thickness. If therefore at ten Foot Distance, for Instance, it be spread into a Breadth 100 times as big as at one foot distance, then consequently to make the equality of Content in the one and the other, there must be but $\frac{1}{100}$ part of the thickness.

For if at the Distances ———	1,	2,	3,	4,	5,	6,	7,	8,	&c.
The Superficies or Bases expanded be as —	1,	4,	9,	16,	25,	36,	49,	64,	&c.
Then the Thickness of those Bases must be as	1,	$\frac{1}{4}$,	$\frac{1}{9}$,	$\frac{1}{16}$,	$\frac{1}{25}$,	$\frac{1}{36}$,	$\frac{1}{49}$,	$\frac{1}{64}$,	&c.

These then will give the Proportions of the length of the Pulses or strokes of Light, at several distances from the Luminous Body, and consequently the Velocity of those Pulses. So that according to these Rules, the Force or Power of Light must decrease in quadruplicate Proportion of the Distances reciprocally taken; that is, as the squared Squares of the Distances Reciprocally; and consequently, as I shall afterwards shew the effect of Light, or the Motion it causes in other Bodies, will be in Subduplicate Proportion of the Powers, and therefore only in Duplicate Proportion of the Distances Reciprocally taken.

So that thence it is evident, that Light does act according to the Proportion of a Body moved, observing exactly the same Proportions, and therefore can be nothing else but that; for what Thing soever hath all the same Proprieties with another, must be the same,

Bulialdus's Notion rejected.

It is not therefore what the Learned and Ingenious *Bulialdus* would have it to be; namely, a certain Substance which is a Geometrical *Medium*, between a Body and a Spirit. *Lux est*, (says he) *media Proportionalis inter corpoream substantiam & Incorpoream:* Light is a middle proportional Substance, between a corporeal Substance, and an incorporeal. A middle proportional (says he) is that which between two extream Lines, does equally divide the Rationes of both, and which does participate of the Excesses and Defects, and communicates the same Habitudes with both; and by how many of its parts it is exceeded by the Greater, by so many parts of the Less does it exceed that. For Instance, says he, Let *A E* be an incorporeal Substance, and *C* a Corporeal. The incorporeal Substance *A E*, exceeds the corporeal Substance *C*, by the Excess

D E,

D E, to wit, by instantaneous Motion and Penetration of solid Bodies; but the corporeal Substance *C*, is defective of the Incorporeal by its Termination and successive Motion. Now we must find a middle proportionate Substance, which is defective of the Incorporeal, and exceeds the Corporeal, but a middle proportional does participate of the Excess and Defect. Now *B G* (the Substance of Light) is defective of *A E*, in Termination and successive Motion, but it exceeds *C* in instantaneous Motion and Penetration. Now that Substance which is defective of one, and exceeds the other, is a Medium, but Light is such a Substance, which by its Penetration and instantaneous Motion, exceeds a corporeal Substance; but it is defective of Incorporeal Substance, in its Termination and Successive Motion. This is his Demonstration, but how much more instructed we are by it, of the Nature of Light, I shall leave to every Man to judge. It is, I confess, above my reach to conceive what Substance 'tis he should mean; it being perfectly new and not thought of before, that ever I could meet with; nor can I see what need he had of supposing any such Substance. For since the same Proprieties that are found in Light are found in Corporeal Substances, or Bodies, as I have before mentioned; I see no reason why on this Account, we have any Reason either to suppose an Incorporeal Substance, or a Substance of a middle Nature, between Incorporeal and Corporeal. 'Tis to me, I confess, very difficult to conceive what a Corporeal Substance is; nor can I have any more clear Conception of what is meant by that Expression, than what I would express by these two Words; *somewhat extended*, which how that differs from a *Vacuum*, or an Extension, without Substance, or an extended Nothing, is not easy to be understood by one that throughly considers his own Conceptions.

Des Cartes therefore makes Extension and Body, or corporeal Substance, to be one and the same thing; and that no other Substance but Body, or Corporeal, can be extended.

But to leave these Metaphysical Notions, 'tis clear from what I have shewn, that as to this Subject, Light, there is no need of supposing any other Substance, but Corporeal, or Body; and that, so and so qualified; that is, perfectly Fluid, and perfectly Dense, and so Receptive and Communicative, of all manner of Motion.

As to the Notion therefore of the Substance of Light; I know not what can be farther added, that is more known or more Intelligible than that it is; First, A Substance, or a something; that is infinitely fluid, or at least, indefinitely; if that be more conceivable, whose least conceivable Part is free from cohesion with any other, and so is susceptible of any kind of Motion, without carrying or moving along with it the Lateral Bodies, whereby it only communicates the Motion it receives behind, to the Parts that lie immediately before it; whence follows that great Propriety of Light, that in a uniform Medium, it propagates its Motion every way in direct Lines or Rays, from a Center of a Sphere. *The true Notion of Light.*

And, Secondly, That it is a Substance, or something that compleatly fills an Extension or Quantity every way extended, and cannot be condensed, or forced into less Extension, Space, or Room, by any Natural Power; but that the same Substance will always have the same Quantity, or Extension, one way or other; what it wants in one, it will have in one or both of the other Dimensions; as what it wants in breadth it will have in thickness, or in length, that shall recompence the whole, and bring it to equality.

Thirdly, That this, as all other Bodies, is susceptive and communicative of all manner of Motion, but is more appropriated to Motion of such a Degree of Swiftness, which is in proportion to the Motion of other Bodies, whose least part is solid and bulky, as the bigness of the one, to the bigness of the other, Reciprocally taken. This may serve for the Explication of the Substance of Light.

4. The next thing we are to consider, is, the Motion of Light, which is the principal thing considerable in it; for the Substance without the Motion has no effect, nor has the substance Light; 'tis that we are sensible of, and not of the Substance; so that be the Substance what it will, whether Corporeal, or Incorporeal, *Of the Motion of Light.*

corporeal, or Middle, Proportional, or None; provided we know what the Motion is, and the Rules, Powers, and Proportions of that, we need not much consider the Substance of it.

In the Consideration then of Motion these thing are observable.

1. The Quantity.
2. The Quality.
3. The Power.

By the quantity of Motion, I understand only the Degrees of Velocity existent in a certain Quantity of Matter.

By the Qualities of Motion, I mean the Modifications of it in Body, as whether it be Simple or Compound, Reflected, Refracted, Direct or Oblique, and the like.

By the Power, I mean the Act or Effect it produces upon other Bodies, in agitating or moving them.

In the Consideration of every one of which, I shall indeavour to reduce the Theory to Calculation and Mathematical Exactness; without which, all other ways are but Random Guesses, and make no certain and demonstrative Conclusions.

Sound how caused.

The Motion produced by the Lucid Particles must be of a certain Degree of Swiftness; otherwise, it is not propagated in the form of Light, for 'tis not every Motion that produces that Effect; for 'tis in Light, as it is in Sound; that the Motion must be of a certain Degree of Swiftness, before Motion will be propagated in the Medium that conveys it: we find that moving a Stick in the Air, if we move it but slowly, we hear no Sound; because the Motion is so slow, that the Parts of the Air that were before it do easily move round the Sides of the Stick and come behind it; so that only those Parts of the Air are moved that lie near the Stick, which do only receive such a circulating Motion as brings them from before to come behind, the ambient Parts of the Air having Power enough to reflect and keep in that Motion, so as only to circulate about the Stick; but if the Motion of the Stick be so swift, as that the Particles before it over power the Resistance of the ambient Air, so that its Motion is not reflexed backwards, but propagated directly forward into the Air, then Sound is generated and propagated from the Stick, every way *in orbem*; whence if you give a very quick Motion to the Stick in the Air, you presently hear a Noise.

A certain Degree of Heat produces Light.

In the same manner, if you take a piece of the most fixed Body that will indure the Fire; as for Instance, a piece of pure Gold, or refined Silver, which will not wast nor burn by heating; if you heat it but with a smaller Degree of Heat, you will not perceive it to shine or give any kind of Light; but if you continue to Augment the Heat to a certain Degree it will begin to shine, and appear Red Hot, as we call it; and if it be heat more, it shines brighter; but if you take it from the Fire, and permit it to cool, its Light grows fainter and fainter, and when it is come to a certain Degree of Heat, it ceases to shine at all, and emits no Light. Now Heat, as I shall afterward prove, is nothing but the internal Motion of the Particles of Body; and the hotter a Body is, the more violently are the Particles moved, and with a quick Motion; but the Particles of Bodies, according as they are more bulky and close, so do they require the greater Degrees of Motion, to make them move with an equal Degree of Motion, with that of smaller Particles; as I shall afterwards prove, when I come to give the Laws and Rules of Motion propagated from Body to Body. In the same manner in such Diamants, as will shine like a Gloworm in the Dark, (for all Diamants will not; but I have seen and tryed many Diamants that would;) the Stone will not begin to shine 'till it has received a certain Degree of rubbing and Agitation, but beyond that Degree, the more you rub it the more it shines, and any little stroke upon it with the Nail of ones Finger, when it so shines, will make it seem to flash. The like I have lately observed in the Phosporus of *Kunkell*, that the rubbing it a little with ones Finger, does make it glow, and as it were flame. So if you take a Piece of Cold Iron, and

Ham-

hammer it on an Anvil, you muſt continue hammering it very ſtrong and quick a good while, before you will perceive it to begin to ſhine; but if you continue to work it with a Hammer for a certain ſpace, it will ſhine very briskly; and grow, as we call it, Red Hot. Now in all theſe Inſtances, and a Hundred more I could produce, 'tis evident that there muſt be a certain Degree of Hammering, Rubbing, or Heating, before the Body ſo wrought on will produce Light: All which do effect an internal Motion of the parts of the Bodies ſo Hammered, Rubbed, or Heated; 'tis therefore evident, that 'tis not every Motion of the Particles of Bodies that will produce Light, but a certain Degree of it; under which no Light is produced, and beyond which the Light is increaſed and augmented.

This kind of internal Motion therefore in the Parts of the Body, is that which produces Light; whatſoever therefore produces this Motion, produces Light; whether it be heat, as in all very fixt Bodys, or Fire, which, as I told you before, is a Diſſolution of the Body by the Air, as in all Unctuous, Reſinous, or Sulphureous Bodies; or Hammering and Strokes, as in Stones, Chryſtals, Diamants, Sugar, *&c.*; or Fermentation and Corruption, as in Fiſh, Glow-worms, Rotten-Wood; or the Motion of Light it ſelf, as in the Bononian-Stone, and Dr. *Baldwin*'s Phoſphoros, and in almoſt all other Bodies held in the Focus of a Burning Glaſs. Light therefore in the Object, is a peculiar kind of Internal Motion of the Particles.

What Light is in the Medium.

The propagation of this Motion into, and through the incompaſſing Medium is that we call Light in the Medium, or the ſpace between the Inlightning and Inlightned Body. This propagation of Motion, as I ſaid before, is every way *in orbem*; and it may be cauſed either by an Immediate pulſe of the Particles of the Body againſt the Parts of the incompaſſing Fluid, as a Stone ſtriking againſt the Water, from whence the Waves of Motion are there propagated in Rings; or elſe by the extruſion of the Part of the Fluid Medium of Light that lies between the ſolid Particles of the ſhining Body; as Water ſqueezed out of a Spunge into Water, or Water forced out of a Syringe, or Pipe, into Water, which will produce the ſame Rings in the Surface of the Water. It ſeems to be in ſome Caſes One way, and in ſome Caſes the other. In burning Bodies, it ſeems to be the firſt way, where every Particle of the Body Diſſolved flies aſunder, and is rarified or diſperſed into a bigger ſpace, in the manner as we may obſerve in the firing of a Grain of Gunpouder, which we ſee expands into a Sphere of Flame, which extrudes and evacuates a Sphere of Air round about the fired Grain. But in hammered Bodies, and ſome other I have named, it ſeems to be the other.

If we therefore conſider what Effects follow in theſe ſenſible Examples, we may the more certainly conclude what muſt follow in the more inſenſible.

The Grain of Gunpouder, then, when it is fired, rarifies it ſelf into a Sphere near a Hundred times as big in Diameter, or one Million times as big in Bulk; this extrudes all the Air that was contained in that Sphere into a Space or Orb without it, and incompaſſing it, large enough to contain it; and conſequently muſt remove the Air that fill'd that ſpace into another ſpace without that, and that the next, and ſo onward ſucceſſively to a certain Diſtance; 'till at laſt the Medium of the Air being a Springy, Rarified, or Yielding Medium, and not a Denſe and Unyielding Medium, the Motion is at length loſt, and ſo this ſound audible but to a certain Diſtance. Whereas in the propagation of Light, the *Medium* being perfectly Denſe and Unyielding, that Propagation is continued *in Infinitum*, or to the utmoſt extent of the *Medium*. The ſolidity therefore of the incompaſſing Spheres, will be to one another as 1, 2, 3, 4, *&c.* in Arithmetical Progreſſion; and conſequently the Diameters of thoſe Spheres will be as $\sqrt{c\,1}$. $\sqrt{c\,2}$. $\sqrt{c\,3}$. $\sqrt{c\,4}$. and ſo onwards; and conſequently if you take the Diameters of the contained, from the Diameters of the containing, the Remainders will be the thickneſs of the containing ſhell; that is, the $\sqrt{c\,1}$. will be the length of the ſtroke of the Pulſe of Light in the firſt ſpace; $\sqrt{c\,2}$.—$\sqrt{c\,1}$. the

 length

length of the ſtroke of that Pulſe in the ſecond ſpace; $\sqrt{c\,3}.-\sqrt{c\,2}.$ the length of the ſtroke in the third; $\sqrt{c\,4}.-\sqrt{c\,3}.$ in the fourth, *&c.* ſo that thoſe indefinitely continued, will be very near to a Series of Numbers in the ſame Proportion, with the ſuperficies of the Spheres reciprocally taken, and conſequently the length of the ſtroke of the Pulſe of Light, will be in duplicate Proportion to the diſtance reciprocal.

I have been the more particular in the Explication of this Power of Light, becauſe, as I ſhall afterwards prove to you, this is the Power of Celeſtial Bodies by which they Act upon, and attract each other; and by which all the Primary Planets that move about the Sun are regulated in Velocities, Diſtances and Motions, whether circular or Oval. As alſo all the ſecundary Planets, as the Moon about the Earth, and the Satellites about *Saturn* and *Jupiter*, make their Periods. And from the true ſtating of this Power, and the Effects of it on Bodies at ſeveral Diſtances, all the Theory of Aſtronomy will be deduced a *Priori*, with Geometrical Certainty and Exactneſs; and conſequently the Tables and Numbers will be eaſily adapted, which will tend to the Perfection of that Noble Science.

SECT.

SECT. V.

A Continuation of the former Subject of Light. Being the Lectures read in June, 1681.

The CONTENTS.

1. *Having ſhewn what Light is in the Luminous Body and* Medium, *the Author comes in the third Place to ſhew the Operations it hath on the Subject; the chief of which is, that Effect it has on the Eye; to which End he gives a particular Explication of the Fabrick of this admirable Organ, in which there are infinite receptive Points within, to receive all the Rays from the Infinite Points without. Viſion is made by reuniting all the Rays proceeding from one Point of the Object, after they have been ſcattered into one Point again.* 2. *A Second Way of conceiving how the Eye multiplies the Power that was by the* Hypotheſis *before explained,* i. e. *that according to the length of the Stroak or Pulſe, ſo is the Power or Strength of Light. Effects of Burning Glaſſes explained and applied to this purpoſe; that the length of the Pulſe at the* Focus *thereof is the ſame with the length of the Pulſe at the Sun.* 3. *The Action of the Eye much the ſame with that of a Burning-Glaſs; ſo that the impreſſion on the* Retina *is the ſame, as if the Action of the Object were really there.* 4. *Why the Eye is not hurt by the Object, tho' it, as it were, feels and touches it: And this is, becauſe it takes in, the* Baſis *but of a very ſmall* Cone *of* Rays *from the radiating Sphere; ſo that tho' the Velocity or length of the Pulſe be the ſame, yet there being but few, their collected Power is leſs; and this is perform'd by the Contraction of the* Pupilla; *whence the Eye becomes weakned by bright Objects, and why we can look on the Sun thro' a very ſmall Hole.* 5. *The Fabrick of the Eye and all its parts, as far as relates to Opticks, examined, and is neceſſary to the preſent Deſign; the more particular Examination of the Parts, and its Humours, being refer'd to the Nature of Refraction.* 6. *An artificial Eye very uſeful for the thorough Underſtanding of Viſion. The Deſcription and uſe af a Perſpective Box, inſtead of a dark Room, which will explicate all the* Phenomena *of Viſion as they are repreſented in the bottom of the Eye. An Explication of Shadows or the defect of Light.* R. W.

I Have in ſome of my former Lectures in this place, explained to you the Nature and Proprieties of Light; and ſhew'd to you what it is in the Luminous Body from whence it proceeds, and what it is in the Medium, through which it is propagated: I ſhew'd you how it came to be propagated every way *in Orbem*, to all imaginable diſtance in an Inſtant, and with what proportion of Strength it was ſo propagated to all aſſignable Diſtances from the Lucid Object; and thence I deduced with what Power it operated, and thereby produced Effects on thoſe Subjects, on which it was impreſſed.

The

What Effect Light has on the Eye.

The first and Principal of all the Operations it hath on Subjects, is that effect which it hath upon the Organ of the seeing Eye, wherein it maketh such an Impression as becomes sensible to the Animal Faculty. This then is the next thing I shall indeavour to explain; namely, the Action or Effect of Light upon the Eye.

For the doing of which, I shall first consider the Fabrick and Make of that Organ. Secondly, The manner how Light comes to operate upon it.

An Explication of the Eye.

First, For the Fabrick of the Eye, It is in it self so truly admirable, that there is nothing in the whole Creation better deserves our Contemplation, and wherein the Wisdom and Design of the Great Creator more sensibly appears; for as of all created Beings, those which are animated seem to have the greatest Contrivance; every thing in each of them seeming to be contrived on purpose, and with a Design, respecting the end of their being and well-being, and continuation either in the individual, or in the Species propagated. So among those animated Bodies, Animals seem to abound with more excellent contrivances than Plants; and of Animals some are yet more curious and perfect than some others; that is, have more Contrivance and Perfection of Organisation and Mechanism than others; though every thing in its kind be furnish'd with those Faculties which are requisite to perform those Functions which are necessary to their Preservation. Now of all the Organisations of Animals, none are more admirable than those of the Senses, and of those, none, that we know, more wonderful than that of Sight, wherein we shall find every thing so adapted for Matter, Form, Situation, Motion, and the like; that it does far exceed the Contrivance of the Wit of Man to come near it, even in Imitation. And yet we find that all things are Consonant and Congruous to our Understanding, and we cannot chuse but approve and admire the great Wisdom and Contrivance of the Maker; so that we may even from thence clearly and demonstratively see, that the Reason of Man is a spark of the Divine Influence, and that whatever is done in the World is adequate to the Principles and Ground of Reason implanted in our Understanding and Knowledge; and that all things are formed and act with Design and Respect to the End, and not fortuitously and by chance.

For an Instance of this, we cannot in Nature pitch upon a better than the Fabrick of the Eye, in which we shall find every thing adapted and formed for that particular part of performing Vision; which is to be performed by it; and every part has its necessity to make up the perfect Effect, and no one is redundant, and there is no part defective.

The Radiations of Light I have formerly Explained, are continually Propagated from every Luminous Object, and from every Point of every Luminous Object, every way from every one of those Points *in Orbem*; as the Rays from a Sphere: So that as there are infinite of those radiating Points in the World, so from every one of those infinite Points there are infinite of those Radiations; so that the Luminous *Medium* has infinite Radiations in every Point thereof; to wit, a single Radiation from every one of those infinite Radiating Points. Now these Radiating Points are not only all such as send out their own Light which is generated in themselves, but all such likewise, as by Reflection or Refraction, are the Causes of reflecting or dispersing the Light, received from other Luminous Bodies. Now the Eye is an Organ or Instrument by which all those infinite Rays that are thus jumbled and blended together, and so might be thought impossible to be separated, are so curiously sifted, culled, separated, and parted from each other, that they are all again made distinct, and every one of them appropriated, as it were, to is distinct Point or Cell. So that as there are infinite of those Radiating Points without the Eye that emit those Beams; so there are infinite of those receptive Points within the Eye that receive them, each of which Points do only receive the Radiations from one of those infinite Points without, and from no other whatsoever at the same time. Now it is not only a Separation of these Rays thus passing in one single Point

only

only of the Luminous Medium, for that would ſeem to be more eaſy, but it is a Separation of all thoſe infinitely infinite Rays that paſs through the infinite Points that are in a Superficies as big as the Pupil, or Black Hole of the Eye, and a Reunion of all thoſe radiations that come from any one Point, into one Point again; ſo that the Eye may not improperly be called a Microcoſm, or a little World; it having a diſtinct Point within it ſelf, for every diſtinct Point without it ſelf in the Univerſe; and when a Hemiſphere of the Heavens is open to its view, it has a Hemiſphere within it ſelf, wherein there are as many Reſpective Points for Reception of the Radiations, as there are differing Points for emiſſion of Radiations, and all thoſe infinitely infinite Radiations, which proceed from that whole Hemiſphere of the Univerſe, and paſs through the *Area* of the Superficies of the Pupil of the Eye, are by this truly wonderful Contrivance of the Eye, ſeparated from each other, and conveyed to the diſtinct cells of the Microcoſm of the Eye. For the exact and curious Performance of which Work, the Fabrick of the Eye is ſo curiouſly contrived, that 'tis beyond the Wit of Man to imagine any thing could have been more compleat. Nay, It could never have entred into the Imagination, or thought of Man to conceive, how ſuch a Senſation as Viſion could be performed, had not the all Wiſe Contriver of the World endued him with the Faculty and Organ of ſeeing it ſelf. How could it have entred into the Imagination of Man to conceive, how it ſhould be poſſible for ſuch an Atom of the Univerſe as Man is, to be informed at the Inſtant that a thing is done, how and where it is done, though Million of Millions of Miles diſtant? Certainly no more than we can now imagine how it ſhould be poſſible for any Man here in *London* to know the particular Thoughts and Inclinations of any one ſingle Man in *China* or *Japan*, or of all the *Chineſe* or *Japaneſe* together, at the ſame Inſtant they are thought there.

Now the contrivance of the Eye is not more admirable for its Power of ſeparating differing Rays from differing Points, one from another, than it is for congregating and culling all the infinite Rays that come from one Point, and Reuniting them again into one Point; for by this, principally, is Viſion made. This is that which makes the Rays produce ſo powerful an Effect as to be ſenſible to the Animal. Now this will appear more plain if we conſider the Explication I have formerly given of the Cauſe of Light in the *Medium*, and the manner of its inſtantaneous Progreſſion through it. This I ſhew'd you was a Motion or Pulſe cauſed by the Protruſion of the Bodies about the Center, a certain ſpace every way in *Orbem*, towards the Circumference. Now though the length of this Pulſe at the Luminous Body, as the Sun, from the Center outwards, ſhould be an Inch perhaps; yet ſince the length of that Pulſe doth decreaſe continually in duplicate Proportion of the Diſtance, reciprocally taken from the Luminous Body; the length of the Pulſe of Light here with us would not be the 1000000 Part of the thickneſs of a Hair; now what can we imagine or conceive could be ſo curiouſly ſenſible as to be moved thereby, or that the animated Body, or any part of it, could be ſenſible of it, or affected by it? certainly it could not, and therefore the all Wiſe Creator contrived the Eye to be an Organ to reſtore again the Strength of that Pulſe, which was deſtroyed by the great interpoſed Diſtance; for by the means hereof, the Pulſe that was, by diſtance, ſhortned Million of Millions of times of the length it had at the Luminous Point; is by the reunion of them by the Eye again, reſtored to a good part of its firſt Power, in the correſponding Point in the Eye: for as, whilſt Rays are diverging and ſpreading from the Luminous Point into a uniform *Medium*, the Pulſe grows ſhorter and ſhorter in a duplicate Proportion to the Diſtance reciprocally; ſo in converging Rays (or Rays drawn to a Point, from a Superficies) do the lengths of the Pulſes increaſe in a contrary order: So that in probability, in the Point of Reunion in the Eye, the Pulſe may be almoſt as long, as at the Point of Emiſſion or Emanation. That this may be the better underſtood, I would diſcourſe a little upon a very common and obvious Experiment of ſetting Fire to a Body by the Rays of the Sun, collected by a Burning Glaſs, whether Reflecting or Refracting, it matters not much to our preſent Reaſoning.

Suppose then we have a Burning Glass of a Foot Diameter, or breadth; which will collect all the Rays from the Sun, and unite them at fourteen Inches from the Glass, into a Focus or circular Figure of the Sun of $\frac{1}{4}$ of an Inch in Diameter, we see first by Experiment, that the Rays so collected will set Fire to Wood, and several other Combustible Bodies and consume them, whereas the Rays of the Sun before this Union of them, were very hardly, perhaps, if at all sensibly warm. If therefore we consider the Reason of this Effect, we shall find that all the Rays which were before expanded into a Circle of a Foot Diameter, are, by this Constipation made by the burning Glass, crowded and thrust together into the space of a Circle $\frac{1}{4}$ of an Inch in Diameter; we must conclude that all that warmth that was in the Circle of a Foot Diameter, is now in a Circle of half a quarter of an Inch. Now the Area of the greater Being, to the Area of the less, as 9216 to one, it follows that the Heat of the greater to the Heat of the less, must be Reciprocal to the Area, that is, as 1 to 9216, and consequently the impression of the Light at the *Focus*, must be more than at the Glass, no less than 9216 times; and consequently the same as the direct Rays of Light from the Sun would be, at one 96th part of the Distance of the Earth from the Sun; and consequently as strong as it would be upon a Planet about the Sun, which should appear to us at the Distance from the Sun of 36 Minutes, or a little more than the Diameter of the Sun. Now in the same manner as this Burning Glass acts upon the Rays of the Sun in constipating and driving them together into a smaller room, does the Eye for all other Rays of Light from Luminous Objects. Where that Impression or Action of the Light; though in it self it be very small, and wholly insensible even to that part of the Eye, which is the most sensible and curious of all the Parts of the Body, namely, the *tunica Retina*, as I shall afterwards shew, yet is made sensible by the Multiplication of its Force upon the Constipation of the Rays into a *Focus*, which Acts and Terminates in that most curious Substance.

This is one way by which we may conceive somewhat of the Reason of the curious Fabrick of the Eye for the Multiplication of the Action or Power of Luminous Bodies, upon the sensible Animal Part.

How the Eye Multiplies the Power of Light.

2. The other way we may conceive how this Fabrick of the Eye does cause this Impression to be Multiplied, Augmented, and become sensible, Depends upon the consideration of the Hypothesis, which I propounded the last Term for the explanation of Light, and that was by a Pulse or Stroke, according to the length of which, I shewed you at that time, the Power or Strength of the Light was.

This I explain'd to you by a sensible Experiment made by firing Gunpowder. For a Corn or Grain of Gunpowder expanding it self, when fired in a Sphere 1000000 as big as its own Bulk, must necessarily act accordingly on the encompassing Medium; but I need not repeat what was then said. Therefore to return to the Instance of the Burning Glass.

Now by the Refraction or Reflection of a Burning Glass, all those Rays which before were Diverging and spreading wider and wider from a Point, and so grew weaker and weaker in the proportion I mentioned (that is, according to the Superficies of the Sphere, or Basis of the Cone) by this Action I say of the Burning Glass, they are made converging and approaching nearer and nearer together; and so of consequence augmented and increased in Power and Effect, and the Strength lost or rarified by the diverging, is renewed and revived by the converging. And whereas in the diverging, the Diminution was very slow and long, in this converging, the Increase and Augmentation is very quick and short; for as the distance of the Burning Glass from the Sun, is to the distance of the Burning Glass from its Focus; so is the Increase of Constipation, by the effects of that Burning Glass upon the Rays, to the decrease of Expansion of them in their Progress from the Sun to the Glass; so that the Rays of Light at half the Distance of the *Focus* from the Burning Glass, is the same with the constipation of the Rays, at half the distance of the Sun from the Burning Glass; and consequently the length of the Pulse, and strength of the Ray is the same; and so at a tenth Part of the distance from the Focus, the Power

Power or Action of Light, is as ſtrong as it is at a tenth part of the Diſtance of the Sun from the Burning Glaſs. So that if the diſtance of the Sun be 10000 Semidiameters of the Earth, and the Focus 14 Inches; the ſtrength of the Light, or the length of its Pulſe or Stroke ſhall be the ſame at 1⅕ Inch from the Focus, that it is, at 1000 Diameters Diſtance from the Sun; and conſequently, the length of the Pulſe in the very *Focus*, muſt be the very ſame with the length of the Pulſe at the Sun.

3. Now the Action of the Eye being much the ſame upon the Rays of Light, from any Luminous Object with this of the Burning Glaſs; it follows that the Eye does by its Power bring all viſible Objects into the bottom of it, and make an Impreſſion on the *Retina*, the ſame, as if the very Action of the Object were immediately there.

3. So that the Subſtance of the *Retina* is affected or moved by the very ſame Action, as if it touched the Object; and the Eye does continually make the Hemiſphere of Actions or Motions within it ſelf, the ſame with the great viſible Hemiſphere without it. And theſe Impreſſions are communicated to the Brain, or ſenſated by the Animal Soul, if that Subſtance be in Health and Sound; if not, the Impreſſion is Defective, and the Sight or Senſation Imperfect. As it ſometimes happens in ſome Diſtempers of the Brain and nervous Parts, in which Caſes the ſight fails, though the Organ of the Eye it ſelf be perfectly formed, as in a *Gutta Serena*. *Theſe applied to the Eye.*

There is a very remarkable obſervation of Monſieur *Mariotte* about Viſion, that the ſenſation of Light is not made in the *Tunica Retina*, but on the *Choroeides*; That that part of the bottom of the Eye which the *Choroeides* does not cover is wholly ſenſeleſs and blind, though the Impreſſion of Light upon the Place be the ſame as on the Parts that are contiguous, and lie about it.

Now this Gentlemans Obſervation is, that that part of the Eye, where the Optick Nerve enters into the Cavity of it, which is not in the Axis of its Figure, but at a pretty diſtance from it nearer to the Noſe, namely, at about 25 Degrees from the Axis inward, is not cover'd with the *Choroeides*. And that we have no ſenſe of the Impreſſion of Light made upon it.

The Experiment is this, take two ſmall Candles in the Night, or in the Day time, two ſmall bits of White Paper of about the bigneſs of a Shilling, let the Candles be ſet on a Table at two or thtee Foot diſtance, ſo that the Flames may be about the height of the Eye from the Floor; let the Papers in the Day time be ſtuck againſt a dark Wall, or dark coloured Hangings, at about the ſame diſtance, and the ſame height; then placing your ſelf juſt before them, and looking towards them, cloſe one of your Eyes with your Hand; as ſuppoſe your left Eye, and look directly on the Candle or Paper on your left Hand, and you will ſee both the Objects very plain, that you reſpect, very clear and diſtinct, and the other ſomewhat more Imperfectly; keeping your Eye thus ſhut, and the right Eye reſpecting the left Hand Object, by Degrees go backwards, 'till at length you will perceive that the Right Hand Object vaniſhes, and is no more viſible; mark that Diſtance and you will find it to be at about 3¼ times the Diſtance of the two Objects, going yet farther backward, you will again begin to ſee them both as before, *viz.* at the diſtance of about 4½; then again going in this Poſture nearer the Objects, you will find the Right Hand Object diſappear when you come to the former Diſtance, and when nearer, they will both again appear, and ſo continue 'till you come cloſe to them. Now the reaſon of this Appearance is, that the Axis of the Right Eye being always kept directed to the Left Hand Object, when you are at the aforeſaid Diſtance, the impreſſion from the Right Hand Object falls on that part of the bottom of the Eye where the Optick Nerve is inſerted, over which there is no part of the *Choroeides* expanded, and the ſenſible part being wanting, the Senſation is not made, though the Impreſſion be the very ſame; as on each ſide of it, as I ſhall prove more particularly, when I come to explain the ſeveral parts of this moſt curious Organ, and what the Function and Uſe of each part is, which I may make the Subject of ſome of my ſucceeding Lectures.

This

This Deduction of his was disapproved by Monsieur *Pequet*, tho' the Experiment was allow'd, who gave his Reasons for maintaining the *Retina*, the chief Organ for receiving the Species. This Dispute may be seen in the *Philos. Transact.* Numb. 35, & 59. whether it be the one or the other, is not much to our present purpose, therefore I shall leave it, and proceed.

4. I have endeavoured to explain to you that admirable contrivance of the Organ of Sight, the Eye, whereby it Collects the Rays of Light, so as to make an Impression upon the sensitive Part of it, of the Action, Motion, or Power of the Luminous Object upon the immediately incompassing *Medium*, though this Luminous Object be never so far distant, and by that means, as it were in an instant, to touch, or feel any such Object, as if it were contiguous to it, but yet so as not to hurt or offend the sensible part; for the Eye taketh but a very small Cone, or part of the Radiating Sphere; and thereby, though the Motion be the same as to Velocity and Length of Pulse in every the smallest Cone or Ray, that it is in the whole Sphere; yet being but a small part of the whole incompassing *Medium*, it contains but a part of the Action of the Luminous Point; for which Reason we are able to look upon the Sun, or a Fire, or an exceeding bright Flame; as melted Silver, or Iron, or Sulphur burning upon melted Niter, without much offending the Organ, if it be strong and vegete; but if the Eye be weak, and the Impression be continued, it will much offend it, and dull the Sense, whence it is that looking much upon Fire, or any such bright Object, does very much decay the Sight, and makes it more insensible of the weaker Impressions made by other less Luminous Objects: And hence we find, that we are unable for a time to perceive Objects in a House or Room, immediately after we come in out of the Sunshine. Now by reason of the great Variety that there is in differing Objects, as to the Quantity and Strength, and that the *Retina*, or sensating part is capable only of receiving Impressions to a certain Degree of Strength, without being hurt by it, there is a contrivance in the Eye, which I shall afterwards more fully explain, by which the Quantity of the Rays admitted is moderated, so as to keep it, that the impression does not exceed that limit: And this is the Aperture or Hole through the *Iris*, which is the black Hole that appears in the middle of the transparent part of the Eye; for this Hole which admits the Rays to pass into the Eye, is contracted or dilated, according as the Object is brighter or darker; that a lesser Quantity of the stronger Rays, and a greater Quantity of the weaker Rays may be admitted, and hence it is, that a brighter Object among dimmer Objects, does cloud and darken them, because the aperture of the *Iris* being contracted proportionable to the Strength of the brighter, the Rays, admitted from the fainter and more dim Objects, are not sufficient to make a sensible Impression. So that the effect of the Rays are by this means proportion'd to the Ability of the sensible Part of the Eye to bear the Impression, and where notwithstanding the utmost contraction of this aperture of the *Iris*, the Rays make too strong an impression upon the *Retina*, we are forc'd to wink and close the Eye-Lids nearer, to shut out part of that quantity of Light which would otherwise have entred into the Eye; or to look through a small Hole, or through an opacous Body. And hence it is, that any one may with ease look upon the Sun, if he look through a small Pin-hole in a Plate, by which means one may with pleasure see an Eclipse of the Sun, without using any opacous Glass; though if the *Cornea*, or any other part of the Eye, be any ways opacous, this way discovers the Defects of them, and does somewhat vitiate the Figure of the Object. But of this, and the manner of contracting of the Pupil, more, when I come to explain that part of the Eye; that which I mention it for at present is, only to explain how the Eye becomes as it were a Hand, by which the Brain feels, and touches the Objects, by creating a Motion in the *Retina*, the same, and at the same Instant, with the Motion of the lucid Object it self. For the make of the Eye is such, in all its Contrivance and Parts, that the Conical Ray of Light proceeding from a Point of the Object, and terminating with a Divergency in the Aperture, or *Cornea* of the Eye; is by the Refraction thereof again reunited into a Point at the *Focus*, which is in the *Retina*; and consequently, whatever the Motion or Power of the Light was in the *Apex* of this Cone, which is at the Luminous

Why the Eye is not hurt by the Action of Light.

Luminous Body the ſame is the Motion or Power of Light, at the Point or *Apex* of the Cone, made by the Refraction, and terminating in the *Retina*, ſo that the Eye does, as it were, invert and ſhorten the conical Radiation, and contracts a Cone 10000 Semidiameters of the Earth in length, into the length of an Inch or thereabout in a Man; from which Explication all the Appearances of Viſion, whether by the naked Eye, or by Teleſcopes, or Microſcopes, will be very naturally, and I conceive very truly explained; and the wonderful Wiſdom of the Great Creator more manifeſtly ſhewn.

5. We are therefore in the next place to conſider the Fabrick of the Organ it ſelf, of what Parts it conſiſts, and of what uſe each of them is toward the compleating this Effect.

1. In the Conſideration whereof, the firſt thing that repreſents it ſelf to our View, is the tranſparent part of it that is placed outwards, which is the entrance by which the Rays paſs into it.

I ſhall not need to mention the poſition of it in the Face, nor the Duality of them, nor the Cells of the Skull in which they lie, nor the Lidds that cover it when Senſation ceaſes, as in Sleep; ſave only that I ſhall afterwards ſhew you the uſe of them for moyſtning, glazing, and clearing the *Cornea* from Duſt and other Fowlneſs; no nor of the various Muſcles that ſerve to Rule it to and fro every way, and direct and fix the *Axis* of it upon the Object to be viewed; the contrivance of which is truly admirable, nor ſhall I take notice of any Anatomical Obſervation concerning it, ſave only ſuch as tend to explain the Make and Fabrick of it, for performing this Effect of Collecting Diverging and parallel Rays, and refracting them into a Point or *Focus*: Other conſiderations thereof being more proper to be handled upon the conſideration of other Subjects.

Having taken the Eye out of its place, or Socket in the Skull, and having taken off carefully all the Muſcles that ſerve for its Motion, as being not now conſidered, we have a round Ball ſhaped ſomewhat like that repreſented in the fixt Figure *A B E B F A*. This Body is in a Man of about an Inch Diameter, and to *B A B*, is very near of a globous Figure, though in divers other Animals it be of divers other Figures; ſome of them more depreſt at the middle, and nearer to the ſhape of a Turnip, and at about 25 Degrees from an imagined Axis, which paſſes through the middle of all its parts; is inſerted into it the Optick Nerve *F F*, which Inſertion together with all the Globous part of the Ball, is covered with a thick, ſtrong, and pretty ſtiff Coat, or Shell, which ſerves as a ſolid Wall, to preſerve the ſhape and figure of the Parts within, to which alſo the Muſcles, for its outward Motions, are faſtned; and likewiſe the Muſcular Parts within the Eye, which ſerve for the inward Motions; this is called the σκληρώδης, or *Tunica Sclerotica*, or hard Coat; and is a continuation of the *Dura Mater*, or the outmoſt ſtrong hard Bag that contains the Brain; and by a curious Diſſection may be found quadruplicate, as is alſo the *Cornea*. This for the moſt part is white and opacous, and ſo permits no light to paſs it any way, though in ſome Creatures I have obſerved it to be pretty Tranſparent, ſo as to ſhew the Picture of Objects without, made at the bottom of the Eye, as in Young Kitlings: The formoſt part of this is of a more protuberant Figure, and ſeems ſomewhat Elliptical; riſing conſpicuouſly prominent above the Superficies of the Sphere *B A B*, continued this Prominent part *B E B*, is perfectly tranſparent, though it be of a flexible Subſtance, and from ſome kind of Reſemblance it has to Horn, is called the *Cornea*, or horny Coat: This, as it is more round in the middle about E, than it is at the ſide *B B*; ſo I have obſerved it alſo to be thinner in the middle, than at the ſides, ſo that it reſembles the deſcription in the Figure. The Ellipticalneſs of the Figure, as it may plainly be diſcovered by the Eye, without any other help, ſo more certainly by the Reflection of Images from its Surface, and by the refraction of it when filled with Water, and looked through toward any near Object. Through this tranſparent Coat or *Cornea*, the Rays enter into the Eye, and receive their firſt and greateſt Refraction towards their converging and meeting at the bot-

Plate 1. Fig. 6.

The Fabrick of the Eye.

tom of the Eye. This is much larger in ſome Animals, as in Cats, Owls, Leopards, and other Creatures that ſeek their Prey in the Night; and ſo is able to receive a greater Quantity of thoſe faint and dim Rays diſperſed from Objects at that time, in which Creatures alſo the Pupil of the Eye is capable of a much greater Expanſion and Contraction, as I ſhall by and by obſerve. This may give a very good hint of the poſſibility and practicableneſs of ſeeing in the Dark, of which I have many Years ſince made divers tryals with very good Succeſs; and I have known ſeveral Men who have had ſuch a Conſtitution of their Eyes by Nature, that they would be able with Eaſe to ſee every Letter diſtinct, when other Men, that otherwiſe had very good Eyes, could not ſee the Lines.

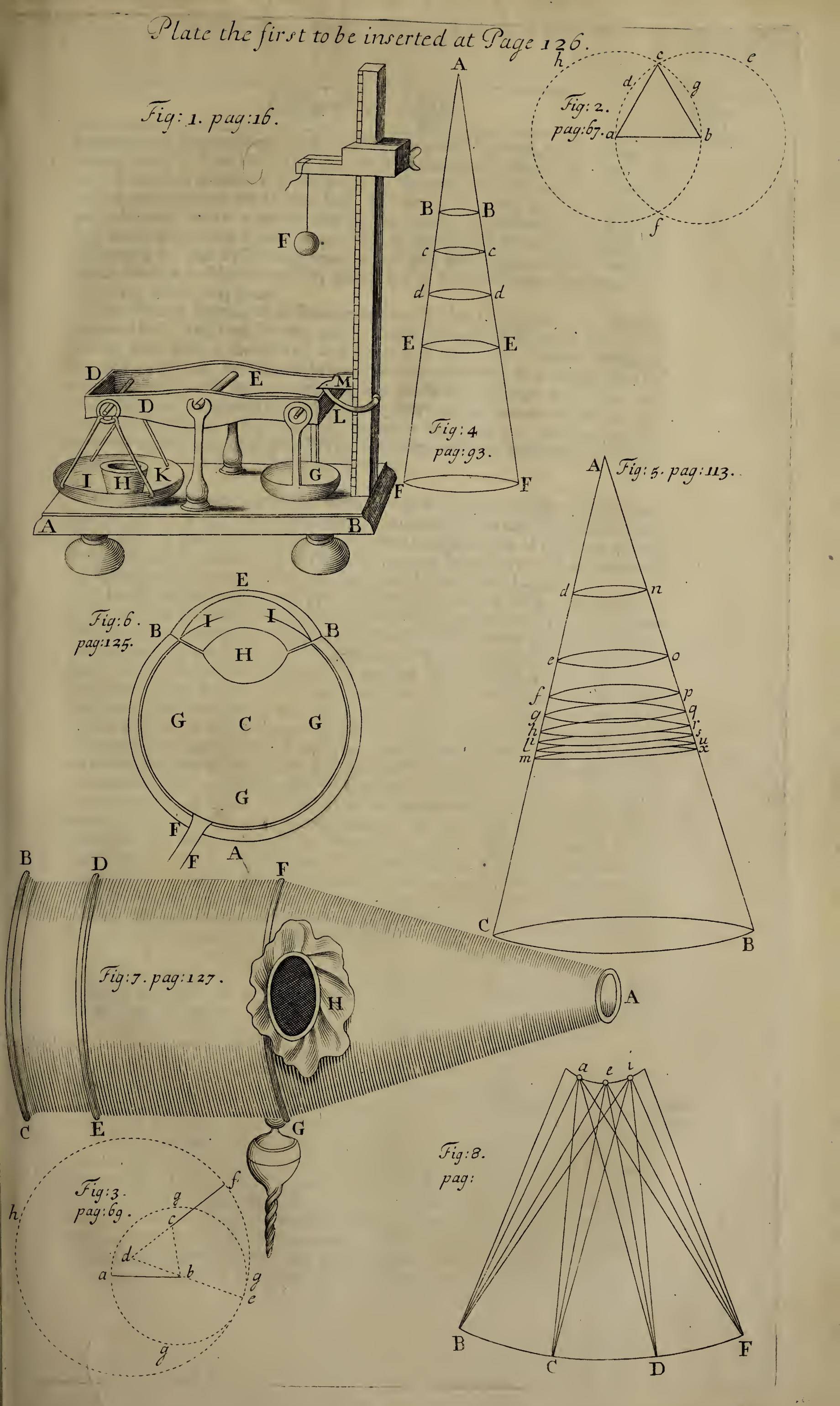
The inſide of this thick and hard Coat of the Eye, is covered with another Coat, being in various Eyes of various Colours, as Black, Blue, Brown, Green, Yellow, and the like; it covers alſo the Optick Nerve, and is joyn'd to the *Sclerotica*, by an infinite company of little Veins, and Arteries and Veſſels; this immediately joyns to, and, as it were, lines the Inſides of the hard outward Coat, ſo far as the vitreous Humour extends; namely, to *B B*, and is called the *Choroeides*. But above this place it is ſeparated from it in the aqueous Humour, and is called the *Uvea*. The uſe of this, as to Opticks, ſeems to be for the imbibing of the Rays of Light after they have impreſt their Motion upon the *Retina*, though I have obſerved in ſome Creatures, a ſtrong reflection from the bottom of the Eye, which could be from no other than the *Choroeides*. What its Uſe is for conveying neceſſary ſupply and Nouriſhment to the Parts of the Eye, is not my Subject.

To the inſide of this Coat is joyned the *Retina*, which is that which immediately covers the vitreous Humour, and is the ſame Subſtance with the Subſtance of the Brain, which is alſo the *Medulla*, Marrow, or Pith of the Optick Nerve. This by *Des Cartes* and moſt others, is ſuppoſed to be the ſenſible part of the Eye, which receives the impreſſion of the Pencils of the Rays of Light; though there are others of another Opinion, that the *Retina* being the ſame with the ſubſtance of the Brain, has no ſenſe in it, as the Brain it ſelf hath not, but that the *Choroeides*, as being the ſame with the *Pia Mater*, and conſequently of the moſt acute Senſe, is that which receives, and is ſenſible of the Impreſſion of the Rays of Light: And to confirm this, the Experiment I ſhew'd and explain'd to you the laſt day is brought as an Argument by Monſieur *Mariotte*, which carries in it indeed very much of probability; for by that Experiment you have a ſenſible Proof, that in that part of the Eye where there is no part of the *Choroeides*, as at the *Medulla* of the Optick Nerve, there you are blind as it were, or inſenſible of the Light; whereas in that Place there is the greateſt Plenty of the *Retina* or *Medullary* Part; within this Coat is contained the Vitreous or Glaſſy Humour of the Eye which fills the whole lower Cavity of it; it is called the Glaſſy Humour, not that 'tis ſo very hard; but becauſe it being very tranſparent and clear, it is of a greater conſiſtence than the watery, being like a Jelly, and yet is ſofter than that which from its exceeding clearneſs, not hardneſs, is called the *Chryſtalline*; this is delineated by the Figure *G G*. This Humour on the upper ſide of it has a Cavity in it, where it receives the *Chryſtalline* Humour, which is ſomewhat of the Figure delineated by *I H*: the under part of which in a Man, and in moſt other Terreſtial Animals, is much more convex than the uppermoſt which is more flat; but in moſt Fiſhes it is of a perfect Globular form; its of a pretty ſolid Conſiſtence ſo as to keep its Form after it is ſtript of the Coat or Skin, that covers it both above and below, called the *Aranea* or Cobweb Coat, which is very thin, ſtrong and tranſparent, and is joyn'd to the *Choroeides* by the Edges, by means of the *Ciliares B H, B H*, which ſeems to be Muſcular, all the ſpace between the Cryſtalline Humour and the Cornea is filled with a very clear and liquid Water, the Figure of which Cavity, and conſequently of the Water contained is expreſt by *I I*, contain'd within the Cavity *E B H B E*.

In this Water between the Chryſtalline and the Cornea, is placed a Skin with a Perforation in the middle of it, that is called the *Uvea*, expreſt by *B I*, *B I*, the outermoſt ſide of which is of various Colours, in various Eyes, as blackiſh, blueiſh, greeniſh, yellowiſh, browniſh, and the like; the Hole of it in ſeveral

* Animals

Plate the first to be inserted at Page 126.



Animals is of ſeveral ſhapes, but in Men it is perfectly round, in Sheep of an oblong Oval, in Cats like a ſlit; in other Creatures of other Forms, the bigneſs of which is more or leſs, according to the brightneſs or dimneſs, the nearneſs or remoteneſs of the Objects ſeen, and has in it a kind of natural Motion not voluntary, which is moved only by the various Impreſſions of the Objects. And we have no other Power to open it than by looking upon dark Objects, or of ſhutting it, than by looking upon bright and near Objects: The Limits of which Motion in Men is not very great, but in Cats and other Creatures, that ſee in the Dark, very great.

This Watery Humour does ſometimes breed a kind of Mother in it, ſo as to become thick, and look White, and ſo hinder the Rays of Light in part, or in whole, from paſſing through it, and when it is grown to a ſenſible Thickneſs, is call'd a *Cataract*, but the Sight may be again recovered by couching that *Cataract*, which is nothing but thruſting in a fine Needle through the *Cornea*, and with the Point of it breaking and cruſhing down to the bottom of the Eye this Mothery Subſtance. This Humour, though it be all let out, will preſently be renewed again, and filled with Water as before, without deſtroying the Sight of the Eye, as has been often experimented.

Thus I have ſhewed you all the parts of which the Eye conſiſts, and the form and manner of their Poſition in order to compleat this curious Organ to make it fit for Viſion; having omitted all thoſe other conſiderations of it, which belong more properly to Anatomy and Phyſick, my aim being only to take notice of thoſe things only ſerve for the explication of Opticks and Light.

It would be too long for this preſent Exerciſe to explain to you the exact Figure, and the various Refractions of the ſeveral parts of the Eye, and to ſhew you the particular uſe of every part of it, for compleating the collection of Rays proceeding from the Points of the Luminous Object, and terminating them in as many diſtinct Points at the bottom of the Eye, which I deſign, God willing, to compleat, when I come to explain Refraction and the Laws thereof. And therefore, I ſhall at preſent only mention to you, that that Collection or Termination is made at the *Retina* or *Choroeides*, which, as I have ſhew'd, you are the Coats that line the bottom of the Eye, and encompaſs the vitreous Humour, on which they do deſcribe, as it were, a perfect Picture, or Repreſentation of all outward Objects, as may be plainly ſeen by the Eye of a Kitling; the *Sclerotis* or bottom of which is tranſparent, or by any other Eye, if the *Sclerotis* be carefully ſhaved off ſo as to leave it tranſparent: And as I have done by a large artificial Eye made with Glaſs, Water, and Jelly, figured according to the ſhapes repreſented in the Scheme, which is a Section of the Eye, made by the Optick *Axis*; that in this Picture are remarkable not only all the Lines and Proportions, but the Lights, Shadows, Colours, Motions of the Objects themſelves. So that from a clear Underſtanding of this, the Reaſon, Cauſe, and Manner of Viſion will be clearly underſtood.

5. Now becauſe the Structure and Making of ſuch an Artificial Eye is very difficult, and the uſe thereof notwithſtanding, very neceſſary for a through Knowledge of Opticks; I having only mention'd this at preſenr, that ſuch as have a Mind to be curious in it, may, if they pleaſe, prepare the like.

I ſhall rather as a Supplement to it, make uſe of a darkned Room, or Perſpective Box, in which all the Appearances that are made in the Eye are in ſome manner repreſented. Prepare therefore a Box of the ſhape in the ſeventh Figure, let it be four or five Foot long from *A* to *D E*, and make the bottom of it *B C*, Concave towards the End *A*, and the bottom of the Box *B D E C*, being made Cylindrical, and not Tapering, as the part *A FG* is, that the movable bottom *B C*, may be placed nearer to or farther from the End *A*. At *A* place a Convex Glaſs of the length of the Box in a Hole as large as the Glaſs, which the larger it is the better, becauſe of ſeveral Tryals that may be made with it, which cannot be made with a ſmaller. To this Hole cut ſeveral, as eight or ten Pieces of Paſt-board that may each of them ſerve to cover it, and in every of them cut a Hole of a Round, or other Figure you would uſe, and either in the

Plate 1. Fig. 7.

the middle of it, or out of the middle of it, and of a greater or less Figure, according to the Tryals you design by them; let the inside of the Concave bottom be made very White, to receive and reflect the Points of Light, and make a Hole in the side of the Box *H*, covered about with Leather, or thick Wollen Cloth, with a Hole large enough to put ones Face into it, so as to see the Species or Picture of outward Objects upon the bottom, then turning the end *A* where the Glass is placed toward the Object (if the Sun shines upon it, it is the better, because of the great Reflection of Light from such Objects,) slide the moveable bottom *B C*, to or fro, 'till by looking in at the Hole *H*, you perceive the Representation of the outward Objects very perfect, then take notice of the distance of the Object, and likewise the distance of the bottom; the Position, Magnitude, Brightness, Colour, and all the other Remarks that appertain to the explaining the several Appearances that may happen to the Eye, then fit it for representing Objects at a greater distance, and take notice of the distance of the bottom, and all the other Remarks necessary for explaining your Inquiry: The like may be done with the various apertures of Pastboards, which may serve to explain all that might happen to the Eye, by the contracting and dilating the Pupil, by observing the definedness of the Species on each side the *Axis*, and where they are most distinct; and so for all other Questions that may happen concerning what Light is in the Eye, and what Effects it there produces. It may be convenient to fix a Ball and Socket underneath it to make it more easy to be managed. It may also be made square as well as Cilindrical, provided the bottom of it, *B C*, be a Concave of a part of a Sphere of the length of the Boxes Radius.

Let this therefore suffice at present for explication of the first Principle of the Emanation of Light from the Luminous Body, and for the Reception therof upon the subject; that the Light is conveyed from every Point of the Luminous Body, to every Point of the Body inlightned, through a uniform transparent Medium by direct Emanations, or in imaginary straight Lines. The same Rule holds in all Light that proceeds from an Object inlightned, that promiscuously reflects the Light cast upon it every way, for such a Body may be said to shine, as it were, by the Light of another Body, and may therefore upon that account be said to be a secundary Luminous Body, and the Light a secundary Light, such as that of the Moon, and the other Primary and Secundary Planets, so that the same Rule will hold in both, and the inlightning and the inlightned Cones are to be considered in the calculation of Rays from Bodies shining by a secundary Light, and the Proprieties and Proportions to be observed in both, in their Power and Propagation, will fall under the same Rules as I shall afterwards more at large explain and manifest.

Next, As light is thus propagated by imaginary straight Lines, so is also Shadow, which is nothing but a Defect or want of a peculiar Light, taken off or intercepted by an opacous Body, or of a Body that will nor permit the Rays to pass onwards in its direct Course, which is only visible by Accident; that is, by finding from that part a defect of the Influence of Light, which we are sensible of, every where about it. And by this means it is that we see the dark or shaded side of the Moon in an Eclipse of the Sun; that is, we perceive such a part of the light of the Sun taken off by the opake Body of the Moon coming between that and us, but of it self it is no ways visible; for though we may be said to see that shaded part of it which hides part of the Sun, yet we cannot see any part of it which is without the Suns Limb, so were the Body of the Moon in an Eclipse of the Moon, perfectly within the shadow of the Earth, and that no manner of Light by the refraction of the Sun-beams in the Atmosphere were conveyed to it, we should see no other appearance of it, but only that sometimes this, sometimes that Star would disappear which was covered by it, and it is only distinguished by the Light about it.

This therefore comes under consideration only relatively with respect to Light, and is to be calculated as a Defect, though the same Rules in calculation of the two before mentioned Cones will here hold also, but as Defects or like Quantities in Algebra marked with a Minus.

SECT.

SECT. VI.

A farther Continuation of the Lectures of Light. Read about April *or* May, 1682.

The CONTENTS.

1. *Light, the* Medium *by which all or most part of the Knowledge we have of the Celestial Bodies is conveyed to us. A farther confirmation of a* Plenum. *Mr.* Romer's *Observation of a temporaneous Propagation of Light not conclusive. That the* Medium *is absolutely Dense, and where the Parts are immediately contiguous, the propagated Motion must be instantaneous.* 2. *Tho' this propagation be instantaneous, yet the impression of this Motion is Momentary, or Temporaneous; therefore every Pulse of Light is Momentary, and requires some time, tho' this is inconceivably short. Mr.* Hobb's *Expedient of a* Conatus ad Motum *insufficient. That there must be an actual local Motion, and that able to break the most solid Bodies. What Light is in the Agent,* Medium, *and Patient, is explain'd by a familiar Example: All Motions local, and differ only in the lengths of Spaces, and Moments of Time.* 3. *How Light is instantaneously propagated* in Orbem, *evinced by a cogent Example, by which all the Proprieties of its Motion are clearly explained. Two different Cones may be considered between the illuminating and illuminated Bodies. Why the Light of the Sun exceeds that of all the Stars collected, if the Stars were brought nearer, tho' their* Areas *remain'd the same, yet their Light would be greater.* 4. *The Proprieties of Light propagated in a transparent uniform* Medium *to the Eye, reduced to four Considerations, each of which are enlarged upon and exemplified. How the same Corpuscle may communicate different Motions several different Ways, in the space of a Human Moment.* 5. *Every sensible Moment of Time, as well as every sensible Particle of Matter composed of infinite lesser; so that in the same sensible Moment, the same sensible Point may be successively moved infinite Ways, when the Vibrations of a string can be no longer discerned, they become the Objects of another Sense, the Hearing; the sensible Moments of Creatures proportioned to their Bulk. Short lived Creatures may have as many sensible Moments as longer lived, and in some Sense be said to live as long as Man. That there are infinite Spaces in the least sensible Space to be moved; and lastly, the Velocities may be infinitely swift in each of these Spaces. The bigger the Body is, the slower are its Vibrations. Lesser Animals see those Vibrations which we can only hear. A Continuation of that Subject of the Propagation of Light. That the vast Number of successive Impulses in a Human Moment is no Objection; so that upon the whole, there may be assigned to the Propagation of Light, a real local Motion.* 6. *From the former Reasons, the Author deduces the Cause of the perfect fluidity of the vast* Expansum *of Matter or* Æther, *between*

the Planetary Bodies. Why one fluid Body hinders Motion thro' it, more than another, instanced by some Experiments. R. W.

Light the Medium to convey all Celestial Knowledge.

I Have formerly explain'd here several Properties of Light, which I have been the more particular in, because it is the *Medium*, by which all the Knowledge we have of the Heavenly Bodies is conveigh'd to us: for though we are affected also by the Heat, yet it seems to be conveyed to us by no other Medium than that of Light; for Light, as I have shew'd you, seems to be nothing else but an Internal Motion of a Transparent, first begun, or imposed by the Luminous Body, upon the Parts of the Uniform, or Transparent *Medium*; and then propagated through that *Medium*, to the utmost Extent, or Limits of it. Now from the boundlessness of its Propagation, and the Instantaneousness also of it, I conceive that the Parts thereof are absolutely Contiguous, and make a *Plenum*; so that at the same Instant that a part is moved by the Lucid Body, at any one part of the *Medium*, the utmost Extreams of the *Medium*, on that side towards which the Motion is impressed, are moved also. And this agrees with the most curious Observations that have been hitherto made concerning it; and though Monsieur *Romer* indeavours to make it otherways by Observations made about the *Satellites* of *Jupiter*; yet, as I have formerly shew'd you, they are not sufficient to prove his Theory; because, supposing his Observations and Calculations exact, yet there may be other as probable Causes assigned to solve the Appearances, as this which he has assigned: So then if the Propagation be instantaneous, it will follow, I say, that the *Medium* is perfectly Dense, or the Parts immediately contiguous one to another; for if there should be Vacuities interspersed, and so the Parts behind should be necessitated to move through that Space, before it could touch the next, and that another space, before it could touch the third, and that third another Space to pass, before it could touch a fourth, and so onwards; it would follow, that the passing of every one of these Spaces would take up some time, and consequently would make the Motion temporaneous but where the Parts are immediately contiguous, the first cannot move without, at the same Instant, moving the second, nor that without moving the third, nor that without moving a fourth, fifth, sixth, and so forward, to an innumerable Series, or to the utmost extent of the Medium. The ingenious *Descartes*, therefore, compares it to a solid Rod or Stick, whose Parts being all contiguous, the one End cannot be thrust forward, but that at the same Instant, the other end is also thrust forwards, which is a plain and very sensible Explication of what is meant by Instantaneous Propagation in the *Medium*, *viz.* a moving together of all the Parts of the *Medium*, and not a successive.

Its Impression on the Medium momentary.

2. Now though the Propagation be thus instantaneous, yet the Impression of this Motion on the *Medium* is Momentary, and though it be never so short a Motion, and never so quick, yet it must be temporary; for if the moving Luminous Body does move, or remove the *Medium* before it; it must remove it some space, and that Space cannot be passed without some time; and therefore, I conclude, that every Stroke, or Pulse of Light is Momentary, and lasts for some space 'till a second Pulse or Stroke is impressed, though the Duration of each Pulse be never so short; as suppose, but the thousand thousandth part of a Second of time, yet a Thousand Thousand of such Pulses will make a Second of Time, and though the space that it moves be but the thousandth Part of a Hairs Breadth, yet even that is a Space, and has a *terminus a quo*, and a *terminus ad quem*, and an interjacent space, through which the Motion must be performed in such a Space of time. Nor will the Expedient which Mr. *Hobbs* has found out, to save a Local Motion, serve the turn; for he would have it to be nothing but a *conatus ad motum*, an Endeavour to move, and not a Real Motion, and *Descartes* would have it a Propension to Motion, and not a Motion; but what the one means by *Conatus*, and the other by Propension, if it be not an actual Motion, I understand not; but as I shall hereafter prove, it must be an actual *Loco*-Motion, for the Experiments I shall bring for that purpose, will manifest it to the Sense to be a Local Motion, and that very considerable too, in as much as it is able to break in Pieces even the most solid Body in the Wolrd:

Hobbs's Expedient insufficient.

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World. Now when I ſee a Maſon holding the Edge of a Steel Chizzel hard againſt a very ſolid Marble Stone, with his Left Hand, and with his Right, ſtriking upon the Top, or Head of that Chizzel, with an Iron Hammer, ſo as to break off a piece of the Stone, I cannot but conclude that that Chizzel muſt have had more than a *Conatus ad Motum*, to make the Marble break, and that there was a real Local Motion of the whole Chizzel together forwards, ſo far as the Edge thereof did penetrate the Marble before it brake it. And this, I hope, may ſerve as a ſenſible Similitude, by which I would inform the Underſtanding what kind of Action or Motion it is, by which Light is firſt generated in the Luminous Body: namely, like the Motion of the Hammer againſt the Head of the Chizzel; next, how it is propagated through the tranſparent *Medium*, *viz.* the Medium is all moved together, even as the Body of the Chizzel: And, Thirdly, How that acts upon the Subject inlightned, and that is, after the manner as the Marble is broken by the Chizzel. This may, perhaps, ſeem but a coarſe Similitude, for the Explication of the Motion or Action of Light, which is the moſt curious and ſpiritual of all ſenſible things. But yet, I have this to anſwer, that the more plain and obvious it is to be underſtood, the better it is to inform the underſtanding of the manner how, an Operation, which is too curious and fine to be reached by our Senſes, is performed: And though I cannot have an imagination of a Space, but the thouſandth Part of the breadth of a Hair, yet, by my Reaſon, I can be certainly informed that ſuch a Space there is, and even by Microſcopes we can make ſuch a Space viſible, and yet our fancy will diminiſh no farther than the leaſt ſenſible Point to the naked Eye; as the point of a ſharp Needle or the like: But we are not leſs certain of it, though we cannot imagine it, that is, make an Image or Repreſentation of it to the Mind. Now we are by the Eye aſſured that there is Light, and conſequently, I ſay, there is a Motion impreſſed thereby upon that Senſe, becauſe there is no Senſe but what is made by an Impreſſion of ſome Motion, and that Motion is not impreſſed but by a Body moved with Local Motion, (for I cannot underſtand any other Motion,) and Local Motion muſt have a Space to paſs, and that Space muſt be paſſed in ſome time; and therefore Motions can only differ in lengths of Spaces and Moments of time; if therefore I underſtand, comprehend, and imagine one Local Motion that falls under the reach of my Senſes, I can by ſimilitude comprehend and underſtand another that is ten thouſand Degrees below the reach of them, they having both the ſame Proprieties, and differing only in the Spaces and the times; whoſoever therefore, endeavours to explain any inſenſible Way of producing an Effect, by ſomewhat that is leſs intelligible than that which he would explain, acts prepoſterouſly, as I could have inſtanced in the Explications of very famous Men, which inſtead of informing, do much confound and perplex the Underſtanding; but it would be too long for this place.

A familiar Example to explain theſe matters.

3. I ſhall therefore proceed, and that is, to explain, how the Motion of Light is propagated *in Orbem*, for ſo we find it, which this Similitude I have here uſed does not reach, but only that of a direct Ray; to make this therefore plain to the Underſtanding, I would propound a hollow Cone of Braſs, or ſome other ſtrong cloſe Subſtance, whoſe bottom ſhould be made of a yielding Subſtance and Spherical, and the *Apex* ſhould have a Cylindrical Hole, by which it might be filled with Water, Quickſilver, or ſome other fluid Subſtance: Into this Cylindrical Hole or Syringe, I would have fitted a Cylinder ſo cloſe as not to let the Water paſs by it, having filled this hollow Conical Veſſel, I ſtrike againſt the end of the Cylinder with a Hammer, and force it to move the whole length of the Cylindrical Hole; In this caſe it is clear, that the Water which filled the whole Veſſel, and Cylindrical Hole muſt be all moved towards the bottom, and at the ſame Inſtant that I force in the Cylindrical Plug; now ſuppoſing the Water not capable of Condenſation, and the ſides of the Cone not ſubject to ſtretch, and only the bottom capable of being moved; I find that the Plug muſt have driven all the Water in the Cylindrical Hole into the Cavity of the Cone, and ſo muſt have driven forward as much as lay next to it of equal ſpace, into the ſpace of another equal Quantity of Water, and ſo onward; 'till that which touches the bottom muſt drive the bottom ſo much

How Light is propagated in Orbem ſhewn.

much lower, as to inlarge the Capacity of the Cone enough to receive the Quantity of Water in the Syringe, forced into the Cone by the Plug. Now if we consider this Similitude, it will explain some other Proprieties of the Propagation of Light. For, First, it is clear that every part of the Water must be moved at the same Instant. Secondly, That there is no reason why the Motion of all Parts that lie at equal Distances from the end of the Syringe, should not have the same Degrees of Motion. Thirdly, Why the Parts that lie more remote from the Syringe, have still the less proportion of Motion communicated to them. Fourthly, It shews us plainly what that proportion is; namely, a Proportion reciprocal to the Square of the Distances; for every of those Spaces must be equal to the first, as therefore the same quantity of Motion is expanded into a bigger and bigger *Area*, so must its Power upon an equal space of any two Distances, have its Power reciprocal to the *Areas* of those Bases; so that hereby we see clearly the reason why the Power of the Light at several Distances is diminished in Reciprocal Proportion to the Expansion of it. And this may serve for the Explication of the Propagation of Light, from any single Point of a Luminous Object. Now the same, thing that we understand of any one shining Point of a Luminous Object; the same thing I say, we are to conceive of every one of the whole Luminous Body; for evey point of it doth in the same manner propagate its Influence, Power, or Motion; for if instead of one Syringe at the end of the Cone, there were Two, Three, or more such Syringes, if any of them were moved, the Effect would be the same, as in that I have mentioned already, and if all were moved together, every one would have its Influence on the bottom, as if it had acted singly, and so evey Point of the bottom would be affected, or moved by it; as well as every of those Points would also be affected, or moved by every one of the other Syringes; as
Fig 8. Plate 1. suppose, *a*, *e* and *i*, were the three Holes of these Syringes, and *B*, *C*, *D*, *F*, were the bottom of the Cone; if the Syringe *e* were moved, it would propagate a Motion, or force to every point *B*, *C*, *D*, *F*, of the bottom *B*, *F*, so likewise if the Syringe *a*, or the Syringe *i*, were moved singly, each of them would propagate their Motion to every one of those Points, *B*, *C*, *D*, *F*, of the Base *B*, *F*, and to every other Point of it. And consequently, all those Syringes being moved together, must every of them influence or move every Point of the Base, *B*, *F*, with its own distinct Influence. Now the same thing that will happen in this Case, in the Pressure or Motion of the Water against the bottom, will also be in the Case of Light; for if we suppose *a*, *e*, *i*, to represent the Body of the Sun, and *B*, *C*, *D*, *F*, the Surface of a Body inlightned by it; It is most certain, that every Point of the Base or Object, *B*, *C*, *D*, *F*, is influenced by every Point of the Superficies of the Sun that shines; so that there may be considered in the Radiation of Light, between a Luminous Body, and an inlightned Body, two sorts of Cones, each made up of infinite Radiations; namely, the inlightning Cone, and the inlightned Cone; the inlightning Cone I call that, which is propagated from one Point of a Luminous Body unto all the Parts of the Body inlightned, such are *B*, *a*, *F*, *B*. *B*, *e*, *F*, *B*. *B*, *i*, *F*, *B*. the active, or inlightning Point being the *Apex* thereof, as *a*, *e* and *i*. And, 2*ly*, The inlightned Cone, I call that, which has the inlightned Point for its *Apex*, and whose Base is terminated at the Luminous Body, and all terminate in the inlightned Point, so if *a*, *e*, *i*, represent the Body of the Sun, then *a*, *B*, *i*, *a*. *a*, *C*, *i*, *a*. *a*, *D*, *i*, *a*, and *a*, *F*, *i*, *a*. do each of them represent a Cone, whence it will clearly follow, that the bigger the inlightning Body is, the more Radiations there will fall upon it, and the more the Cone will be inlightned; and this is one of the Reasons why the Light of the Sun does so much exceed the Light of all the Stars, because that in the Hemisphere of the Sun that Shines upon us, there are more Luminous Points or Radiations than from all the Stars of a whole Hemisphere of the Heavens; but there is also a second Cause, and that is to be fetcht from the greater Distance of the inlightning Bodies of the Stars; for, as I shew'd before, the Power of the Light doth decrease reciprocally to the squares of the Distance. For should all the Luminous Bodies of the Stars be diminished in Diameter, according to their differing Distances, and be brought so near us, as the Sun, and so appear all under the same Angle they now do, their Light would be considerably stronger, and greater to us in the Night, and even in the

Day

Day than now it is; though the *Area* of them all put together, would be no bigger than now it is; for the Light from the brighteſt Star, as of the great Dog Star, though in a Dark Night it ſeem very vivid, yet could it be ſeen with the Light of a part of the Sun appearing of the ſame Diameter with it, it would look very faint and weak. And when I have viewed a Star in the Day-time, with a Teleſcope, though by the help of the Teleſcope I have mightily fortified that Light, and ſo centuplicated its Power, yet after all, I found that the Body of it has appeared fainter than the Body of the Moon at Noon.

4. Theſe then are all the Proprieties we need to take notice of in a ſimple Propagation of Light through a tranſparent uniform *Medium*. Namely, firſt, that there is a Propagation of Light from every Point of the Surface, in every part of the tranſparent incompaſſing Medium *in orbem*, that they each of them exert their particular Influence in that Orb, as if they were all ſingle and diſtinct. And, Secondly, That the more of theſe ſingle Rays there fall upon an inlightned Point, the more it is inlightned, and that each of theſe Rays does act upon the inlightned Body with the ſame Power, as if it acted ſingly, though at the ſame time, Millions of Radiations from other Points do act upon it. *Proprieties of Light to be obſerved.*

This does ſeem ſomewhat difficult to be underſtood how it ſhould poſſibly be ſo: But yet if we conſider, that though we cannot by Senſe apprehend the very Manner of its Acting; yet we are not without ſenſible Examples of ſuch kind of Actions naturally performed: For if on the ſmooth Superficies of a ſtanding Water, we let fall a Drop of Water, we ſhall, I ſay, plainly ſee how the Motion made by the fall of that Drop is every way propagated in Rings or Waves increaſing and ſpreading further and further from the Point where the Motion was begun; and this every way with equal Velocity; which may be argued from the perfect circular form of ſuch Rings. But that which comes yet nearer to the Similitude of Light, and for which Property only I mention it, is, if we let fall at the ſame time 10 or 20 Drops in ſeveral diſtances one from another, we ſhall find that every one of them will produce Rings about it; each of which will continue to be propagated equally every way as regularly, as if there had been but one Drop let fall: And though they variouſly croſs one another, and ſo, one would imagine, ſhould confound the regular progagation of each others Rings; yet whoever ſhall obſerve any one of them in the time of ſuch propagation, ſhall find that they are not in the leaſt diſturbed by the Action of any other, though they may be croſt with 20 ſuch differing Conſecutions of Rings. And though, I confeſs, after all this, it does ſeem not a little difficult to comprehend how one and the ſame Particle of Matter, or of the tranſparent *Medium*, ſhould at the ſame Inſtant propagate through it a thouſand differing Motions, a thouſand differing Ways; yet ſince we are aſſured by the laſt Similitude of the Rings or Waves upon the Surface of the Water, that it is actually done in Nature, and that viſible to Senſe, though we cannot ſo clearly comprehend the Metaphyſical Reaſon thereof: yet 'tis enough for a Principle to build upon, that we are aſſured it is ſo, and that ſuch and ſuch are the Effects that flow from it. So tho' it be difficult to comprehend the Metaphſical Reaſon, why a Body which is by another moved with a certain Degree of Velocity, ſhould continue to move forwards in a right Line with the ſame Velocity it received, till it be ſtopt by meeting with other Bodies, and communicating that Motion to them: (For who can underſtand what it receives, and what it parts withal, and what it is diſtinct from the Eſſence of a Body that ſo moves it or ſtays it?) Yet ſince we are ſenſibly informed that really it is ſo, it will be enough for a Phyſical Principle of Nature, of which we can have no further Light or Information, that will make it more plain and certain to us. Now though it do ſeem thus difficult to be explain'd, yet 'tis not wholly impoſſible. I do confeſs, the Conſideration they have about it, of the neceſſity of the Propagation of it many various Ways through the ſame Body, in the ſame Inſtant, does much confound the Imagination; becauſe who can imagine a Body to communicate Motion to another, without its being actually moved it ſelf? And if it be actually moved it ſelf, how can it move more than one way at once? And if it moves but one way, how can it move all the oppoſite Bodies with their peculiar Propagations? *How a Body may communicate different Motions different ways.*

Sensible Moments composed of infinite other.

5. But to this it may be answered, first, that there are in every *sensible* Point of Matter a sufficient number of distinct Particles to convey every one of those Motions distinct, without interfering one with another: For as there may be Millions of Motions communicated to a *sensible* Point, so there may be as many Millions of distinct Particles to receive each of them distinctly.

But besides that every sensible Moment of time is composed of infinite Instants, or of an indefinite number of other Moments of time of a shorter duration; so that within a moment of time that is sensible to a Man, the same sensible Point may be moved many Millions of ways successively, and so communicate each of those Motions distinct, without being confounded with any two: And the next human Moment may have and convey as many others, as many several ways. Now that this may be so, we may yet farther consider, that Motions may be infinitely swifter than sensible Motions; that is, than those Motions that we can see a *Prius* and *Posterius* in: For the swiftest Motion that we can see, is that wherein we can distinguish the Body moving from the *Terminus a quo* to the *Terminus ad quem*, in a sensible time, or a sensible moment: For if it be in both within the least moment of time we are able to distinguish, it seems to us as if it were in both the terms and the interjacent space altogether. For instance, take a long String, and stretch it out between two Pins; if it be long and but slack, we are able to see and distinguish it, as it moves from one side to the other, and how it returns again, because it makes its Vibrations within the compass of several human Moments of time; and if it come within three sensible Moments, we seem to see it in three sensible Places. But if it be strain'd yet straighter, so as to make its whole Vibration within one human Moment, we see it as if it were in all parts of its space and in the two *Termini* at once, about which time, and not before, it begins to sound. Upon the same account it is, that if you take a Coal of Fire in the Night, and move it to and fro pretty quick, it seems to make a perfect Line of Fire; whereas if it be moved slow, you see it distinct as a Body moved. I could give a hundred Instances by which I could make it manifest, that the *Phænomena* thereof proceed only from the length of time there is in the shortest Moment of a Man.

Sensible Moments of Creatures proportioned to their bulk.

And I do not at all doubt but that the sensible Moments of Creatures are somewhat proportion'd to their Bulk, and that the less a Creature is, the shorter are its sensible Moments; and that a Creature that is a hundred times less than a Man, may distinguish a hundred Moments in the time that a Man distinguishes one. For when I hear a Fly moving his Wings to and fro so many times, with such a Swiftness as to make a Sound, I cannot but imagine, that that Fly must be sensible of and distinguish at least 3 Moments in the time that it makes one of those Strokes with his Wings, for that it is able to regulate and guide it self by the Motion of them. And the like may be said for the quick Motions of other lesser Creatures. So that many of those Creatures that seem to be very short lived in respect of Man, may yet rationally enough be supposed to have lived, and been sensible of and distinguished as many Moments of time as a Man; because within that space of time it has lived, it has had as many distinct Moments of time, and has had as many distinct Differences of Moments, as a Man hath in the Age he lives. But this only by the by.

But farther, in the third place, as there are infinite Parts in the least sensible Part, and infinite Moments in the least sensible Moment; so there may be infinite Parts of Space in the least sensible Space to be moved. For since all Space is infinitely divisible into lesser, we cannot say how little a Space is necessary to be moved to make a sensible Propagation of Light. Possibly the thousand thousandth Part of the least sensible Space, may be sufficient to be moved, to make the continuation of the Propagation of Light through a Particle. Now we are sensibly informed by the Microscope, that the least visible Space (which is that which appears under an Angle of half a Minute of a Degree) may be actually distinguished into a thousand sensible Spaces: And could we yet further improve Microscopes, 'tis possible we might distinguish even a thousand more Spaces in every one of those we can now see by the help of those Microscopes we have already. Now possibly a less Space than the least of these may be

be enough for a Body to be dislocated in the Motion that is necessary to produce the Propagation of a Ray of Light.

But then in the fourth place, Velocities may be infinitely swift in those Spaces: For who can imagine the smallness of time that a Motion can be performed through the smallest of those Spaces?

To explain which a little further, I say, 'tis evident first to the Sense of Seeing, that the bigger the Body is, the slower is its Vibration, and the smaller, the quicker: Which is evidenced to the Eye in all pendulous Motions, and in the Recursions and Vibrations of Pieces of Timber, which the longer and bigger they are, the more slow are the Vibrations made by them; and the smaller and shorter, the quicker. But then where the Eye is unable to assist us any further in distinguishing the swiftness of Vibrations, there the Ear comes in with its assistance, and carries us much further: And as I shewed before in the Vibrations of Strings, so now I instance further in Bells, where we find by the Tone, that the smaller the Bell, the sharper and more shrill its Sound; and this carries us on to a Sound so sharp, that we only call it screeking, and at length it becomes offensive to the Ear, because beyond that it cannot endure the Sense of a shriller Note or quicker Vibration: For that the Shrillness of the Note depends upon the quickness of the Vibration, I think I need not instance. Hence I conceive that there may be yet beyond the reach of our Ears infinite shriller and shriller Notes, which may be distinguished by Ears or Organs of Hearing adapted by their lesser Bulks and finer Parts, to distinguish those quicker Vibrations: And therefore those lesser Creatures that we discover, tho' possibly they cannot hear those Sounds which we hear, but are able to distinguish every Turn and Return of the Vibrations of them by the quickness and aptness of their Sight; yet they may have as great variety in the differences of Sounds wholly imperceptible to us, as we have within the reach of our Ears. And as the Voice of Man is limited to a certain number of Notes, lower or higher than which no Human Voice can reach; so may it be in the Voices or Sounds made by those smaller Creatures. That this may be so, we may argue yet farther from the Curiosity and Make of their Sight; for we plainly enough see, that the smaller the Eye is, the smaller is the Picture of the visible Object that is made at the bottom of it upon the *Choroeides* or *Tunica Retina*. And this, as I may hereafter explain, is as demonstrable from the Principles of Refraction and Opticks, as any one thing in that Science: Which if so, how small will be the Picture of the Object that is painted at the bottom of one of those Eyes which by a Microscope we discover in the Cluster of the Eyes of Flies, and other small Insects? And yet after all this, we have no reason to doubt that these Creatures are able to distinguish as many single Parts in those Pictures, as a Man can in a proportionate Picture at the bottom of his Eye. For as the Sensation of a Man's Sight is limited to a certain bigness, less than which none can distinguish; which, as I have elsewhere shewed, is not less than what is comprised within about a half a Minute of a Degree, at most, of the Orbicular Part of the bottom of the Eye; which in all probability is from the bigness of the smallest sensible Part receiving the Image, or of the Optick Nerve that is capable of conveying a distinct Motion or Sensation to the Brain, as *Des Cartes* has very ingeniously explained: So in these small Creatures, where every thing else is proportionably smaller, 'tis not at all to be doubted but that those Fibres that convey the Sensation to their Brain, are proportionably also smaller; and consequently that they must have at least a Faculty of distinguishing the Parts of that Picture, which whole Picture may possibly be made upon much less than half a Minute of a Degree of the Orbicular Part of the bottom of their Eyes only: For as the Space of those Fibres is shorter between the bottom of the Eye and the Brain, so may their bigness be proportionably smaller. All which Particulars consider'd, it does seem that Nature has as it were ballanced the Gifts bestowed upon them by some other Means adapted more particularly to each of their Constitutions; as were it proper for this Time and Place, I could more particularly explain and demonstrate. But these Speculations being only by the by, I shall rather proceed with my Discourse concerning the Nature of Light, so as to make the manner of its Operations mechanically and sensibly intelligible; by considering further, that if there be a real Motion necessary for

every

every diſtinct Propagation of Light; then it will ſeem to follow, that every luminous Point muſt have its diſtinct Moment to be propagated this way and that way within the ſpace of a ſenſible Moment: Which if it be affirmed to be ſo, I ſee no Reaſon in Nature why it may not be poſſible, and that from thoſe four Conſiderations I before ſpecified. So that though the whole Hemiſphere ſhould be filled with lucid viſible Points, as we find in a clear ſtarry Night, that it is pretty thick ſet with Stars, and by Teleſcopes we diſcover it to be yet thicker: Why, I ſay, Impreſſions may not be made from every one of them diſtinctly and ſucceſſively upon one ſingle ſenſible Point of Matter in one human moment; and conſequently why the ſame Chime of Impulſes may not be again repeated the next Moment, and ſo perpetually in every human Moment: For 'tis not the Number of them that would at all impede ſuch a Concluſion, no, not if there ſhould be ten thouſand times as many more; for there might be found ſmaller Moments enough within that Space of a ſenſible or diſtinguiſhable Moment, to fit every one with one at leaſt: ſo that the ſame point of Matter might communicate every one of their Impreſſions diſtinct and ſucceſſively within that Period: And beſides this, there might be found diſtinct Parts enough, within the Orb of this leaſt ſenſible Point, to propagate every one of thoſe Motions diſtinct, their various ways, by appropriated Parts, all at the ſame Inſtant.

So that upon the whole, we may aſſign to every Propagation of Light through the leaſt ſenſible Space, a real temporary local Motion. And if Monſ. *Des Cartes* by his Propenſion to Motion, and Mr. *Hobbs* by his *Conatus* or Endeavour to Motion, do not mean ſuch a real local Motion, their Notions are neither of them intelligible to others, nor did they really underſtand them themſelves. For bare Propenſion to Motion, is not Motion, and conſequently cannot propagate Motion: And Endeavour to move is not moving, and ſo cannot progagate Motion: But for the Propagation of Motion, Motion is neceſſary. And this I hope has ſhewed a Poſſibility at leaſt, if not a Probability, how it may be made.

The Cauſe of the Fluidity of the vaſt Expanſum.

6. If then this be ſo, we may hence deduce the Cauſe of the perfect Fluidity of the vaſt quantity of Matter which fills the whole *Expanſum* of Space between the ſolid Cæleſtial or Luminous Bodies of the Univerſe. And we may thence bring a demonſtrative Reaſon why it becomes ſo free from impeding the Motions of the Planetary or Cometical Bodies that are moved through it. For if every one of theſe Luminous Points, the Fixt Stars, which fill almoſt every Point of the Heavens in a clear Night (as is made yet much more viſible by the help of long Teleſcopes) be as glorious and Luminous Bodies as the Sun itſelf, though they here appear incomparably leſs, and of a fainter Light, by reaſon of their Diſtances indefinitely almoſt more diſtant from us than that is: If, I ſay, every one of thoſe Fixt Stars, or glorious Suns, be ſtuck up and down here and there in the vaſt *Expanſum* of Matter that fills the whole of Nature, not at equal but various Diſtances one from another; and every one of thoſe do really once at leaſt within the ſpace of one human Moment of time, really move the whole *Expanſum* of the Ethereal Matter (as 'tis moſt evident and demonſtrable they do;) then what can there poſſibly be more rationally contrived to make and preſerve the perfect Fluidity of the *Æther*? For every Point of Matter is Millions of ways, and conſequently with incredible Velocity moved to and fro within the compaſs of one ſingle Moment, and ſo muſt neceſſarily have its Parts indefinitely divided, and looſe one from another; and conſequently being thus fluid, and the minute Motions ballancing each other in every Point of Matter, and theſe Motions being proportionably ſwifter than the ſwifteſt Motion of the more bulky Maſs: It follows, I ſay, that the Impediment to any bulky Bodies moving through it, muſt be inconſiderable, or almoſt nothing. For the Parts of this Matter being indefinitely ſmaller than the leaſt ſenſible Point, and the Motion of each of them, though never ſo ſmall, being within the compaſs of a human Moment determined every way, or infinite ways, the Motion of them one way muſt ballance that of others another, and conſequently give no Impediment to the ſenſible or bulky Body moved through them. I could have proceeded further from one and the ſame Principle to have

explain'd

explain'd how this continued Chime of Motions from every Part do create various sorts of harmonical Motions in concrete Particles, which have their various and admirable Effects in producing the Harmony which is in Nature. But of that some other time, this will be enough at present, to intimate that every one of these Cælestial Bodies have their share in the Motion of the Matter of the World, and every one of them act more or less powerfully, according as they are nearer and nearer posited to the Parts acted upon; and consequently the Sun, as I before hinted, becomes in our Parts more considerable than all the other Cælestial Bodies. 'Tis possible there may have been in some former Ages of the World, a Notion somewhat like this; but not so well understood by those that we are beholden to for the Hint of it: Which may be argued both from the *Platonick* and *Pythagorick Theorys*, and much more from those Scraps we have of the Philosophy of *Confucius*, the *Chinese* Philosopher, who was contemporary with *Pythagoras*, but wrote of the Philosophy of an Age fifteen hundred Years before him: But the regaining of it is not to be hoped from any of their Hints, but from a clear and steddy Geometrical Method of Reasoning, proceeding from the more sensible to the more abstruse and insensible Causes and Effects of things.

Why one Fluid hinders Motion more than another.

Nor can I conceive any other Notion why one Body should resist or hinder Motion more than another, than that the one is less fluid than another; that is, that the solid Parts of the one fluid Body are smaller than the solid Parts of the other fluid Body. And we find it evident to Sense in sensible Fluids, where we may sensibly be assured, that the grosser the Particles of the fluid Body are, the more impediment does that Body give to the Motion of another Body through it: As upon the evaporating of Liquors that have solid Bodies in them, in the mixing of Pouders with Water or other Liquors, and in the mixing of Salts and Sugars; which give a much greater impediment before they are dissolved into Fludity than afterwards. If then from sensible Experiments we proceed to Effects insensible yet evident to Reason, we may conclude that the Æther must be abundantly more fluid than any other Body, and indeed may be said to be indefinitely fluid; and so the Resistance that it must give to bulky Bodies, must be indefinitely small, because there is so mall a Part of it dislocated by the transit of a Body, being indeed nothing but a meer Superficies, or the Parts of it that are next contiguous to the Body moved through it. But of this I shall upon onother occasion say more, when I shew the Cause why the Bodies moved through them, though they do really every moment dislocate as much Body as is equal to them in Bulk, do notwithstanding receive little or no impediment to their progressive Motion.

SECT. VII.

The CONTENTS.

BEfore I give the Contents of this Section, I think it may be convenient, in order to the better underſtanding of what follows, to premiſe, That our Author having thus far proſecuted his Inquiries into the Nature of Light, What it is in the Luminous Body, to wit, a certain Vibrative Motion of its Parts, of a determinate Velocity. 2dly, What the Medium *is, how it is acted upon by Light, and how Light is thereby propagated, with all the neceſſary Qualifications of this* Medium. *3dly, What this Action is on the Eye, and how the Powers of Light are exerted upon the ſenſible Part thereof, to cauſe Viſion: Inſtead of proceeding farther in the Method he had propoſed to himſelf, of explaining how the Rays or Pulſes of Light from the Luminous Bodies are Reflected, Refracted or Inflected, by a ſucceſſive Refraction, bending the Ray into a Curve; which ſeveral Subjects I ſuppoſe he deſign'd to treat of, though I do not find he ever did (except of Inflection, of which ſee* Micrography, *p.* 217.) *being diverted by other invervening Subjects, which carried his Thoughts other ways: And indeed the Field of Nature is ſo large, and ſo plentifully adorn'd with tempting Curioſities, that it is a Reſtraint upon the Collector, not to leave one before it is thoroughly examined, to reach at another. I ſay, when our Author had treated on theſe Heads ſo far, he leaves this Subject, I muſt confeſs, in ſome ſenſe imperfect; and taking occaſion from his having mention'd Time and a Human Moment, he wrote the following Diſcourſe, wherein,*

1. *The Author attempts to ſhew how we come by the Notion of Time, tho' the Impreſſions on the Senſes are all momentary. The* Communis Senſus *not ſufficient for this purpoſe, therefore there is a neceſſity of ſuppoſing ſome other Organ. This he conceives to be what we call Memory, and then he proceeds to give an Hypotheſis to explain Memory, and how it is performed: That Memory is organical: That the Soul, tho' an Incorporeal Being, yet in performing its Actions makes uſe of Corporeal Organs: That Memory is the Repoſitory of Ideas form'd by the Senſes, or rather by the Soul it ſelf. 2. The Action of the Soul in ordering and ſtoring up Ideas, is call'd Attention. The Author's Notion what it is: That the Place of the Repoſitory is ſomewhere in the Brain, whoſe Subſtance is the Material out of which Ideas are formed, the Chain of which is coyled up in the Repoſitory, the Soul being at the Center where the preſent Idea is made, which is the preſent Moment; and hence comes the Notion of Time and Duration, and is apprehended as a Quantity. 3. A Mechanical Repreſentation ſuppoſed for the better Underſtanding the ſeveral Operations of the Soul,* viz. *Apprehending, Remembring and Reaſoning. That there may be ſome certain Point in the Brain, where the Soul has its chief Reſidence, and there receives its Informations, and gives its Orders. This Repoſitory is furniſhed with*

adapted

adapted Matter for the Uses of the Soul: Five sorts of Matter for the Impressions of the Five Senses: That for Sight explain'd by the Bononian Phosphorus *: That for Sound by the Vases in antient Theaters and Unison-tuned Strings. Smelling, Tasting and Feeling also after the same manner are explained.* 4. *Out of this adapted Matter the Ideas formed are material and bulky, of determinate Figures, Sizes and Motions. That the Soul forms one Idea each Moment, which Moments differ in duration in different Men. A Computation of the number of Ideas that may be form'd in a Man's Life. That the Number will not be found to be an Objection against this Hypothesis. That Attention is the Action of the Soul in forming Ideas, and what they are. That they continually protrude each other from the Center. That the Soul by its Radiation and the Re-action of the Ideas, becomes sensible of them, and so of Time. How it is sensible of many concomitant Ideas. How some Thoughts lost may be recovered. That this Radiation and Re-action weakens in a duplicate proportion to the distance of Time. That the Soul may exert its Power on any particular Idea according to its own Will. That there is a continual Radiation of the Soul in the Repository of Ideas, and is in some sense reacted upon by them; whence comes what we call a bringing to remembrance.* 5. *The Action of the Soul called Thinking, is a more particular Radiation thereof to this or that part of the Repository. Thinking is partly Memory, and partly an Operation of the Soul in forming new Ideas. Reason a more compleat Action of the Soul from comparing Ideas. As the Repository is better stored, so the Soul acts better. The Soul a self-moving* Principle *and* Primum Movens. *The Soul compared to the Sun in the Great World. If the Sun had Understanding, it would be sensible of the Resistance its Rays meet with. This explain'd by Hearing and Seeing. A double Influence from the Sun on Bodies and their Motions. Tho' we cannot conceive how the Soul, being spiritual and incorporeal, acts upon Ideas that are corporeal, or can be acted upon by them; yet we are assured such Effects are performed. That the Soul is not confin'd to act only upon these Ideas, but may extend its Power to every part of the Body, and possibly to some considerable Distance from the Body.* R. W.

How we come by the Notion of Time.

BEfore I come to the discussing of the particular Matters treated of the last Section, I would a little further consider what I have been discoursing of, *viz.* Time: And here, since it is a general Maxim in the Schools, that *Nihil est in Intellectu, quod non fuit prius in Sensu*, I would query by what Sense it is we come to be informed of Time; for all the Information we have from the Senses are momentary, and only last during the Impressions made by the Object. There is therefore yet wanting a Sense to apprehend Time; for such a Notion we have: And yet no one of our Senses, nor all together, can furnish us with it, and yet we conceive of it as a Quantity. For this therefore, since we cannot find any external or outward Sense, we must seek within, and we shall find there is somewhat like that which is called *Communis Sensus*, which is receptive of all the outward Impressions of the other Senses. But still this is insufficient to afford us the Notion or Knowledge of Time; for the Impressions on that can be no other than the Impressions from the other Senses, conveyed by the *Media* of the sensory Nerves, which must be also momentary, as well as the first Impressions, and consequently do not yet sufficiently inform us of the Notion of Time. Considering this, I say, we shall find a Necessity of supposing some other Organ to apprehend the Impression that is made by Time. And this I conceive to be no other than that which we generally call Memory, which Memory I suppose to be as much an Organ, as the Eye, Ear or Nose, and

and to have its Situation ſomewhere near the Place where the Nerves from the other Senſes concur and meet.

Memory Organical. Now that it is really Organical, I argue from this, that it may be both improved and impaired, it may be deſtroyed and exalted to a great Perfection. It is at ſome times ſenſible, and at other times wholly inſenſible, as particularly in Sleep: And whenever 'tis ſo, we have no Senſe of Time, but we paſs over all that Space of Time, as if it had not been, and we only come to underſtand it by other Circumſtances. Beſides, we have often known that the Memory has been quite deſtroyed by a Fall, or great Blow upon the Head, by a Fever, or other great Sickneſs; nay often by Exceſs of Drinking, all which affect not the Soul: And in probability, this might be cauſed by ſome Wound, Hurt, Bruiſe, or ſome orher Diſtemper of that Part, which we conceive to be the Organ of Memory; which makes it an unfit Organ for the Soul to make uſe of for that effect; and conſequently the Soul can no more remember without the Organ of Memory, than it can ſee without the Organ of Sight, the Eye, or hear without an Ear. For the Soul, or firſt Principle of Life, tho' it be an Incorporeal Being, yet in performing its Actions, makes uſe of Corporeal Organs, and without them cannot effect what it wills.

Memory then I conceive to be nothing elſe but a Repoſitory of Ideas formed partly by the Senſes, but chiefly by the Soul it ſelf: I ſay, partly by the Senſes, becauſe they are as it were the Collectors or Carriers of the Impreſſions made by Objects from without, delivering them to the Repoſitory or Storehouſe where they are to be uſed. Which Impreſſions being actual Motions, as I have plainly proved in the Explication of the Organ of the Eye, and the Operation of Light, thoſe Motions conveyed to this Repoſitory become Powers ſufficient to effect ſuch Formations of Ideas as the Soul does guide and direct them in: For I conceive no Idea can be really formed or ſtored up in this Repoſitory, without the Directive and Archiectonical Power of the Soul; and the Actions or Impreſſions ceaſe and fail without the concurrent Act of the Soul, which regulates and diſpoſes of ſuch Powers.

2. This Action of the Soul is that which is commonly called *Attention*, by which what is meant no one does further or more intelligibly explain, than only by giving the ſame Notion by ſome other ways of Expreſſion, which, it may be are as little intelligible. My Notion of it is this, that the Soul in the Action of Attention does really form ſome material Part of the Repoſitory into ſuch a Shape, and gives it ſome ſuch a Motion as is from the Senſes conveyed thither; which being ſo formed and qualified, is inſerted into and incloſed in the common Repoſitory, and there for a certain time preſerved and retained, and ſo becomes an Organ, upon which the Soul working, finds the Ideas of paſt Actions, as if the Action were preſent.

The Author's Notion concerning Ideas. This Repoſitory I conceive to be ſeated in the Brain, and the Subſtance thereof I conceive to be the Material out of which theſe Ideas are formed, and where they are alſo preſerved when formed, being diſpoſed in ſome regular Order; which Order I conceive to be principally that according to which they are formed, that being firſt in order that is firſt formed, and that next which is next, and ſo continually by Succeſſion, from the time of our Birth to the time of our Death. So that there is as it were a continued Chain of Ideas coyled up in the Repoſitory of the Brain, the firſt end of which is fartheſt removed from the Center or Seat of the Soul where the Ideas are formed; and the other End is always at the Center, being the laſt Idea formed, which is always the Moment preſent when conſidered: And therefore according as there are a greater number of theſe Ideas between the preſent Senſation or Thought in the Center, and any other, the more is the Soul apprehenſive of the Time interpoſed.

Theſe are the *Supellex* of the Soul, and theſe are the Inſtruments it makes uſe of in the apprehending of things or Actions paſt; and by theſe it becomes ſenſible of all that it really knows, and according to the Perfection or Imperfection, the Multitude or Paucity, the Regularity or Irregularity of the Order and Diſpoſition of theſe Ideas in the Repoſitory or Memory, the Aptitude or Ineptitude of the Subſtance for Formation, Radiation, Diſpoſition, *&c.* ſo is the Soul the better enabled, Firſt, to form new Ideas aright, or rightly to apprehend the thing to be known. Secondly to apprehend the Order according

to

to which they have been formed, and are ranged; that is, to know the time, or, to ſpeak in the common Phraſe, to remember what is paſt, as if it were preſent, and how long it is ſince it was done, by the number of Ideas beween. The Soul therefore underſtands Time, or becomes ſenſible of Time, only by the help of the Organ of the Memory, which Organ is this Repoſitory of Ideas, and by means of the Order, Situation and Diſtance of the ſaid Ideas, from the Center, or one among another, ſo it becomes ſenſible of Time: And Time, as unnerſtood by Man, is nothing elſe but the Length of the Chain of theſe Ideas, between any two that are at any time apprehended together: And according to the Number of the Links in this Chain, ſo is the Impreſſion made to the Soul that apprehends it, of a longer or ſhorter time interpoſed; and the Notion of Time is the Apprehenſion of the Diſtance of Ideas from the Center or preſent Moment. And ſo Time comes to be apprehended as a Quantity, and ſo falls under the Conſideration of Geometry and Menſuration.

3. Now becauſe nothing is ſo well underſtood or apprehended, as when it is repreſented under ſome ſenſible Form, I would, to make my Notion the more conceivable, make a mechanical and ſenſible Figure and Picture thereof, and from that ſhew how I conceive all the Actions and Operations of the Soul as Apprehending, Remembring and Reaſoning are performed. *A ſenſible Repreſentation of the Matter.*

I ſuppoſe then that there may be a certain Place or Point ſomewhere in the Brain of a Man, where the Soul may have its principal and chief Seat.

I will not now enter upon Arguments or Reaſonings from Experiments or Obſervations, to determine the preciſe Place, though concerning the definitive Poſition thereof, I have much that I may at another time produce: But I will only ſuppoſe at preſent, that there may be ſome ſuch Place whereinto all the Impreſſions made from the Senſes upon adapted Matter may be deliver'd; which Impreſſions, as I have elſewhere explain'd, are no other but actual Locomotions given to the Parts of Matter or Bodies ſo or ſo moved.

I ſuppoſe then this Repoſitory to be furniſhed with variety of Matter adapted for the Uſes to which the Soul applies them, which I call the Elements out of which Ideas are made; among which Variety there are principally five ſorrs fitted and adapted to receive the Impreſſions from the five Senſes; that is, one peculiar Kind for the Impreſſions of Sight, which is of ſuch a Quality, Form, Make, Bulk, or other Conſtitution, as makes it Receptive and Retentive of the Impreſſions of Light and Colours, which none of the other Bodies are capable of. Which may a little be explain'd by the Matter of the Phoſphoros made of the *Bononian* Stone, or that found out by *Baldwinus* made of Chalk and Niter; which Matters are ſo made and adapted by the Chymical Preparations of them by the force of Fire and Mixtures made in their Proceſſes, that they, ſo ſoon as expoſed to the Impreſſions of Light, receive and retain thoſe Impreſſions, though for no long time, yet enough to ſhew us a Specimen of a certain Qualification not to be found in moſt other Bodies, which may yet poſſibly be done much more powerfully and effectually by the Chymiſtry of Nature in the Digeſtions and Preparations made in the wonderful Elaboratory of the Animal Body; where all things are are ordered and adapted by the All wiſe Creator, for the Work to be done: So that nothing can be imagined wanting or redundant to perform what is by his Intention deſign'd to be done.

Another ſort of Matter I ſuppoſe to be that which is fitted to receive the Impreſſions of Sound, ſomewhat like thoſe Bells or Vaſes which *Vitruvius* mentions to be placed in the antient Theaters, which did receive and return the Sound more vigorous and ſtrong; or like the Uniſon-toned Strings, Bells or Glaſſes, which receive Impreſſions from Sounds without, and retain that Impreſſion for ſome time, anſwering the Tone by the ſame Tone of their own. And though in theſe Examples (which I am fain to bring for Explication only) there ſeems wanting the great Requiſite of a Power to retain for a long while thoſe Impreſſions which are ſo given, they all of them loſing them in a very ſhort time; yet, as I ſhall by and by ſhew, they do and will each of them retain their ſeveral Impreſſions long enough to make them ſufficient for producing the ſame Reactions whenever they are again acted upon. And ſuch an Impreſſion I ſhall prove is again given both by the Soul and by ſucceeding ſimilar Sen-

ſations: For having Potentiality of receiving, and being excited by ſuch Impreſſions, they do again renew their former Impreſſion, and afreſh ſhew their Power, in the ſame manner as the Muſical String or Bell, or the well prepared *Bononian* or *Baldwin* Phoſphorus do each ſhew their Natures, when the one is ſtruck or agitated by Motion, and the other acted upon by Light.

The like appropriated Materials I ſuppoſe alſo for the Impreſſions of the other Three Senſes, *viz.* Smelling, Taſting, Feeling; each of which are qualified to receive and retain the Impreſſions from the other Senſes. As for inſtance, the Smell being cauſed by a ſubtil and curious Exhalation from the odoriferous Body imbibed by the Air, the Olfactory Nerves are prepared with an aerial Body fit to diſſolve or imbibe that Subſtance in the ſame manner as the Air does from the odoriferous Body; which aerial Body, by means of the Olfactory Nerve, having an immediate Intercourſe and Paſſage to the Brain, does immediately convey it thither: And according to the nature of this aerial or ſpirituous Subſtance with which the Olfactory Nerve is furniſhed, ſo does it diſſolve or imbibe this or that Exhalation out of the Air. Whence I conceive that it is of diſtinct Natures in every Species of Animals, and thence that every one of them have diſtinct Senſations of the ſame *Effluvia*, and that which is congruous and agreeing to one, is of a contrary nature to another; and thence what is grateful to one is odious to another. And again, what is ſenſible to one ſort of Creature, who has an aerial Subſtance fitted to diſſolve and imbibe ſuch or ſuch a Steam, is wholly inſenſible to another that wants that aerial Subſtance, and is furniſht with one of a differing Nature. Which I conceive to be the reaſon, why Dogs and other Creatures have ſo ſtrong a Faculty of ſmelling the Scent of Animals, or the Fleſh of them, which are very hardly diſcoverable to a Man. On the other ſide, in probability Man is ſenſible of many things, as the Smell of Flowers, Herbs and Fruits, which poſſibly a Dog does very little, if at all ſcent.

The like may be ſaid of the Taſte, which I conceive lies only in the Nature of the watery Liquor conveyed by the Nerves of Taſte to the Tongue, according to the Nature of which for diſſolving this or that Subſtance of the Bodies touching it, is the Impreſſion of Taſte conveyed to the Brain. And ſo we may ſee a clear Reaſon why one Taſte may be taſted by one, which is not by another, and why one Taſte is pleaſant to one Creature which is not ſo to another, and how a Body becomes guſtable or taſteleſs, and how that which is taſtleſs in itſelf may be made taſtable, and why that which is taſtable may be made taſteleſs. Of both which kinds I could give hundreds of Inſtances which would much confirm this my Theory, and ſhew what Improvements of this kind could be made. The like, I conceive, is to be ſaid of an adapted Matter for receiving and retaining the Impreſſions of Feeling, ſomewhat after the nature of the warming Stone, and ſeveral other ſuch Subſtances, which do imbibe thoſe Impreſſions more readily, and retain them for a longer time. Now I do ſuppoſe, that the Repoſitory is continually ſupplied with a ſufficient quantity of theſe kinds of Subſtances, with which the Senſe does continually form Ideas, and diſpoſe of them into the Repoſitory of Memory, and that without thoſe Materials, and the concurrent Impreſſions of the Senſes, it cannot form them: For otherwiſe a blind Man would have Ideas of Colours, which yet he has not, and a ſick Man would have a true Idea of Taſtes, which yet he has not.

But to return to the conſideration of the Place or Repoſitory where theſe Ideas are form'd and retain'd.

The Ideas material and bulky.

4. I ſuppoſe there may be about this place, which I will henceforward call the Center, a certain Sphere of Capacity fill'd with adapted Matter, for the Formation, Reception, and containing of all the Ideas which ſhall be emitted from the ſaid Center. Theſe Ideas I will ſuppoſe to be material and bulky, that is, to be certain Bodies of determinate bigneſs, and impregnated with determinate Motions, and to be in themſelves diſtinct; and therefore that no two of them can be in the ſame ſpace, but that they are actually different and ſeparate one from another; and as they have their diſtinct Figures, ſo have they each of them their diſtinct Qualifications of Motions and Conſtitutions.

I will ſuppoſe further, that the Soul may every moment, partly by its own immediate Power, and partly by the help of the Impreſſions produced by the Senſes, form one of theſe Ideas, and inſert it into the Repoſitory. Which Moments in ſome Men may be more, in ſome may be leſs, within the ſame compaſs of time, according to the Activity of the Soul it ſelf, and according to the Aptitude or Unfitneſs of the Matter to be wrought upon. So that in ſome there may be Four of them formed in a ſecond Minute of Time, in others poſſibly not One in two Seconds of Time: And according to the Perfection and Aptneſs of the Matter to be formed, and the Activity of the Soul in performing its Effects, ſo are there more of theſe Ideas formed within the ſame Space of time. So that a Man of an ordinary Conſtitution of Soul and Body, that is, one of a middle Degree between the more active and quick, and one of the more ſlow and dull, may within the compaſs of his Life, ſuppoſing he ſhould live to a hundred Years of Age (which yet not one of a hundred thouſand thouſand does arrive to) form within that compaſs of time, and ſtore up in his Repoſitory, a thouſand Millions of diſtinct Ideas; all which may have followed each other in a continued Series, beginning with the time of the firſt Advertency of the Child, and continuing to the time of the actual Separation of the Soul and Body at Death, Which I thus compute: A hundred Years contain 36525 Days, and 36525 Days contain 876600 Hours, and 876600 Hours contain 3155760000 Seconds. Now one with another, when the Soul is intent and acting, there may be 3600 formed within the compaſs of an Hour, and ſo one in a Second of Time. So that if the Soul could through the whole Courſe of 100 Years be continually ſo intent, and ſo acting and forming theſe Ideas, and inſerting them into this Repoſitory or Organ of Memory, there might be there repoſed 3155760000 Ideas. But by reaſon of Sleep interpoſed, one third Part of the Number will be taken off, the Soul then for the moſt part ceaſing to form Ideas, or when it does, they are only imperfect and loſt. So that there will remain but 2103840000, or to take a round Sum, but 21 hundred Millions. Now if we examine this remaining two thirds of Time or Moments, and therein conſider what part of the time remaining is loſt in Infancy, Old Age, Sickneſs and Inadvertency, we may well reckon that two thirds of theſe remaining Moments are loſt, and no Ideas at all formed in them; and ſo inſtead of 21 hundred, there will remain but the number of 7 hundred Millions. And if we again conſider how ſmall a part of theſe are induſtriouſly and carefully ſtored up, we may very well agree, that not above a ſeventh Part of theſe are ſtored up: And ſo one hundred Millions may be a ſufficient Number to be ſuppoſed for all the Ideas that may have been treaſured up in the Organ of Memory through the whole Courſe of a Man's Life, though of a hundred Years continuance; and conſequently one Year with another may be ſuppoſed to add to this Store about one Million of Ideas. But if we conſider how much this will amount to for every Day, we ſhall find that yet the Number is very much too big, and muſt be yet very much diminiſhed: For when we conſider that this will ſtill make 2738 Ideas for every Day of the hundred Years; and if a Man conſiders with himſelf how many he conceives he may have added to his Store in one Month next laſt paſt, I am apt to think he will conclude, that one with another, it will be enough to allow one Tenth of that Number for the Number of Ideas that have obtained a Place in this Repoſitory, the Organ of Memory. So that if a Man allows but two or three hundred a Day, nay, but one hundred for every Day he hath lived, ſince he was born to his preſent Moment, he will find that Number large enough to contain all the Ideas he has really ſtored up in the Organ of his Memory. As ſuppoſing a Man of fifty Years of Age, who according to that compute muſt have lived 18262 Days; and conſequently if you reckon but a hundred for each Day, muſt have 1826200. It will be very hard, I conceive, for a Man of that Age perfectly to remember ſo many diſtinct things, though yet I will not ſay it is impoſſible. But ſuppoſing he could by recollecting remember 100 Millions, and conſequently muſt have as many diſtinct Ideas, I ſee no Reaſon why all theſe may not actually be contained within the Sphere of the Activity of the Soul acting in the Center. For if we conſider in how ſmall a bulk of Body there may be as many diſtinct living Creatures as here are ſuppoſed Ideas, and every of theſe Creatures perfectly

fectly formed and endued with all its Vegetative and Animal Functions, and with sufficient room also left for it to move it self to and fro among and between all the rest, so as to pass by every one and touch none, we shall not need to fear any Impossiblity to find out room in the Brain where this Sphere may be placed, and yet find room enough for all other Uses, of which we may afterwards assign some very necessary.

Attention what. But to return to the Description of this Organ. I do suppose that what we call Attention is nothing else but the Action of the Soul in forming certain Ideas, which for the present I will call little Images, which bear the Stamp, Seal or Mould according to which the Soul formed it in the Center of the Repository. I suppose further, that these are continually formed by the Soul in the Center, and the present always protrudes those that were formed before it further into the Repository. So that the greater the number of Ideas are that have succeeded any ones Formation, the greater is the Space of Time of which we have a Sense: and the Ideas become further and further removed from the Center, and more and more new-form'd Ideas interpose themselves between the Center and the said Ideas placed in Orbs at a greater distance, by the intrusion of fresh Ideas between the Center and them.

I suppose further, that all these Ideas, though they may for a long time retain the Forms and Motions impress'd on them by the Senses, and by the Action of the Soul; yet notwithstanding they being material, and so subject to change, I conceive, that as the Motions may in time decay, so the Form may (by shifting and changing place in the Repository or Organ of Memory, and being protruded farther and farther from the Center or Seat of the Soul, and crouded into Orbs, though further off, yet closer and closer stuffed and crouded together) be in time alter'd, and sometimes quite lost.

I suppose further, that the Soul being seated in this Center, and there acting, as I said, by the help of the Information and Impressions of the Senses, and forming continually new Ideas, and so protruding them onwards, and filling the Sphere of the Repository fuller and fuller from the Center, increasing outwards. I suppose, I say, that this Soul by its Radiation does actually apprehend, or as it were feel, or is sensible of any Idea that remains treasured up within this Repository: And this it becomes sensible of, partly from its own Power of Radiation, and partly from the Re-action of the Ideas. It becomes, I say, sensible of them, wherever placed within the Repository; partly by its own Radiation, by which it acts upon the fluid Spirits incompassing it, propagating from it self every way *in Orbem*, a Radiation like the Sun, by which, as by a Stick, it becomes sensible of all those Ideas that are yet unwasted within the Repository, feeling as it were their Form, their Resistance, and their Re-action to its Radiations: Partly, I say, only by their lying in the way of the Radiation, and partly also by their re-acting and repercussing a Radiation back upon the Soul. By the Distance of it from this Center the Soul becomes sensible in some measure of the time in which the Idea was made, and how long since it was inserted, there being so many Orbs of later or more inner Ideas formed and lying between them, which have been since inserted.

By this means it becomes sensible of many Ideas that accompanied that Idea, when made, many of them having kept the same Order in which they were made; though oftimes other Ideas, not formed immediately before or after, intrude and thrust in themselves between, out of the order they did really succeed in, so as often to interrupt and break the Chain or Order of Insertion.

I conceive further, that besides the natural Decay there may be of the Form and impress Motion of the Ideas, there may be also an Impediment to this Radiation of the Soul, by the Interposition of other Ideas between the Center and the Idea sought, much after the manner as the Earth interposing between the Moon and the Sun, hinders the Sun from radiating upon the Moon. And in such case the Idea may sometimes be thought to be lost, which yet may afterwards be found again when the Obstacle is removed.

Again, as in the Radiation of the Sun, which is as it were a Representation of the Soul of the World; the Radiation of the Soul is more powerful upon Ideas at a nearer than at a further Distance; and their Reaction is also more powerful back again, and that in a duplicate proportion to their Distance reciprocal,

procal much the ſame with that of Light, which is the moſt ſpiritual Action of all we are ſenſible of in the World. And thence it is, that the Memory of things long ſince done is for the moſt part very faint, unleſs in ſome caſes, where the Impreſſions made upon thoſe Ideas were at firſt very powerful, or often recalled, which may be ſaid to be a new forming of them.

I ſuppoſe further, that though by means of the continual Radiation of the Soul into this Repoſitory or Organ of Memory, it has at all times ſenſe of all the Ideas that are there repoſed, yet that Senſe is but imperfect and confuſed by reaſon of the Multitude; yet can it readily exert its Power more particularly and ſtrongly to this or that Idea, according to the Determination of its Will. And whenſoever it is upon the Action of Thinking, that is, of fixing or darting its Radiation more powerfully upon this or that Idea placed in the Repoſitory, it does according to the Power of its Radiation receive a more ſenſible Impreſſion or Repercuſſion from thoſe Ideas upon which it radiates, and thereby it does not only apprehend their Qualifications more diſtinctly, but alſo it does as it were renew or refreſh the former Impreſſions, and add to them a further degree of Perfection: And ſo though they are in a Place farther diſtant from its Center, and by the length of time or the number of Ideas that have been ſince inſerted, and ſo lie in the way of Communication, it be become more faint and weak in the retaining the firſt Impreſſion, and conſequently in its re-acting Power; yet by this ſecond Action or Radiation of the Soul upon it, its Form and Qualifications are renewed and perfected, and for the future it becomes more powerful than the reſt of thoſe at the ſame or leſſer Diſtances, that have not been by ſuch ſecond Radiations ſo renewed and invigorated; and beſides every ſuch Action of the Soul does create and form a new Idea at the Center, which has Impreſſions that are the Reſult of thoſe renewed Actions: And this having ſomewhat the like Figure and Motions or Qualifications, it has a Sympathetick Agreement with the other; and the Impreſſions from the one do more readily make the Impreſſions from the other more ſenſible, in the ſame manner as a Muſical String being moved, does make another String that is uniſon or harmonious with it, move alſo, and ſo together make the Sound the louder, or the Impreſſion the ſtronger.

There is a continual Radiation of the Soul into the Repoſitory.

Next, as I ſuppoſe there is a continual Radiation of the Soul into the whole Repoſitory of Ideas, ſo I do conceive likewiſe that every Idea ſo placed being ſo qualified as above, by particular Impreſſions of Motions, which continue for a long time ſo to move, as they were at firſt impregnated, does from ſuch its Power ſo retained, radiate a Motion of its own, which may in ſome manner alſo act upon the Soul, ſo as to excite it to Attention; and by this means alſo whenever any Idea is created and impregnated with Motions or Qualifications ſimilar to thoſe of other Ideas placed at ſome diſtance in the Repoſitory, the concurrent Impreſſions or Re-actions of thoſe ſimilar Ideas upon the Soul at that time do make the fainter to be the more notable, and ſo excite the Soul to Attention or Radiation that way alſo; and by that means it has an Excitement to be more ſenſible of the other alſo at that moment: And this I take to be that Impreſſion which we are ſenſible of, when we ſay, This brings to my Mind, or This puts me in mind, or this makes me remember, *&c.*

5. I do further conceive, that that Action of the Soul which we call Thinking, is a more particular Radiation of the Soul to this or that part of the Repoſitory, or on this or that Idea placed in it, and at the ſame time forming new Ideas in the Center of the Repoſitory; which Action of the Soul in framing new Ideas at the Center, is continued almoſt every moment: And though it doth not every moment make a diſtinct Idea, yet may it be perfecting of one, and giving new Impreſſions every moment: And thence I conceive the Body of one Idea (for as I before mention'd, I ſuppoſe them to be really corporeal and material) may have many and various Impreſſions and Motions annexed to it, poſſibly of 100, nay of 1000 Moments, whence that Idea may be ſuppoſed to be more compleat and perfect in it ſelf: And when it again comes to be acted upon by the Radiation of the Soul, all the Impreſſions or Qualifications thereof become of Power to affect the Soul with thoſe Impreſſions which it had formerly received from the Soul.

What Thinking is.

So that Thinking is partly Memory, and partly an Operation of the Soul in forming new Ideas.

Another and more compleat Action of the Soul, is the forming new Ideas from the comparing the Re-actions from several Ideas placed here and there in the Repository, and its being sensible of the Harmony or Discord of them one with another, which does produce an Idea wherein all those various Respects are in some means united and impressed upon one and the same Idea. This is an Idea of greater Perfection, and according to the Attention of the Soul in being sensible of more and more variety of former Ideas, and the Regularity and Order of its proceeding in that Action, and the more steddy and distinct manner in the Course and Progress of it, so is the Idea more compleat, as well as more compouuded: And this I conceive to be that Action of the Soul which is commonly called Reasoning; and the Conclusion is the new Impression made upon the Idea informing from the comparison of other Ideas which may be contain'd in the *major* and *minor* Propositions.

Now according as the Repository is stored with more and more Ideas, so has the Soul a greater variety to range and expatiate into, whether these Ideas are only the first and more simple, such as are the Results from the Impressions of the Senses; or the more compounded, such as are made by the Result of comparing several together: And therefore accordingly the Ideas that are made from fewer and more simple Ideas, are less compounded Ideas; and those which are made from a greater number, and those more compounded Ideas, are yet more and more compounded, and more and more accomplish'd and perfect. This will give some Reason why the younger and first Results of the Actions of the Soul in forming Ideas, are more simple and less perfect, and from whence the Results of the Actions of the Soul in the elder Years, become the more compounded and perfect.

The Soul a self-moving Principle.

The Soul then is the *Primum movens*, the self-moving Principle, which has in it self a Power of radiating every way *in Orbem* from its Center of being every instant and for ever, and so is always by means of that Radiation every where as it were actually present, in every point of the Sphere of its Radiation, though yet it may be supposed to be more immediately and powerfully present in the Center of its Being. It is not, I conceive, possible to be truly understood or described, but only by Similitude; and the best Similitude for that purpose, I conceive, is the Sun in the great World.

Compared to the Sun.

Now if we consider the Sun in the Great World, we shall find it first a Being which has in it self a Power of radiating or dispersing Light into the Whole of Nature, and (consequently by this its Influence) of being as it were every where present, and of being sensible of all those other Bodies that are placed any where throughout the whole *Expansum*: For as it doth by its Radiation influence and affect every Point of the Universe, so must there be a kind of reflex Influence upon it self from every such Point: For as any one, and every one Ray it sends forth, does meet with and affect any Body in its way, so consequently must that End of the Ray that touches the Sun, have a greater or less Resistance to be moved forwards; and consequently if there were Understanding in the Sun it self, it must be sensible that this or that Ray does somewhere in its Progress receive such or such an Impediment to its Propagation or moving forwards that way. And be not only sensible, that somewhere that Ray meets with an Impediment, but it may be sensible also at what distance that Impediment or Re-action is given to its Progress: For supposing the Resistance or Re-action of all those impeding Objects, where-ever placed, to be in themselves equal, the Impediment or Resistance to that End of the Ray that is moved by the Sun, must receive a Resistance proportion'd to the nearness of the impeding or re-acting Object; and consequently the Impediment made thereby upon the End of the Ray protruded by the Sun, must be reciprocally proportionate to the Distances of the impeding Object; and consequently by the proportion'd Resistance or Re-action of the Objects, there is a manifest Distinction at that End of the Ray that touches the Sun, of the Distance of the Object touched by it. Next by the number of the Rays that receive Impediment from that Object, there is a manifest Distinction of the bigness of that Object; for if the Angle of the Cone of Rays that receive Resistance from any Object, be

be actually made and has its Being at the Sun, and that the Distance of that Resistance be likewise distinguishable at the Apex of it at the Sun, then is there a Manifestation or Indication at the Superficies of the Sun (by means of this Radiation) both of the Distance of the affected or affecting Object, and of the Angle or Magnitude of it at that distance, and not only of the Magnitude and Distance, but of the differing nature of the Resistance or Re-action of the Object of such a bulk and such a distance, by the consecution of momentary Impressions. This I could plainly demonstrate by a Similitude drawn from the Action made upon the Organ of Heating, from which the Ear is not only inabled to judge of the Magnitude and Distance of the Sound, but of the Flatness and Sharpness, the Mulicalness and not Musicalness by the like Distinctions in it.

But it may be much better explain'd by the Eye, wherein we find, that though there be no Radiation immediately emitted by the Eye, which would make the Reactions to the Center the stronger; yet is the Eye able by the reflected Reactions only of Objects that are acted directly upon by the Sun, to discover the Figure, Colour, Magnitude, Distance, &c. of all Objects from which there can come to it self that free Radiation. So that the Soul in the Center of the Repository, is sensible of all the Ideas placed in it, as the Eye is sensible of all things that are placed before it.

Next, if we consider the Sun in the Great World, we shall find it to be placed in the Center of a Space, all which Space, and all Bodies placed within that Space, it does more particularly influence by an attractive Power of drawing all bulky Bodies to it, or of commanding all the Motions of them; and consequently may have sense of the Renitency of Bodies, as well as of the Motions and Distances of each of them. So that all Bodies, more especially within the Sphere of its Activity, do receive a double Influence from it; first of being radiated, inlightned and vivified; and secondly of being regulated and govern'd in their Motions by it. And hence the Bodies so placed, as they have each of them peculiar Properties, Shapes and Motions of their own, so have they also particular Influences, Radiations, Excitations and Regulations communicated to them from the Sun, which gives them not only their regulated Motions and Positions, but also a kind of new Being or Activity, by which they become visible and sensible to the rest of the World, which would otherwise be dark and insensible, and vagrant here and there uncertainly in the *Expansum* of the Universe. So that the Soul forms to it self a Microcosm, or Picture of the Macrocosm, in which it radiates, and is sensible of every thing contain'd therein, in the same manner as the Sun in the Macrocosm.

Somewhat of this kind is the Influence of the Soul upon the Ideas placed within the Sphere of its Radiation: And though I cannot cenceive how the Soul, which is incorporeal, should move and act upon the Ideas which are corporeal, or how those on the other side should by their Proprieties, Qualifications and Motions, re-act upon and influence the Soul; yet I am assured, that such Effects are performed both by the one and the other Beings; and without them, neither the Sensation, Cognition, Remembring, nor Ratiocination, could be performed; all which are plainly the Results of the conjunct Influences of the Soul, and the Ideas or Bodies placed within the Repository or Sphere of its Activity.

Now though by what I have been saying, I have endeavour'd to shew that the Soul has by its Radiation a more than ordinary and commanding Power over all the Ideas placed within the Repository; yet I would not be understood so to limit its Sphere of Radiation, as not to suppose that it may have a much bigger Sphere of influencing Power, and thereby may extend it, not only to all and every Point of the Body inlivened and preserved by it; but possibly it may extend even out of the Body, and that to some considerable Distance, and thereby not only influence other Bodies, but be influenc'd by them also. And upon this account I could produce a Multitude of Observations and Reasons, to prove not only the Possibility, but the Probability, nay almost Certainty of such an Influence, and this from the Sensibleness of others Ideas, *Lupus in Fabula*, *Fascination*, &c. of which possibly some other time.

Here

Here our Author leaves off, nor as I can find, ever reassumed this Subject; and though possibly some Persons may imagine that the foregoing Explication of these abstruse Actings of the Soul is too mechanical, and tends to the making the Soul a material Being, yet I hope the candid Reader, perusing it without prejudice, will not find the least Cause for such an Imputation, it being throughout the whole Discourse asserted and shewn to be a Spiritual, Immaterial and Self-moving Principle; and it is granted by all Men, that it both acts and is reacted upon by Body, only our Author supposes the Pictures conserving the Ideas to be material, which I hope cannot justly give offence: However, as I have said in the Preface, I hold my self not in the least obliged to defend or maintain any of his Opinions or Discourses, but fairly present them to the Ingenious as he left them. The next that follows is a Discourse of Comets wrote about Michaelmas *in the Year* 1682, *containing a Physical Hypothesis and Explication of them, from Observations made of one that appeared in* August 1680, *and on that very unusual one apppearing in* December *the same Year, and the beginning of the next Year, and on the following in* August 1682. *Wherein, after an Introduction, and setting down several Opinions of Authors that have wrote of Comets, he gives us his own Observations, Hypothesis and Explication.* R. W.

A DISCOURSE OF THE Nature of Comets.

Read at the Meetings of the ROYAL SOCIETY, soon after *Michaelmas* 1682.

The CONTENTS.

At the End of the Year 1680. *there appearing a very great, and indeed the most remarkable Comet that the Heavens have shewn us in our Age, the Author was diverted from prosecuting his Theory and Explication of Light in the several other useful and necessary Disquisitions relating to Reflected, Inflected and Refracted Rays; though something of the two last was formerly publish'd by him in his* Micrography, *p.* 47, & 217. *In the present Disquisition, he does not so much relate and confute the Opinions of others (though there is something of that also) as plainly give us his own Observations of the Appearances, as he viewed them through several Telescopes, night after night, when he could. By the way, I must in all gratitude acknowledge, that the Figures relating to this Discourse were generously communicated by the Ingenious* Dr. Woodward, *who purchased them, (put in loosely into* Bayer's Uranometria) *at the publick Auction of Dr.* Hooke's *Library. Though indeed these Figures were all very rudely designed, only as Helps to his own Memory, which the Author himself could much better have fitted for the Graver; yet I have endeavoured to supply this Defect as well as I was able, and hope the Reader will pardon the Failures. I think they pretty well answer his Descriptions, those being my chief Directors in perfecting the Draughts. I need not be particular in the Contents of this Discourse, the Marginal Notes which I have added will sufficiently inform the Reader: Therefore I shall only give some account of what is immediately annext to it, and which indeed the Thread of the Discourse led him to; that is, a short Treatise of* Gravity: *For there being a Gravitation of all Bodies to the Sun, it seemed a difficult Problem (at least according to his Hypothesis of Comets) to give a reason of the Blaze or Tail's being nearly opposite to the Sun. We have then here annext a pretty large, and (if I may be allowed to speak) an ingenious Discourse of* Gravity *or* Gravitation. *The*

Running Title will direct the Reader to it. In this he considers the most known Proprieties of the Celestial Bodies, and having made several Deductions from Observations, as to the Nature of the Æther, Air, and the like, in which in transitu *he explains Thunder and Lightning, asserting a Levitation, as well as Gravitation (or a receding from as well as tendency towards the Center) having also shewn that the Æther or vast fluid* Expansum *is the* Medium *to convey the Motions of Gravitation as well as Light; he comes in the next place to treat more particularly of* Body *and* Motion, *explaining what he understands by each of them, and then treating of Motion, says, that the two great Laws of Motion are* Light *and* Gravity, *and having before treated of the former, he comes to explain the latter more particularly, when having shewn that there is such a thing as Gravity, with the Limits and Proportions of its Power, and that it exerts it in all Bodies, he comes at last to the Principal Part, the* Cause of Gravity, *and after the Enumeration of its Proprieties, gives his* Explication *and* Hypothesis *of the Cause thereof. The Author designed to have answered several Objections against this his Hypothesis, but having reply'd to one only, the Discourse ends. To supply this Defect, I have added some Fragments which I found relating to the same Subject, which the Reader will find immediately annext.* R. W.

Of COMETS.

The Introduction to the following Discourse of Comets.

I Have formerly in this Place read several Discourses concerning the Nature and Proprieties of *Light*, and have therein explain'd some of the most wonderful Qualifications thereof. I should have proceeded farther in that Disquisition, after another Method than what I now take, had I not been diverted by an extraordinary and unusual Light, which since offer'd it self to my View, and exacted a more nice Observation and Contemplation upon it; and that was the Comet in *August* last. This new appearing *Light* caused me sooner to fall upon the Contemplation of this Subject, than according to my *intended Method* I should have done, tho' I designed to have come to it hereafter in its due Place and Order, wherein I design'd also to have given an account of what I observed concerning those of 1680 and 1682.

THO' the Frequency of *Comets*, and some of them very considerable, has excited the Lovers of Astronomical Learning to search and find out what they are; yet I have not hitherto met with any (tho' I have seen and perused the *Theorys* published by very many Ingenious Men) that has given such an account of them, as to me seems natural and satisfactory. For tho' these Bodies seem very heterogeneous, singular, and of a distinct Nature from all the rest of the Celestial Bodies we contemplate; yet I am very apt to believe, that whenever we attain a true Knowledge of them, we shall find them to be the Product of the same regular Course of Nature. 'Tis true our Knowledge, even of the most conspicuous, is very imperfect, and not brought to the utmost Perfection of Improvement that the Helps which Nature has afforded us may seem to require; tho' even then we shall be to seek after divers other Proprieties of them, which are by other Helps afforded to the Inquiry after the Qualification of terrestrial Bodies. For whereas we have for the Examination of Terrestrial Bodies all the Five Senses, for those of the Heavens we have but Two at most, or indeed (the Information of the second being so very little) but one; and that is the Sight, the other, *viz.* that of Feeling, being so very little, that 'tis almost inconsiderable in all, except the Sun. This may be argued from the Experiments

periments that have been made to find whether the Rays of the Moon convey any Heat, by the help of Burning-glasses, whereby tho' the said Rays have condensed the Beams above 500 times, and consequently augment their Power accordingly, yet I could never find the least sensible Alteration as to the heating or cooling Quality of them; and this try'd, not only by casting them on the back of the Hand, as on a Part of the Body very sensible, but by throwing them upon the Ball of a Thermometer made with Air, which would be rarify'd with the least degree of increased Heat, and condensed with the least degree of Cold. Whence we may very rationally conclude, that if the Alterations of Heat and Cold caused by the Rays of the Moon, when full and wholly inlightned, be so very insensible and inconsiderable, certainly the Influence of the other Planets, as to the Alterations of Heat and Cold, must needs be very much less: For if the Sun's Light reflected from a whole Hemisphere of the Moon, which is first abundantly more near to us than any of the other Celestial Bodies, and so appears an illuminated *Area*, which is bigger than the *Areas* of all the other Celestial Bodies put together, both Fixed Stars and Planets, does produce no sensible Alterations as to the Degrees of Heat and Cold, how much more insensible must the Alterations be which are caused by some other Body, which alters not in its Light a 10000 part of the Light of the Moon, as those Alterations of the other Planets will be found to be upon strict Examination? Next, if the Reflection of the Sun's Light from a Body so near us as the Moon is, in comparison of the other Planets, works no sensible effect, how much less effect must the other Planets produce, which are vastly much farther from us. Again, if the Reflection from the Moon, whose Distance from the Sun is much the same with that of the Earth, produces no effect, how much less significant must be the Reflection from *Saturn*, *Mars* and *Jupiter* be, which in the nearest Approach to the Sun are much further off from the Body of the Sun, than ever the Moon can be. So that upon the whole, we may conclude, that tho' it cannot be denied, but that the Celestial Bodies may have some kind of power and effect in the Alterations of Heat and Cold, yet compared to the Influence which the Sun hath in that Particular, it may be said to be almost nothing, or at least wholly insensible. I do not say that the Fixed Stars and other Planets, besides the Sun and Moon, are wholly insignificant, or without effect, as to the Body of the Earth; for that, as I shall in another place shew, they may and have all some Influence; but to be found out by other *Media* than the immediate Senses: But as to sensible Effects, as to Heat and Cold, I conceive them so subtle and curious, as not to be distinguished by the more gross Organs of our Sense in any of the Planets, nay of the Moon it self, save only of those of the Sun.

What the Sight informs us as to Comets.

So then the Sight being the chiefest Sense that can inform us concerning the Nature of Celestial Bodies, we may next consider what kind of Information concerning the Nature of Comets this Sense can afford us, and see whether we can find in all or any of the Authors that have yet written of them, so full an Account as for this purpose were very desirable, and, as I conceive, might, if care had been accordingly taken, without much difficulty have been attained. For my own part, I must confess, tho' I have read and examined a great many, and consider'd and compar'd them together, to find Answers to those Questions I propounded to my self concerning them; yet I was so far by this means from procuring to my self a satisfactory Answer to them, that I was more to seek after this my Enquiry, than I was before: For I found the Accounts of several Historians concerning them so very different one from another in most things, that I knew not which to rely upon. Which I suppose might be caused, either from their differing way of observing, or from the difference of the goodness of their Sight, or for the most part from the differing Hypotheses they had made to themselves, or been prepossest withal from the Writings or Doctrines of other Men. 'Twas a long time that the Opinion prevailed in this Part of the World, that they were nothing but sublunary Meteors tossed and blown to and fro by the Winds or Motions of the superior Regions of the Air, and the Accounts we find given of them by Men of that Persuasion to be very suitable to that Supposition. So that for all the time that the *Peripatetick* Philosophy and the *Ptolomean* Astronomy prevailed, all the Accounts concerning them are idle and insignificant to this purpose, and seem only suited to the Use which they designed for them,

No Accounts in Authors satisfactory, and why.

which

which was to make them only as Messengers, to foretel, by the help of their own Chimeras and Fancies joined with them, what Alterations were like to happen in human Affairs, and thence I doubt not, proceeded the strange Shapes of them which they have painted out unto us of Targets, Shields, Spears, and Daggers, with Hands, *&c.* of Dragons and Serpents, and such like. A great variety of which kind of Figures you may find in Authors that have written concerning them; and you may see a great many of them together in *Hevelius*'s *Cometagraphy*, most of which, I confess, I look upon only as the Products of a prejudicate and prepossest Poetick Fancy in the Historians: For of those five which I have observed, I could not observe any thing like them, no more than I could any of those Figures of them which are delivered to us by the said *Hevelius*, as Observations of his own: For the Figures of them, which I observed both with my naked Eye, and with the best Telescopes I had (some of which I am sure were very good) I found the Appearances of them much of another kind. And of these Figures I was not assured by the Appearances of one or a few Observations, but by the Repetitions of them some hundreds of times, and by changing the Position of the Tube, Apertures, Eye glasses, Posture of my Head, and the viewing of them with the Right Eye, and sometimes with the Left, that if those Appearances had been caused by any thing peculiar either in the Glasses or the Eyes, I might have found them out. And lest somewhat in the Air or Atmosphere might cause them, I examined them when at a good hight above the Horizon, and continued ever now and then to observe them, even to the very setting of them at the Horizon; in all which Observations I plainly saw and took notice of the true appearing Figure and Shape thereof. Wherefore this imperfect and differing Account I found concerning Comets, made me resolve to throw aside all manner of Hypotheses concerning them, and to observe them as if there never had been any such Appearance before, and to attend wholly to what the Appearances themselves would teach me: And this I have done in every one that I have yet observed; for tho' I have already published my Conjectures, which were grounded upon those Observarions I had made on the three preceding Comets, yet I did not at all confine my self to be of that Opinion, or not to seek farther to inform my Judgment by other Appearances I should happen to observe in my future Trials; nor should that at all have prevailed with me to defend a former Conjecture, that I had owned such an Opinion to the World, and had brought several Arguments to make it more probable, fetch'd from other collateral Agreements in the Operations of Nature. For in things of this nature, where the Informations are but few, and at best but imperfect, and where a little unheeded Circumstance may be of great importance in determining the Significancy of it, and where there is oftentimes so great a Similitude between the Effects produced by Causes and preceding Circumstances vastly differing, 'twould be a high Piece of Arrogance and over valuing ones own Judgment positively to assert the true Cause of such appearing Effects to be this or that, and not another. And therefore as in the former, so in this, what I deliver as my Opinion, I would have no farther to be rely'd on than as the Result of my Ratiocination and conjecturing from the best Information I could hitherto obtain; only, I do positively affirm, that the Observations I here shall mention were made with all the Care I could, and that the Appearances to me were such as I here express them; and that I do verily believe that there was no kind of Fallacy in them, but that any other Persons might have seen the same, had they heedfully attended what they saw; which to do, nothing is more advantageous than the present designing and drawing what is seen, and writing a Description thereof. Now tho' I did in this Enquiry throw off all Prepossession of other Hypotheses, so as not to be biass'd by them, yet was I not so unmindful of them, as not to make some good use of them; and that was, to consider them as propounded by their several Authors, and thence by Synthetical Ratiocination to conclude what the Appearances ought to be, if such or such an Hypothesis were true, and consonant to the thing it self, and thereupon to examine whether any such Appearance could be discovered. To this end I consider'd those of *Galileo*, *Hevelius*, and divers others, who explain the Blaze or Tail by the Light of the Sun, refracted in the Head, and so constipated into a Stream, to make the Appearance of that light Emanation which

The Appearances different from what they make 'em.

The Author's Candidness in Philosophical Matters asserted.

which is on the Side opposite to the Sun; and putting such Suppositions, as if real, I deduced what must probably then be the Appearances that would follow from them; and then making Observations afresh, I inquired whether I could discover any Appearances that would favour such or such a Supposition: But upon the whole, I must needs say, I found no one Remark that did any ways incline me to be of such Opinions, though I had many that for the present convinc'd me, that the Blaze must needs proceed from some other Cause. It would be too long to recount here the several Hypotheses I did for this purpose consider, and the particular Remarks I made to satisfy my self concerning them, that they were not in such Particulars agreeable to the Theory supposed: And therefore I shall rather give an account what the Particulars were which I my self did observe.

My Observations of the first, which appeared in *November* 1680, were but few, having the opportunity but of two Mornings to see it, which were the 22d and 23d of the said Month; at which times being in the dawning Light of the Morning, and the Air above not so clear, I could not make any certain Determination of its Place, but by comparing its Position with the Stars that appeared near it, of the greater Magnitude: For on Monday Morning, *Nov.* 22d 1680, at half an hour after 6 a Clock, it was almost in the Line that past through *Spica Virginis* and *Cor Leonis*, but not full so much toward the South; and its Distance from *Spica*, as near as I could judge by my Sight, for I had then no Instrument ready, was very near the same with that of *Algorab* in the Right Wing of *Corvus*, or rather somewhat more. Whence (by the Globe) I conceive it was about 3 ½ Degrees enter'd into *Scorpio*, and about 3 ½ Degrees South of the Ecliptick. Its Blaze was but short, but pointed towards *Spica Virginis*, not directly, but a very little on the South of it. It reached more than half way towards it, and sometimes by Glances it would seem of the whole length almost. Its Appearance was but faint, as was also that of the Head, which though it seemed bigger than any Star of the first Magnitude, yet it had but a faint, hazy and duskish Light, like the Appearance of a Star of the first Magnitude, through a hazy or foggy Air. I then viewed it with a six-foot Telescope, and found the Head of it to appear very large, but very feint; and though it were considerably brighter in the middle, yet the *Nucleus* thereof was not so defined as I had seen some of the former, but seemed inveloped in a Cloud or Fog, not well defined: The Haziness about which somewhat brighter Middle part, was pretty well defined, and round towards the Sun; but the other part seemed to spread parabolically, or rather hyperbollically from the Sun. The dawning Light increasing apace, and the Air thickning, I had not long to observe it; however I followed it as long as I could, till it appeared but like a faint hazy Star with little or no Tail.

The next Morning, which was the 23d, I saw it again; but it was got much farther into the dawning Light of the Morning, and the Air was much more hazy: It was then got to the South-East of *Lanx Libræ*, and by placing it according to its Position to those Stars I could see, I judged it to be removed more Eastward about 4 or 5 Degrees, than it was the preceding Morning, and I conceived it to move pretty near in a Parallel with the Ecliptick, or rather to be got somewhat more Southward. The Appearance through the six-foot Telescope was much the same with that I saw the Morning before, and the time being very short, the Air thickning, and the Light increasing, I could add no more Remarks, hoping some other clear Morning would better accommodate me; but though I attended, yet I could not from that time see it again: Though by others I find it was observed a good while before, and by others several days after. Mr. *Thomas Hill* of *Canterbury* saw it first the 12th of *November*, at half an hour after Five in the Morning, and by its Distances from *Cor* and *Cauda Leonis*, taken with an Instrument of four Foot and a half Radius, he found it then, as he says, in 12 Degrees of *Virgo*, and in two Degrees of North Latitude, with a slow Motion, having not passed above four Degrees in three days. Its Tail was then about 30 Degrees long. Sigr *Montanari* at *Venice* in *Italy*, on the 19th of *November*, saw it at 4 Degrees distance from *Spica Virginis*, and about the same Latitude with that Star. He judged it in 23 of *Libra*, with about one Degree and half of South Latitude: Its Tail directed

 towards

towards *Spica*, not directly, but a little to the Southwards of it. Its Head appeared as big as a Star of the first Magnitude, but of a dusky Light, and pale like a *Stella Nebulosa*: Its Tail was very short, and reached not much more, than two Degrees towards *Spica*.

Afterwards viewing it with a Telescope 17 *Venetian* Feet in length, he saw the Head of it three times as big as that of *Jupiter*, which was seen that Night, only its Figure was not so well and round defined, but of a smoaky dusky Colour which caused several of those that viewed it to differ somewhat in their Judgments about this Measure: And (he says) that one thing was very remarkable, that he could not in this see any distinct round *Nucleus* more shining than the rest of the Head, as was plain to be discovered in those of 1664 and 1665, wherein they were pretty clear, and not without a roundish Termination. But in this the Light was considerably greater in the middle than towards the Extremes, but without any certain Boundary, whence it had more the resemblance of a little illuminated Cloud, than of any thing else, illuminated but with a dusky Light. This he resembles to the Appearance of Smoak issuing out of a Chimny or Furnace, wherein there is a great Fire, when seen at some distance in the Night; for there the Smoak seems to be a kind of Flame tapering to some distance, and there to vanish. *Note, the Latitude of* Venice *is* 45°. 27′.

The 21st it was distant from *Spica Virginis* 8°. 28′. the 22d in the Morning 13°. 10′. the 23d he could not see it for Clouds; the 24th it was distant 23°. 30′. the 25th it was distant 28°. 13′. From which Observations he concludes its Longitudes to be, the 21st in 27°. 51′. of ♎; the 22d in ♏ 2°. 33′. the 24th in ♏ 12°. 52′. the 25th in ♏ 17°. 45′. Its Latitude was South, and it moved almost parallel to the Ecliptick, and seemed to tend towards the Sun, so as he hoped it might be seen to pass through, or eclipse the Sun: And the straight Line from the Comet through *Spica Virginis*, passed very near *Cor Leonis* all the times he saw it. Comparing the Spaces that it passed the several Days which he saw it one with another, he found it to accelerate in its Motion; for between that of the 21st and 22d, it passed but 4°. 42′. whereas in the next two Days it had passed 10° 19′. So that he supposed its greatest Acceleration would be pretty near its Conjunction with the Sun, which would be on the 28th of the same Month; and thence he conceived it might re-appear, after it had past the Sun in the Evenings, and be seen for a good while. Which whether it did or not, I cannot learn from any Place since that time, for I find no mention of any Comet till the 10th of *December* following, when the Tail of a Comet was seen to rise out of the West South-West, above the Horizon, to a great length, by some in *Oxford*. And Dr. *Wallis*, at the same Place the Night following, being the 11th of *December* about seven of the Clock at Night, saw the Tail of it very bright and long, which he judged to be about three quarters of a Quadrant, but narrow upwards; the Head of it he judged, by the Position of the Tail, to be about the Head of *Sagittary*; the Point reached as high as the *Swan*, but somewhat to the Eastward of the bright Star therein, pointing towards the Constellation of *Perseus*, from which time forward it was continually observed. Some are of opinion, that this was the second Appearance of the same Comet, after it had past the Sun, though there are more of the contrary Opinion, and suppose them to be two differing Comets, and that because of the differing Tendency of both their Motions: The Comet of *November* daily increasing its Latitude to the South, as several of the Observators make it; but other Observations make it to be at its greatest South Latitude on the 23d or 24th of *November*, and that from that time, till it disappeared, its Latitude continually diminished. But which of the two observed best, I know not; but sure I am, that the Observations I have hitherto met with of it, are so uncertain, that 'twill be hard to say which of them is right. However, somewhat more concerning this matter shall be added hereafter, when I come to speak of the Motions of Comets in general; for however strange the differing Observations of several Men, who possibly may not be sufficiently skilful to make the Observations, and of others who though they may have Skill enough, may yet want fitting Instruments for that purpose; yet by all that I have observed my self, and by what I have found in the Observations of Learned Astronomers, I conceive they are all of them of the same kind, and are moved with the same regular Motions,

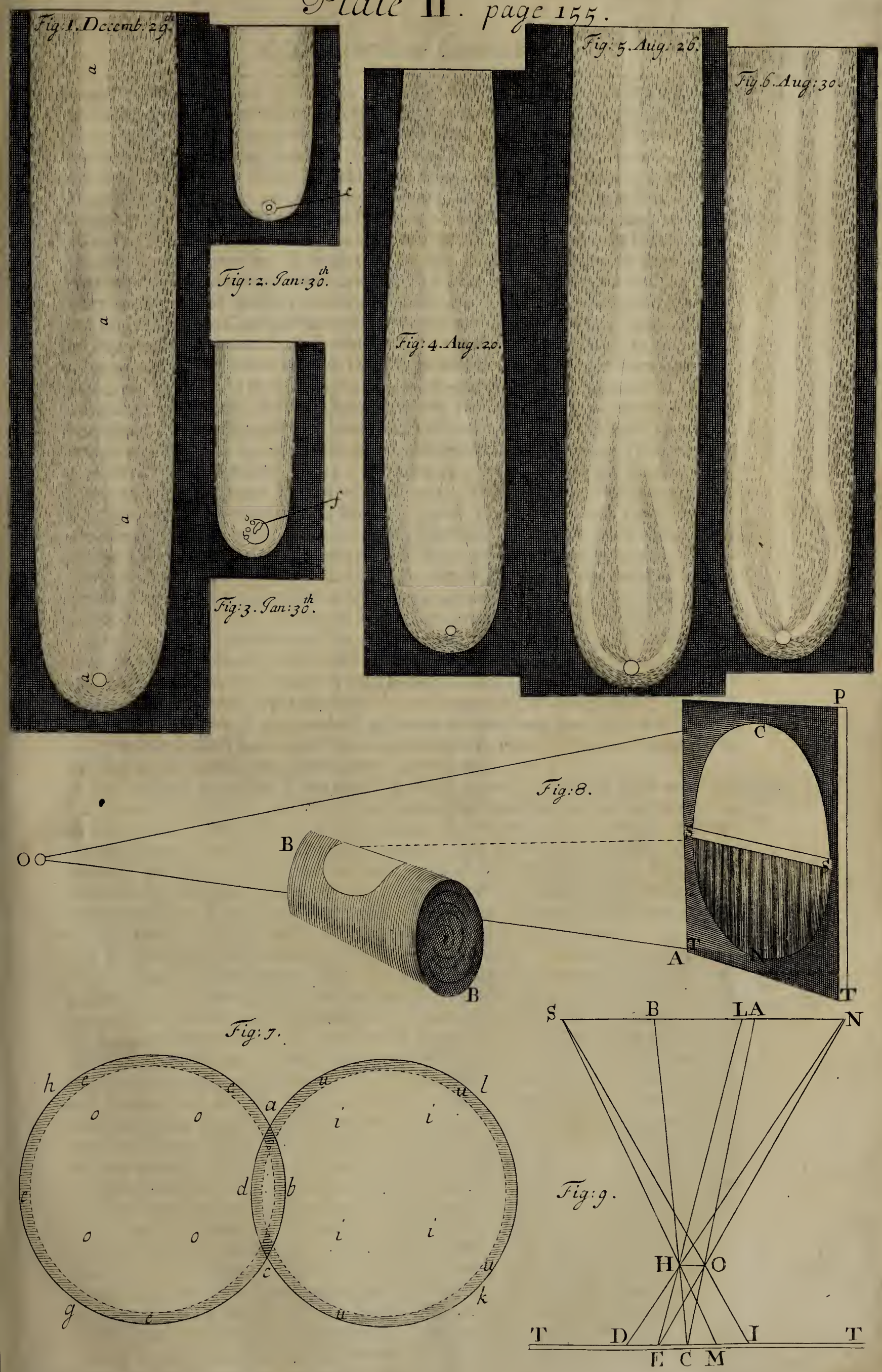
Observations of the great Comet in December 1680.

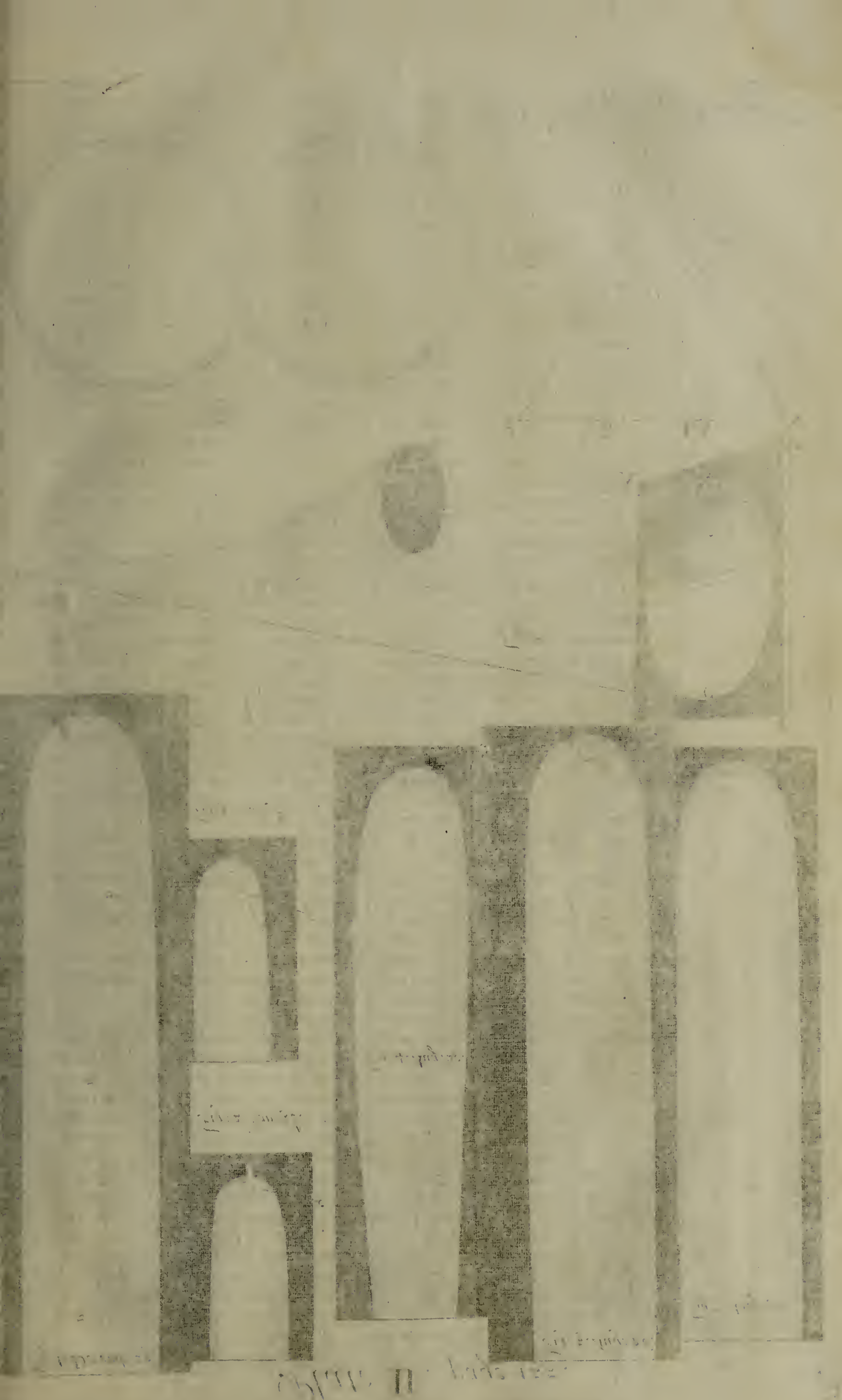
Whether it were the same with the former in November.

NB. *This the Author never performed.*

The Nature of all Comets the same.

Plate II. page 155.





tions, and for the most part agree in their other Affections and Proprieties. I shall therefore, by reason that all the Observations I meet with of this first are but very few, and scarce any one that may certainly be rely'd on, rather leave any further Disquition upon this, and proceed to the Observations and Appearances of the 2d, the Blaze of which, as I say, began to be seen the 10th of *December* 1680, rising up above the Horizon, and on the 11th was seen by Dr. *Wallis* at *Oxford* to rise above the Horizon so high as the *Swan*, and was conceived to come from a Head below the Horizon in some part of the Heaven near the Head of *Sagittarius*. I find also by Mr. *Cassini*'s Relation of the Comet, that Mr. *Flamstead* at *Greenwich* saw the Tail of it on the 10th and 11th, a little after the Setting of the Sun, and took notice, that on the 10th it passed through the middle of the Constellation of the *Eagle*, and terminated at 3 Stars mark'd by *Bayer* with *A w* and *b*, and that on the 11th the Tail extended to the extremity of the Dart. The 12th he saw the Head of it at 4 of the Clock and 40 Minutes, in 5 deg. 9 min. of *Capricorn*, with 9 degrees and 4 Minutes of North Latitude. The same day Mr. *Cassini* saw the Tail of it rising above the Clouds near the Horizon, and appearing bent like a piece of a Rainbow; whose Convexity, which was sensible, respected the South: It seem'd terminated with two Circles concentrick to each other: At 24 ½ Minutes after Five, he saw the Head 4 ½ degrees high, in the same Verical with *Aquila*. The Tail rose, oblique to the Vertical, declining towards the North; so that the 3 Stars of the *Eagle*, which are in a right Line, were as much to the South of it, as they were distant one from another; and it past by the most Western Stars of the *Dart*, and tended towards the Tail of *Cygnus*: It ended at the Milky Way, and was of a pale Gold Colour. The Length of it was about 40 degrees. From that time it continued to be observed almost every Night somewhere or other, as I find by comparing the several Accounts of it which I have seen; but most of the Observations are so imperfect, that nothing certain can be built upon them. I shall therefore pass them by, and only take notice of those of Mr. *Cassini* made at the *Observatoire* at *Paris*, and only such Observations of his as are Physical, omitting at present those which are purely Astronomical, and shew the Place and Motion of it, which I shall have occasion to use hereafter, when I shall also take notice of the like Observations made here by Mr. *Flamstead*.

Cassini's Physical Observations.

The 17th of *December* I find that Mr. *Cassini* viewed the Head of it with the Telescope of his Quadrant, but found the bigness of the *Nucleus* not to exceed the bigness of a Star of the 3d Magnitude to the naked Eye; not of a determinate Figure, but confused and irregular; and observing it through a Telescope of 35 Foot, it appeared of the bigness of the Ball of *Saturn*, but confused also and irregular, which he ascribes to the Vapors near the Horizon which encompassed it, for that the Bodies of the Planets near the Horizon are so confused likewise. The Length of the Tail he judged 48 Degrees.

The Author's own Observations.

I saw it several times between the 18th and 19th Days of *December*, but in Places where I had no Convenience of making any good Observations of it; but the 29th at 7 in the Evening, I view'd the Head with a 14 Foot Telescope, and found it of this Form: There was a hazy Brightness, which seem'd through the Telescope about half a Degree in Magnitude, or as big as the Moon would appear to the naked Eye. This was fainter and fainter, as it was farther from the middle, but no where certainly defined; yet the half of it, which respected the Sun, was pretty round, and beyond that the Sky was dark and clear, without any Light: Toward the middle it grew lighter and lighter, and about a 6th or 8th part of it was pretty near of an equal Degree of Light, not defined any way, but somewhat like a whiter part of a Cloud: Out of this there was plainly to be seen a kind of Stream issuing out, not directly opposite to the half round Part, but a little to the Northward of a brighter small Stream, which passed through the rest of the Head into the Blaze; and though it seem'd to issue out of it towards the North Pole, yet it suddenly bent into the middle of the Blaze, and ascended a good way into it like a Pith. The half-round part also toward the Edges of it, struck into the Tail, making the Outsides of the Tail or Blaze both brighter than the rest of the Blaze, except the Pith: These were a little diverging upwards, and so bounded the Sides of the Blaze. The Stream out of the middle, as it appear'd through the Telescope, seemed as if there had been a brighter Stream of

Plate 2. Fig. 1.

some

some more shining Matter that had issued out of it, not perpendicularly, but a little inclined to the Right Hand, and imitated a Stream of Water, if it had run out of a Vessel a little inclined to the Perpendicular: For it bent quickly into the Axis of the Blaze. This is represented in the Figure by the bright Part issuing from the round *Nucleus*, *aaaa*. This appeared sometimes more plain and sometimes more faint, so as sometimes to be much like the rest of the Blaze: But for the most part, so much of the Head as I could see at once, was brightest of all in the middle, and then brighter on the Edges than the rest of the Blaze. Its Blaze or Tail then extended to a very great Length and Breadth, and ended between the two Stars in *Perseus* marked by *Bayer* with γ and η. At first it seemed to turn off at φ and υ on the Right Hand, or towards the North; but as the Evening grew darker, I plainly saw it to reach the Stars γ and η. As concerning its Place at that time, and the tendency of its Tail as to the Sun, we shall speak of them hereafter in their due Places: For I shall now only mention to you what I observed in its Shape and Appearance.

December the 30th, at half an hour after 8, I observed the Comet both with my naked Eye, and with a Glass of six Foot: Its *Nucleus* was hardly distinguishable, only there was a cloudy Whiteness in the middle, with a hazy Light about it, which by degrees grew fainter and fainter; but still it was more defined towards the Sun, yet as before very imperfectly, though the outermost Edge had somewhat considerably more light than the Sky, and had a rounding like a Cloud. This Haziness spread from the Head on that Side that was opposite to the Sun, somewhat like a Parabolick Figure, and made up the Blaze or Tail; but the Head was considerably lighter than the Blaze. Looking often upon it, and diligently inquiring, and remarking what I could discover, I saw the same Stream of Light issue out of the *Nucleus* as I had the Night before, and this in the manner of a sudden Spouting of Water out of an Engine to quench Fire, which would presently again disappear, and be much like the rest of the Blaze. These Dartings I could perceive to rise to a considerable height into the Blaze or Tail. I often saw the Telescopical Stars through the Blaze, and this Night I observed one almost up to the very Haziness about the Head of the Comet, appear through the Blaze. After I had discovered this issuing of Light through the Telescope, I diligently attended the Appearance of the Comet with my naked Eye, and I could plainly perceive such a kind of Darting of Light from the Head, which did sometimes seem to dart almost the whole Length of the Blaze or Tail, which I have some hundreds of times since taken notice of.

Jan. 5. I hoped to have seen it eclipse ♪ of *Pegasus* in *Bayer*; but it passed very near it, but missed it.

Jan. 7. I observed it about 11 a Clock at Night, I could not see the Length of the Blaze for the Clouds. It tended towards *Perseus*, but seemed not to reach it. It was grown very faint, and seemed much wasted. It was very strange that there appeared little or no Halo or Atmosphere about the Head on that Side that respected the Sun; but the Parabolick Edge seemed to touch the very *Nucleus* or light Cloud in the middle. The brighter Dartings out of Light at some times more than at others, now manifestly appeared; and I was then assured by above 20 several times taking notice of it, and examining it with all imaginable care through my 14 Foot Telescope, that these Appearances were no Optical Fallacies. I thought the Alteration in the Air might have been some way a Cause of this Appearance; but then I should have discovered some such thing in the Fixed Stars, which yet I could not: And therefore I judge it a true and real Appearance of the Mutation in the Comet it self, how instantaneous soever it appeared; of which I shall shew more in my following Observations. I this Night also took notice of the Stream, as before, issuing out of the *Nucleus* into the Blaze, with a brighter Pith or Axis of Light, and it seemed to issue in the same manner as before, by spurts, and then as suddenly disappearing. The Appearances were neither caused by the Eye; for I saw it both with the Right and with the Left Eye, and with several Inclinations of my Head, and so altering the Postures of each of them, I turned the Telescope, and varied the Glasses and Apertures, to see if any of these would make them not to appear, or alter any of them; but I found them in every Trial, and therefore they must be caused by a real Effect in the Object it self.

Jan.

Jan. 9th, from 9 till 12, I observed the Places, Motions, Positions and Appearances of the Comet. The Places of it I shall not mention here. The Blaze of it was sometimes pretty clear and bright, especially about the Girdle of *Andromeda*; which was just within the Rays to the naked Eye, but through the Telescope it was sometimes clear of them, though sometimes in the Glass also it was manifestly within them: They spread also so wide upwards, as to touch the Foot of *Andromeda*, a little beyond which they seem'd to terminate, though at other times they reacht even to ♏ of *Perseus* in *Bayer*, so that ♏ seem'd to be in the very middle or Axis of the Blaze. This Night again, as I had several Nights before, I very often observed the sudden Radiations or Flashings from the *Nucleus*, but especially in the middle of the Pith or Blaze. It was exceeding wonderful, and, all things consider'd, it seems very difficult to be explained from what Cause, or by what means it was effected. I oftentimes observed the Head with very little Radiations, and then upon a sudden a bright Stream issued from the *Nucleus* or light Cloud in the middle, and ascended into the Blaze, sometimes straight up from the middle, and almost as big as the *Nucleus*, and would shoot sometimes to a good distance from the Head into the Blaze, which I discover'd by viewing a part of the Blaze at a pretty distance from the Head, with the Telescope, without seeing the Head it self. Sometimes it would issue from one side, and sometimes from another, and so shoot upwards into the Pith of the Blaze. Sometimes it would be dispersed, as it were, into a broad Light, and undefined, whilst the other ascended straight, and defined; and that also sometimes on one side, sometimes on the other, and seemed somewhat like the flaring of the Flame of a Candle or Torch. These Appearances I am farther certain were not caused by my Eye, or by the Glasses of the Telescope, or by the Alterations of the Air: Not by my Eye, because I saw the same Appearances, whether I looked with my Right, or my Left Eye, and changed the Posture of my Head when I looked; sometimes seeing them with my Head upright, sometimes with my Head inclined horizontal on one side, and then on the other; and so in all variety of Postures, in which I still saw them. Nor were they caused by my Glass, for I saw them with the same Glass changed with several Apertures, and turned every way round, so as sometimes one Side of the Tube was upwards, sometimes another; yet the Appearances were the same, as they were also through 4 or 5 other Glasses, through which I saw them in the same manner. Nor were they caused by the Air, for the Fixed Stars near the Head of the Comet had no such Alterations. Again, if it had been the Alterations of the Air, the Flashings would have been seen to descend sometimes, and sometimes to cross the Blaze; but these always issued from the Head, and shot upward into the Blaze, and never any other way, that I could observe. And I have hundreds of times observed such Flashings with my naked Eye, darting from the Head even to the whole Length of the Blaze, almost in a moment. Besides, when these Flashings ceas'd, as they often did, I could see divers small Telescopical Stars in the middle of the Blaze very plainly: Whereas when the Flashing appeared, they could not be seen for the Light, especially the smaller of them; and I saw them on the one side that was without Emanation, close up to the Pith, but on the other side of the Pith that had the light Emanation, I could not perceive them, and so after a little time *vice versa*. Sometimes also I could see them on both sides up to the Pith, in the middle of the Blaze, and sometimes they would be all hid. This Night I exactly observed its Progresses among the small Telescopical Stars, to see if I could have found any sensible Parallax of it, but I could discover none.

The Appearances were real.

Telescopical Stars seen through the Blaze.

No Parallax to be observed.

I took notice of the same Appearances on the 16th of *January*, and the 23d and 24th but very little, as also on the 26th and 27th.

January the 30th at 11 at Night, I observed the Position of the Comet, and several other Particulars. I observed this Night also, as I had done several Nights before very often and very plainly, that the Appearance was perfectly a Resemblance of Flame, but that exceeding thin and rarify'd, and of a faint Light: That it waved, flared, or undulated to and fro: That it sometimes seemed to burn clearer and stronger, and sometimes fainter and more dim; sometimes on one side, and then on the other, and sometimes in the middle of the Blaze also, or in the Part opposite to the Sun: And which I took more no-

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tice of, as more considerable, it would be sometimes more on the Side next the Sun, and sometimes less: Sometimee it appeared with little or no *Halo* about it, but only the *Nucleus* or white Cloud with a little Stream or Blaze issuing from
Plate 2. Fig. 2. it like the 2d Figure. At other times, for the twinkling of an Eye, or small moment, I could see a very small bright Point of Light in the middle of it, as at *c*, which appeared no bigger than a Telescopical Star, which was very near it, which immediately disappeared, and seemed to be covered with the white cloudy *Nucleus*. This cloudy *Nucleus* was also much bigger and brighter than at other times, and sometimes seemed to have several bright Parts in it, as in the
Plate 2. Fig. 3. 3d Figure at *f*. Every one of these Remarks I observed at least half a score several times, and the Changes were very quick; so that I was fully satisfied in my self, by all the ways of examining I could think of, that these Mutations and strange Appearances, possibly never heeded by any before (for I never met with any mention of them in any Author, or from any Person that had taken notice of Comets, but only I have been told by some antient Men that saw that in 1618, that it did perfectly sparkle and shoot forth Fire; but I confess I did not then give credit to them, but attributed the Cause of their having such an Idea or Remembrance of it to their having possibly more dreadfull Apprehensions of it in their younger Years, and also to the great Brightness of the Tail of that Comet): I say, I was fully satisfied that they were real Mutations in the very *Phænomenon* it self. And this I was the more satisfied of, because I had hundreds of times taken notice with my bare Eye, of the Glancings and Dartings out of the Light of the Head into the Blaze; in which 'tis almost incredible with what Swiftness the Flash or darting of Light passes from the Head to the very Extremity of the Blaze: For I never observed the Dartings of the Lightning (which I have often diligently remark'd and computed to move above a Mile in less than half a Second of Time) to move more swiftly from Place to Place, than I did see through the Telescope such kind of Dartings from the Star to move: I mean the actual Flame of the Lightning, and not the spreading of the Light it self, which I conceive rather to be instantaneous; and though it do seem to be successive, and to spread in a very quick time from the Center *in Orbem*, and that the more remote Parts are inlightned after the nearer; yet I take that to proceed partly from the weaker Impression made by the remote parts on the Eye, and partly from the Yieldingness of some parts of the *Medium* through which it is propagated. Now if this Appearance be really in the Object, as I am satisfied it is, and that this Object be at so vast a distance from us, as by all the accurate Observations that have been hitherto made for this purpose, 'tis certainly prov'd to be; we shall find by comparing the distance of the Lightning with the distance of the Comet, how incredibly much swifter these Dartings of Light in the Comet will be than the Dartings of the Flame of Lightning it self: And yet after all, how incredible soever it seem, I am satisfied by my often repeated Observations, that the Matter is really so. It seem'd to me upon my viewing them often, that 'twas not improbable but that these Flashes or Sparklings were caused much after the same manner as the sudden Kindlings of Steams or Smoke in a Fire, beginning at the Head, and kindling like a Train into the Tail, which may possibly be made up of such a Stream of combustible rarify'd Parts, and that the whole Light of the Head and the Blaze was from the actual shining of the Head and the Parts of the Blaze; but of this more hereafter. However, this I think is very plain, that the whole Blaze proceeded and issued from the Head in material Steams, and that it is not at all produced by any manner of Refraction of the Rays of the Sun passing through the Head, as many are very apt to suppose and assert; for which I shall add, I observed all the same Appearances again the 3d of *February*, and continued to see them till 12 of the Clock at night; so that I was sufficiently confirmed in the reality of the Appearance, and that it was not a *Deceptio Visus*. I observ'd it again in its Progress the 7th and 9th, and diligently set its Place among the Fixed Stars that lay near it in its way.

The last time I saw it was on the 10th of *February* at Night, when I fixed its Place among the Telescopical Stars, with the Direction of its Blaze, which to the last I all along observed very conspicuous. I this Night also, through my 14 Foot Telescope, discover'd all the before-recited *Phænomena*, as before, tho' they

they were very much fainter and paler, and every thing diminished as to its Vividness; so that I did not expect that it would last much longer: However, I believe I might have followed it for a Fortnight or Three Weeks longer, had not partly other Occasions, and partly the Cloudiness and Thickness of the Air, prevented me from seeing it for 7 or 8 days after, till which time I continued so often as I had Opportunity, to look for it. Mons. *Cassini*, it seems, follow'd it some days longer, till it arrived at the Foot of *Perseus*, where he also lost sight of it. I do not yet hear that any one has certainly seen it beyond that time, and Mr. *Cassini* seems not to be very sure of some of his last Observations.

Thus I have given you in short the Sum of what Physical Observations I have made concerning these Comets, which as they are new, so they may possibly seem the more strange, for that no other that has writ concerning them, has mention'd any such Appearances, and for that several Appearances mention'd by some very famous Writers, seem very differing, if not contradictory to these. However, what I did observe I have set down, that such as cannot find cause to believe them from what I have here set down, may by their future Opportunities and Observations better inform themselves, and more critically search and find out the true Appearances, and at least the probable, if not the true Reasons thereof. For I am perswaded, that there was scarce any Appearance in this Comet, but may in some degree, more or less, be found in every one that shall appear for the future; for that I look upon them to be all of the same nature, and to have all the same Proprieties in some measure; and I shall be content not to be believed, if making the Observations in my way, and with as good Instruments, they do not find the like Appearances.

These Observations had still lain by me neglected, had not the Appearance of this last Comet in *August* made me find them out; which put me in mind again of repeating my former Care and Scrutiny after the true Appearances thereof. I did therefore, so soon as ever I had discover'd it, put my Glasses in order, (which had lain by neglected since that time) and resolved in this wholly to mind those kind of Observations, for that I hoped I should from other hands receive sufficiently exact Astronomical Observations thereof, of which I shall afterwards have more occasion to make use, when I come to enquire concerning the Distance, Course, Velocity, Magnitude and Original of them. And tho' the Determination and Demonstration of all these do require a great Stock of accurate Observations purposely and pertinently made, which is hardly to be obtained from all that have hitherto writ concerning them; yet from such as they are, I shall shew some Conjectures, which to me seem to have somewhat of probability in them, which may serve at least as Hints to such as have Opportunity to observe them, and are furnished with better Abilities and better Instruments than I have hitherto been furnished with.

NB. *These Astronomical Observations, and our Author's Remarks upon them, I have not met with amongst his Papers; so that I verily believe he never procured them, or at least never made any Animadversions, as is here mentioned.* R. W.

But to proceed to the Observations I made of this last Comet, which appear'd *August* the 16th 1682. The Forepart of the Night being exceeding clear overhead, looking upon the Heavens, I discover'd a Comet in the North a little above the Horizon, glancing its Blaze toward the South-East, between some thin Clouds that were near the Horizon, and presently fetching a six-foot Telescope, and viewing the Head of it, I remarked its Position to some Telescopical Stars that were near it, and with my naked Eye found the Place of those Stars, as to the Stars about them; the most conspicuous of which were two little Stars of the 3d Magnitude, in the Fore Foot of the Great Bear, marked by *Bayer* with *s* and *x*, and 'twas near in a Line with *s* and *T*; 'twas pretty vivid, and through the Telescope seemed to have a bright and strong *Nucleus*, though small, not very defined, and the Light or *Halo* about the Head was much of the Form of all the other I had seen, when very conspicuous. The Side next the Sun was pretty round, and at a good distance from the *Nucleus*, and the Blaze struck from it in a Parabolick Figure.

I had not the Opportunity of obſerving it again till *Auguſt* the 20th at 9 at Night, at which time I took its place.

Plate 2. Fig. 4. Through the Teleſcope it appeared of a Shape which is ſhewn in the Draught or Picture. See *Fig.* 4.

The *Nucleus* was the ſmalleſt, but the brighteſt I have ſeen; the hazy Light about it was ſo much the brighter, the nearer it was poſited to the *Nucleus*. The brighteſt part of the Head diminiſh'd to about 5 or 6 Diameters of the bright Star, as I may call it, in the middle, without which was a thinner *Halo*, which was about twice as broad without it, which was of a pretty equal Light; and this towards the Sun was terminated in a rounding Figure, not very defined, yet ſo much, that immediately beyond the Sky look'd black, and was clear of it. The brighter part about the Star or *Nucleus* ſeemed to ſpread more or brighter towards the Blaze than any other way, a little tapering; but the thinner part was much more ſpread that way, aud extended about eight or ten Degrees, which made up the Blaze. This ſeem'd to be a kind of Smoke or Steam, which taper'd towards that length from the Sun; ſo that the brighter part ſeem'd ſomewhat like a thin Flame, and tapering a little into the Blaze, but was ſoon ſpent, and the other thinner part, or Flame, made up all the reſt of the Blaze.

Aug. 21. I ſaw it again, and noted its Place, but was diverted by accident from making Teleſcopical Obſervations, and ſetting them down.

Aug. 22. I noted the Poſition, Shape and Length of its Blaze, but nothing elſe.

Plate 2. Fig. 5. *Aug.* 26. At 7 in the Evening, I delineated the Figure and Shape of the Comet exactly like that I ſaw through my 14 Foot Teleſcope, which will appear more plain by the 5th Figure than I can otherwiſe well expreſs it. It had a pretty bright round *Nucleus*, and about that was an Atmoſphere of thinner Light, which was terminated towards the Sun with a round Figure. That part of this *Halo* or lighter Atmoſphere towards the Sun, was not ſo bright and radiant as another kind of Light, which ſeemed to iſſue from the *Nucleus* or Star both ways at Right Angles, with the Axis through the Sun; which lighter Iſſuings bent into a kind of Parabolical Figure within the former *Halo* or Atmoſphere, and was terminated within it, and ſeem'd to form as it were a 2d Parabolical Termination towards the Sun, in the *Apex* of which *Parabola* was the bright *Nucleus*, and this brighter Parabolical Line of Light ſeemed as groſs or thick as the *Nucleus* it ſelf. This iſſued on both ſides, but that on the Right Hand, or the Northermoſt, was much more conſpicuous; inſomuch, that that on the Left Hand, or towards the South, was to be ſeen but ſometimes, but that of the other ſide was very plain and conſpicuous, and ſeem'd like a Stream of Flame blown out of a Candle by a Blowpipe aſcending or bending upwards juſt as ſuch a blown Flame of a Candle will do, if it be made by a gentle Blaſt. This I remark'd very carefully, to ſee whether I could find by any ſucceeding Obſervations, any Alteration of the Magnitude, Figure, Brightneſs or Poſition in reſpect of the Comet's *Axis*.

Theſe two brighter Spoutings of Flame or Light turned or bent upwards from the Sun, and after a ſhort ſpace ſeemed to unite into the *Axis* or Middle of the Blaze, and form the Shape of the outſide of the Flame of a Candle tapering to a point; the fainter part alſo without it ſeemed to taper much in the ſame manner. I ſaw alſo ſeveral Corruſcations or Flaſhings of the Flame ſhooting out to a great diſtance into the Blaze.

Aug. 29. I noted the Place and Poſition of the Comet at ½ an hour after 8 at night. Its Blaze pointed exactly at the bright Star in the Crown.

I obſerved the Body of it through a 14 Foot Teleſcope, and ſaw the Spoutings out of the brighter Streams from the *Nucleus*, but eſpecially of that on the Right or Northern ſide, which was very large and conſpicuous, that on the Left or South ſide being much fainter and leſs conſpicuous. They ſeemed not now at Right Angles with the *Axis*, but to be ſomewhat more towards the Sun, both of them; but cloſe by the *Nucleus* they turned about again, and extended into the Blaze with a kind of tapering Form, as on the 26th, and in all other Particulars it ſeemed to be much the ſame as it then appear'd. For it ſeem'd, as I ſaid before, like a Stream of Light, or Flame, or Fuzee, iſſuing more eſpecially on the Right or Northern ſide, and turning about into the Blaze, where it

it made a kind of tapering Light; but the opposite Side was not near so plain or easy to be seen.

Aug. 30. I viewed it again with my 14 Foot Tube, and found its Figure such as I have described in the Draught. The *Halo* or Atmosphere about the Head, on that side which was next the Sun, was thinner than the last time I saw it, not spreading so far that way as then. The Fuse or Stream on the North side of it was very plain and bright, but seemed not to issue now at Right Angles with the Axis of the Blaze, but, as it were, at 45 degrees with it, and then bent into the Blaze with a kind of Parabolick Figure, and so ran Parallel with the Axis to a great length, and did not taper in towards it, as on the 29th. The issuing on the opposite side was hardly at all visible, only it seemed a little brighter in that part, than in the middle part of the Blaze near the Head.

Aug. 31. I took its Place and the Direction of its Blaze by the 14 Foot Telescope. The bright *Nucleus* appeared much as it had done the preceding Nights, and the Fuse or Stream of Light had much the same Inclination to the *Axis* as last Night, only it seemed now to run farther parallel to the *Axis* into the Blaze. The Hazinesſ of the Head about the *Nucleus*, on that side which was next the Sun, was now much thinner and nearer to the *Nucleus*, and pretty well defined.

There was a little Emanation answering to it on the Left Hand, but that was exceeding faint; yet the Sides were brighter than the middle part near the *Axis*. I saw the flaring of the Light, and the Corruscation, as I had done almost every time I saw it. The *Nucleus* was not a tenth part of the bigness of the *Halo* or *Haze* about it.

September the 1st, I viewed it again with my 14 Foot Telescope. I could see no small Stars near it; the Fusee or Stream of Light appeared much as it had done the two preceding Nights. I still plainly saw the Flaring or Flashing of the Light, and sometimes also saw a Shooting or Spouting as it were of Light from the *Nucleus* directly into the Blaze, which as quickly disappeared.

I began to see it *September* the 4 at 7 ½, the *Crepusculum* being yet very bright. The *Nucleus* was pretty clear and round, but the Blaze from it was only two Emanations of a kind of Parabolick Figure on each side, as in the Figure; but the Northern Side was brighter than the Southern still, and they seemed to spread one from another with an Angle of about 60 Degrees, so far as I could see them then; for they extended but a little way from the *Nucleus*. The middle part of the Blaze between them was hardly visible. But as the *Crepusculum* diminished, it appeared much brighter and fuller, and then I could see its Light also in the middle part of the Blaze. Scarce any *Halo* between the *Nucleus* and Sun appear'd, at first, and but little more when it appear'd brightest. I observed also the flaring or flashing of the Light, and a kind of moving of the Fusee on the North side. It was at its brightest about 8, when I observed also its Positions. I followed it with my Telescope downwards towards the Horizon near half an hour after it disappeared to my Sight; and I was able to see it almost to the very Horizon, even till it went behind a Steeple a little above the tops of the Houses, though the Smoke much thickned the Air. As it grew lower and lower, the Blaze disappeared by degrees, and at length also the Hazinesſ about the Head; so that I conld not see the two Streams, but only now and then by glances; but the *Nucleus* it self I saw very plain, but verymuch smaller than before, and seemed about the bigness of *Oculus Tauri*, but very dull and faint, in comparison even of the small Fixed Stars which were not far from it.

The Figure of it when brightest this Night, was much of the shape of the Flame of a Candle close snuffed, the *Nucleus* representing the End of the Snuff; tho' that in a Candle so order'd looks perfectly black, but the *Nucleus* was very light.

Sept. 8. I saw it from 7 ½ till almost 8; I took notice of its *Nucleus*, and of the Emanations on each side, as also of the flashing and flaring of the Light. The Beams were darted on each side parabolically, and seemed at first almost like two Sides of an equilateral Triangle, but when it was clearest they were much longer. The Clouds near the Horizon hinder'd me, that I could not see it till 9.

Sept 9. at 7 h. 28 m. I saw it perpendicularly over the top of *Bow*-Steeple; it was 3 times the length of the Dragon above the top of it. The Fusee or Stream

seemed just above it in that posture, as if it had been the Blaze it self bended, the opposite side being so faint, that I could only now and then perceive it. The Blaze was at Right Angles with a Line from *Arcturus* through the Head. I saw very plainly now also the flaring, flashing and wavering of the Light. I continued to observe it and make my Remarks till it almost toucht the Horizon, though the Air was very smoaky near the tops of the Houses.

Sept. 10. I first discovered it with a 4 Foot Telescope, at 7 ¼. It appeared very faint: There was nothing besides the *Nucleus* and the Parabolical Edges of the Blaze, or the two Emanations from the *Nucleus*; the Northern side was still the brighter and longer. It was very much smaller and fainter this Night than Yester-night and yet the Sky clearer and darker. I could not find any Fixed Stars near it through the Telescope, nor could I see any Stars with my Eyes, the Sky being very cloudy all above it, it just appearing under and between several Clouds: Nor could I, nor I believe any body else, see it now with his naked Eye; and yet through my 14 Foot Telescope I perceived very plainly the Streams, with the Flaring, Flashing, and sometimes a perfect Lightning, as it were, in the parts of the Blaze pretty far distant from the Head; which I 6 or 8 times took notice of to be almost in the very *Axis* or middle of the Blaze. I by many trials this Night also satisfied my self that these Appearances were no Delusions of the Sight, but proceeded from real Mutations in the Body it self.

Since which time I have never been able to make any farther Observations of it, by reason of the cloudy thick Air.

An Explication of the Appearances.

Now by all these Observations it appears very evident to me, that a Comet is a Body most probably round, situate in the middle of that part we call the *Nucleus*, or the brighter part in the middle of the Head, which is inveloped by a kind of Atmosphere of thick Clouds or Smoak: That a lighter or thinner kind of parts, like Vapours, spread from it to a much greater distance, possibly 8 or 10 times as far towards the Sun, which by their Limitation in respect of the Sun, are driven back again, and return upwards, and opposite to the Sun. Of these kind of Emanations there seem two sorts: One that goes to a greater distance, and is but very fine and thin, which makes the outmost Edge of the *Halo* about the Head, when the Comet appears biggest and brightest, and is in its nearest Approach to the Earth. The other, which is a thicker and grosser, which descends not so far towards the Sun, but is possibly more firey, and so recoiles upwards sooner, and makes the Parabolical Emanations that appeared on both sides of it. The biggest and brightest of which was that towards the North, or that part which was the hindermost in its way of Motion, the Foreside thereof being very thin, and but at some times visible; whereas the other was always very conspicuous. As it went farther and farther off from the Earth, so the thinner part more and more disappeared (which was very visible when it it was in its nearest Approach): So that all the time I saw it in *September*, the second or thinner *Halo* disappeared, which I suppose was caused, first by the greater distance of it from the Earth, and secondly the Light of the *Crepusculum*, in which it was always placed. And this I judge, because even when it was much more visible, if I viewed it pretty early before the Day-light was much spent, I could only see those two Radiations from the *Nucleus*, without seeing the thinner *Halo* about the Head; which yet I saw afterwards when the Evening was darker, which I several times took notice of, and which did reconcile what I had observed concerning the differing Appearance of other Comets towards the latter end of their Appearance.

The white Cloud about the Body, which I call the *Nucleus*, I take to be somewhat analogous to a thick Smoak or Steam before it was fired, which only inveloped the firey Body in the midst of it, which I take to be the Solid, through which I very often perceived a sudden small bright momentary Glance of Light, which I conceive was either the bright Body in the middle, or else some kindling of the Smoak or luculent Flame about it; but I rather took it to be the former. The two Emanations I take to be the under Edge of the actual, though thin Flame, which, as I have noted, did perfectly resemble the Shape of the Flame of a Candle tapering above the Comet towards the *Axis*, and sometimes meeting in it pretty near the Head, though at other times it were prolonged to

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a much greater distance, and seemed to ascend almost parallel. The thinner hazy part without this, which made up the Head, and a great part of the Blaze or Tail, I take to be a kind of Halituous Substance, that did not actually kindle into Flame, but appeared by the Light of the Sun, and in part also by the Light of the Comet it self, that is, of the shining Cloud or luculent Flame. The sudden Flashings I so very frequently saw, I think are evidently a certain kindling of some parts within the compass of the Flame, which like Lightning, the one End of them near the Comet taking fire, a whole Train of them follow, as one may also commonly see in the Flame of a Fire. The flaring of the Light, now on one side, and then on another, I take to proceed only from the nature of the Emanations, which sometimes proceed on one side, and sometimes on the other, which are more apt to take fire and turn into Flame. The sudden Dartings out of Light, which seemed to extend, to the naked Eye, even to the whole Length of the Blaze, I take to proceed partly from such a kind of kindling as I just now mentioned, and partly also possibly from a temporaneous Propagation of Light, which, as I shall afterwards shew, in a yielding or springy Body, is temporaneous, and not instantaneous. So that possibly some such sudden Glance of bright Light, which I often saw break through the middle of the *Nucleus*, might be propagated to the reflective parts of the whole length of the Blaze, and so be reflected successively; which is otherwise so exceeding rapid and quick, that considering the vast length of the Blaze, it seems unconceivable how it should be moved: For the quickness of Lightning is nothing to be compared to it, though by many Observations I have seen it move near a Mile in a quarter of a Second Minute of Time, but this must necessarily move many thousands of Miles in a shorter time.

To conclude, all the *Phænomena* did so perfectly resemble the Appearances of a burniug, flaming and steaming Body here in the Air near the Earth, that so far as I can yet inform my self, I see no reason to doubt, that it is a Body qualified much in the same manner as a Body on fire, or burning in the open Air with us. Though if Fire be only a Dissolution of a Body by the nitrous part of the Air, it may seem pretty difficult to explain how there should be any Fire in those Places through which Comets have been observed to move. Next, though the Existence of somewhat analogous to Fire and Flame, should be shewn probable in Comets, and in the Places through which they pass, yet it may seem difficult to conceive how the Flame and Steams thereof should chiefly issue and move towards those parts of the Space that are fartheft off from the Body of the Sun; for so it has been observed to do by all the latest and best Observations: And thence it has happen'd, that almost all that have written more particularly concerning them, have explain'd the Appearance of the Blaze, not by a Matter issuing from the Head of the Comet, but by a certain Collection of the Sun Beams made by a Refraction of them in the Head of the Comet; some without any consideration of a denser Matter fit to reflect those Rays so collected back to our view; though there be some others, among which is Mons. *Hevelius*, that have seen the necessity of such a reflecting Matter, besides the meer Refraction of them in the Head. But in short, I have not yet met with any Hypothesis of that kind that has given such an Explication of the manner of those Reflections and Refractions, as will accord with the visible Appearances that any one that will be diligent and circumspect may easily observe: For taking Refractions and Reflections to be made as they suppose them, and considering what the Figures of the Appearances must then of consequence be, they will be found exceeding different from what they really are, and will give no satisfactory Explanation to a strict Enquirer. Leaving therefore the further Examination of these Hypotheses to their Assertors, or to such as may think them to contain somewhat more of probability than what I am here willing to allow them; I shall rather proceed to the consideration of that Hypothesis which the Observations I have made do more incline me to embrace. Now though I confess there may at first considering of it appear several, and those no ordinary Difficulties in this my Supposition, yet when I have a little further explained the Reasons and Causes, which I conceive of the Celestial Appearances, they may appear to have somewhat more of probability than possibly some may imagine.

That Reflection and Refraction of the Sun-beams are insufficient to explain the Appearances.

The

Five Difficulties in this Hypothesis.

The greatest Difficulties that I conceive in this Hypothesis, are Five, namely,

First, If the Comet be a burning Body, or a Body in dissolution, how comes it, that it can supply so vast a quantity of Flame or steaming Emanations, as to form an Appearance of so prodigious a bigness and length, as those of necessity must be which have been so often and so exactly observed; as in those, to instance in no more, which were observed by all the Northern World in 1618, and lately in 1680, and yet notwithstanding, last, without a sudden and total Dispersion or Consumption of that exceeding small Body in the Head, from whence they are supposed to be all supply'd.

Secondly, Next if the Blaze of Comets be from the Head, and that the Comets are Bodies which are moved with a pretty swift Motion through the Spaces of the *Æther*, how comes it to pass that this Flame or Steam does not follow after or point directly to the way through which the Head or Body it self has past?

Thirdly, If the Blaze be in part an actual Flame, and the Head be a Body actually on fire, or in a State of Dissolution, and that all the Fires and Flames we know have need either of actual Nitre, or of a Nitrous Air to make them, which being satiated, the Fire or Flame will no longer continue; without a farther Supply either of actual Nitre or Nitrous Air; how comes there to be either such a quantity of actual Nitre in the Body of the Comet, or of Nitrous Air in the *Expansum* in which the Blaze is observed to extend, and yet neither the Head of the Comet be supposed a terrestrial Body, nor the Nitrous Air be supposed to extend beyond the Limits of the Atmosphere about the Earth, which those that have given it the greatest Extension, do assign to be not above 50 Miles above the Surface of the Earth and Sea, and those others that think this too great, will not allow it to be a 5th part of that height?

Fourthly, Supposing there could be found a Reason or Cause, why the Body of the Comet should be supposed to contain some such Substance as Nitre, and that there might also as probably be supposed such a Substance dispersed through the *Æther*, as would produce a Flame like that of a Candle, or other flaming Body here in the Air; yet what Cause can be assigned why it should not equally disperse it self every way from the burning Body, as we find Flame here with us to do every way from the Center of the Earth? And why does it always extend it self towards that part of the *Æther* only that is farthest off from the Sun in respect of the Head of the Comet?

Fifthly, If this Appearance of the Blaze were an actual Flame, yet how should it be possible, that it should continue a Flame so long, as to extend to so vast a length; as possibly of some hundred thousand, nay of some Millions of Miles, and not be extinct in some very short Space, as the flaming Parts of Bodies here with us are observed to be, which are suddenly kindled and converted into Flame, and that Flame as suddenly wasted and dispersed, as indeed every part of the Flame we see of a Fire or Candle is? For though the Flame of a Candle seems to last till the whole Candle be burnt out, yet 'tis not really two moments the same Flame, but the parts of the Flame are every moment annihilated, and others in the same place every moment afresh supplied from the Steams that are continually issuing out of the Wieke. Now it seems inconceivable how it should be possible, either that Steams should be carried to so great a distance, or that Flame should last so long a Journey, as from the Head to the utmost Extent of the Blaze.

The Explication continued, to prove the Author's Hypothesis.

These and some other Difficulties there are, which when one has well considered, of the vast Distance of them, even when nearest to us, which all the accuratest Observations do most manifestly evince, and consequently the exceeding Magnitude of their Body, and prodigious Extent of their Blaze, and as a consequence of these, the great Swiftness of their Motions, 'twill be enough to startle one, and make one despair of ever being able to render a true Explication

cation of the Causes of these Effects. And 'tis very apt to make several Persons to have recourse to an immediate, extraordinary and divine Power acting, not according to the general Laws and Methods of the rest of Nature, but according to a singular and particular Determination of that Power for the exhibiting those Appearances extraordinarily to Mankind: Whence some ascribe them to the miraculous Power of good Angels immediately directed by the Will of the omnipotent Creator: Others (of which we have lately a Treatise on purpose, upon the occasion of the great Comet in 1680.) to assert them to be produced and moved by the Power of Evil Spirits or Devils. But these, as the Subterfuges of Ignorance, and the want of Industry, we leave to their Assertors. And though I must confess it to be a very difficult Attempt to manifest and demonstrate the true Theory of them, yet I shall endeavour from that small Stock of Observations I have hitherto met with, and those Imperfect and mean Helps I have hitherto had, to shew at least a probability, what they are, and how moved, and that they may be some such kind of Bodies as I conjecture them to be; and that in many Proprieties they may be consonant and agreeable to the other Celestial Bodies. Now to do this as it ought, one should be acquainted with what those Proprieties are, which may be known of any other Celestial Bodies: For if they be found agreeable in those, we may more rationally suppose a further Agreement in other unknown Properties.

Now there seem to be but two sorts in general of Celestial Bodies, and those are either fluid or solid. By solid I understand all those Bodies that appear, and are made sensible to us, either by their own Light, or by the Light of another Body reflected from them. So that these Solids do seem of two kinds, that is, either Bodies appearing by their own Light, or Bodies appearing by the help of some other Light. And possibly the Comets may be a third sort, that is, such as appear partly by the help of their own Light, and partly by the help of other Light reflected from them.

The fluid parts of the World I here suppose of two kinds, that is, one whose Parts are in some sort solid, and may have determinate Figures, Magnitudes and Motions; and the other, which hath no one Part that may be called a Solid, but its Parts are infinitely or indefinitely fluid. *2. Fluids of two kinds.*

The first I call the Een-fluid, or almost-fluid *Æther*; the second, the quite fluid *Æther*.

The former part of this Division of Mundane or Æthereal Bodies, I suppose is easy enough to be understood and granted: And the second, though it seems a meer Chimera, and without real ground in Nature, yet by those Observations and Experiments I shall afterwards produce, I hope it may appear, at least to be possible, though there may be no one found that can positively demonstrate it to be so, and not otherwise.

And this possibly may be the utmost that Man's Senses and Reason will ever inable him to perform, in the acquiring of the Knowledge of such Causes, Principles and Operations; the Method and Instruments wherewith they work being far removed beyond the reach of our Senses: And therefore the best and utmost we can do towards the discovery of them, is only accurately to observe and examine all those Effects produced by them, which fall within the Power of our Senses, and comparing them with like Effects, produced by Causes that fall within the reach of our Senses, to examine, and so from Sensibles to argue the Similitude of the nature of Causes that are wholly insensible. And this is the utmost Bound and Limit of our most exalted and regulated Reasoning, beyond which that Power cannot carry us. We may therefore rest satisfied with what that will furnish us; and 'twill furnish us with a great deal, and far more than possibly any one has thoroughly shewn and demonstrated, or perhaps so much as ever conceived it could, if a right Method be followed in the making of Observations pertinent, and of using them so as they may exert their utmost Power toward producing the Discovery. The Power of Man's Faculties in this kind, has not, I fear, been sufficiently thought upon, much less discovered, and all that has been hitherto produced seems rather to be some lucky hits of chance, than the necessary Products of a regular Art grounded upon the unerring Indications and Dictates of Nature. But this only by the by. I return then to the Explication of the Comet, and in order to the removing *The most that Man's Sense and Reason will enable him to perform.*

Answer to the former Difficulties.

those Difficulties that I have named, and some other, it will be necessary to consider what are the most known Proprieties of the solid Celestial Bodies, to see how far this Body, we are considering, will agree or disagree with them.

Of the Solid Celestial Bodies.

All solid Celestial Bodies then have two Proprieties; first a Faculty of emitting or reflecting Light; secondly an Orbicular Figure.

1. They have or reflect Light.

The Sun and Fixed Stars, by the best Observations I can yet make, seem to have the Power of emitting Light, the Planets, both primary and secondary, of reflecting the Light cast upon them from other Bodies; among which the Earth may be reckoned for one. This most certainly does, as well as the other Planets, reflect the Light of the Sun; one Evidence of which is the inlightning of the Moon thereby, when it is near the Conjunctions.

2. They are Orbicular, and thence have a Gravitation to them. These the two chief Principles in Nature.

The second Propriety of their Orbicular or Spherical Form, is an Indication of another active Principle, which I conceive universal to all solid Bodies in Nature, and that is, of a Gravitation or Power of attracting similar solid Bodies towards their Centers. Which two Principles I take to be the most considerable and the most active in Nature, and those from which the most considerable Effects are produced; and when they are understood and explain'd as they ought, I question not but that they will afford us Solutions and Reasons for a 1000 *Phænomena*, the Explication of which do now so much puzzle and perplex us.

In his Lectures of Light.

Concerning the first of these I have already pretty largely discoursed, and explain'd thereby the manner of its Production and Propagation, and what Effects are thereby produced; how it comes to produce Sensation in the Eye, and how it causeth Heat, Rarefaction, Liquefaction, Ignition, and the like; and somewhat also I have mentioned concerning the Refraction, Reflections, Inflection, deadning and quickning of the Radiations thereof; as likewise of compounding, dividing, and variously blending of them in the Production of Colours. But I shall not now farther enter upon the Explication of them, reserving them to some other parts of my Discourse, which are yet behind, concerning the Nature of Light. That which I have at present to consider, is rather how Light comes to be produced in the Head and Blaze of Comets.

How Light is produced in the Head and Blaze of Comets.

Now these Bodies being so far removed from our reach, and appearing so seldom, and the Helps we have hitherto met with affording us so very little that is to this purpose, I hope it will not be expected that I should be able to bring such powerful Arguments as may not be at least doubted of, if not positively contradicted. I confess my great want of such; however, I find from those few Observations I have made, some Arguments that do much incline me to think, that what I have conjectured of them is very consonant to the appearing Effects of them, though in every Particular it does not so exactly agree.

1st Supposition, that there is a dense bright Body in the Nucleus.

First then for my first Supposition, that there is in the middle of that white cloudy part near the middle of the Head, which we call the *Nucleus*, another more dense and bright shining Body than what is ordinarily taken notice of; I argue from two Particulars. The first is, that I hundreds of times have taken notice of some short and momentary Appearings of such a Star like Spot, as I have mention'd in my Observations; which is almost an ocular Demonstration; I say almost, because possibly it may be said, that those were but (like some of the rest) Flashings or Kindlings of some parts of that Cloud of Smoak. And I confess I was often of that opinion my self, when I compared them with the other Flashings and Spoutings of Light I have mention'd: But then when I consider'd the second Argument, that there must be somewhere a very solid Body, otherwise it could not be moved with so swift, and so regular and uniform a Motion, as all Comets that have been accurately observed, have been found to do; I conceived there was more likelihood to conclude, that it might be some part of the Star it self through some Chasms in the smoaky Atmosphere. For unless there were some such Body, 'tis not to be imagined, that a Cloud, such as *Hevelius* has supposed, should be able to be moved so vast a Space so regularly, and with so swift a Motion; nor that it should be able to afford Matter enough to make and supply so vastly big and long-extended a Blaze. For there cannot be allowed to it an *Æther* moving along with it, in which it should swim like a Cloud in the Air, or Froth on the Water: For if so, how could

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that in 1664 go Retrograde, and quite contrary to the Motions of the Heavens, if it paſſed between the Earth and *Mars*, as I have ſeveral Arguments that make me believe it did? Nay, how could all of them move Retrograde to the Motions of the Planets, which I hope I may ſhew ſome Arguments to prove? Thoſe that hold ſolid Orbs, will afford it no room, nor thoſe that hold *Vortices*. Thoſe indeed that ſuppoſe Demons, may ſuppoſe what they will, but to little purpoſe.

Next, unleſs there were ſome very denſe and very violently burning Body ſomewhere in the Head, it could not afford ſo vaſt a quantity of Steams, Smoak, Vapours and Flame, as muſt neceſſarily go to the making up of ſo vaſt a Blaze, which is not a conſtant abiding Body like a Cloud; but, as I manifeſtly diſcovered, rather of the Nature of Smoak, Steams, and Flame, from a burning Body, which are continually in a State of Diſſolution and Waſting, and are continually ſupply'd by ſome Fountain or burning Body in the Head; and this Body can be no where placed but within the cloudy *Nucleus*.

Thirdly, if there were not ſome ſuch Body within the cloudy *Nucleus*, the Roundneſs of that ſide of the Head, that is next the Sun, could not be, nor the greater Denſity of the Light about and near it: For we ſee that Clouds and Smoak, and the like unconjoin'd Bodies, have irregular difform Shapes; but the ſolid Body in the middle muſt be that which made the uniform Roundneſs thereof, as I ſhall afterwards more fully prove, when I come to explain the Nature of that other univerſal Principle, Gravity, in the proceſs of my enſuing Diſcourſe.

But (which ſeems to make the thing yet more probable than all the other Arguments) I have made a Ball of combuſtible Subſtances mixed together, which being ſuſpended by a Wire in the open Air, and there kindled, would ſo very well repreſent all the Appearances in little to the Sight, that the very Reſemblance thereof ſeems to be a very perſwaſive Argument, that the Effects and *Phænomena* of both were produced from like and homogenous Cauſes. And ſince the *Phænomena* of the Ball are produced by the Fire, and by the Gravitation towards the Center of the Earth of the ambient *Medium* of the Air, it ſeems not incongruous to conclude, that the *Phænomena* of the Comet may be produced by a ſolid combuſtible Ball actually fired, and by a Gravitation of the ambient *Æther* towards the Center of the Sun. But I know it may be ſaid, that *Omne ſimile non eſt idem:* And I will readily grant, that it is not a poſitive Proof, however 'tis poſſibly as poſitive as the thing it ſelf will bear: For in a Subject where we cannot obtain ſuch ſufficient Proofs as we can deſire, we muſt be contented with what we can obtain. And let me add this Conſideration, that all the Theorys of the Heavens and of Celeſtial Bodies, we have hitherto had, are ſubject to the ſame Objections that this is; for which of all the Motions of the Celeſtial Bodies hath not been explicated by various Hypotheſes? Some ſuppoſing the Annual, others the Diurnal Motion of the Earth neceſſary: Others ſuppoſe neither of them, others only one: Some ſuppoſe both the Earth and the Sun alſo to be moved; others again ſuppoſe neither of them, but that both the Earth and the Sun may ſtand ſtill, and only the Heavens of the Fixed Stars may move round them, as *Cocceus* in his Hypotheſis: Others have ſuppoſed the Moon to ſtand ſtill, and all to move about that, as ———: Others have placed ♄, ♃, ♂, ♀, and ☿, as the Central Body, and ſolved the Appearances by ſuppoſing all the other to move about ſome one or other of them: And others, imaginary Points here or there in the *Æther*: And yet every one of them, grant them but their Suppoſitions, will make a ſhift to ſolve the Appearances. But then there will be found ſo many Inconcinuities in their Suppoſitions, which yet will be found neceſſary to be granted to ſolve the Appearances, that at firſt hearing we reject them as very improbable, and readily bend to that which avoids them, and hath all things very conſonant and congruous: Which is the reaſon why the *Copernican* has obtained with all the modern and beſt Aſtronomers, againſt all the other, as being the moſt ſimple, and the leaſt incumber'd of any; eſpecially as it is improved by the Incomparable *Kepler*. All the Reaſon of which is from this Maxim, that *Natura nihil egit fruſtra, ſed fruſtra fit per plura quod fieri poteſt per pauciora.* The Simplicity therefore of the Hypotheſis to be granted,

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and the Concinuity of it with the known Operations of Nature, is as cogent an Argument as can be urged for any Hypothesis of this nature, and that I hope I shall be able to manifest in this I have pitched on.

In the mean time, I shall now only hint, that those visible Appearances of Comets which I have with much care and circumspection observed and examined, with what strictness and unprejudicateness I could, do incline me to deduce them from these following Particulars, which I shall more particularly endeavour to prove hereafter.

Several Deductions from the Observations.

1. The Medium must be exceeding thin and fluid.

First, That those Parts of the Heavens through which Comets do pass, must be a very thin and rarify'd, and an exceeding fluid Medium; otherwise so very thin a Body as the Halituous Steams about the Head, and especially the more thin Halituous Steams which make up the Blaze or Tail, could not be moved through it with so swift a Motion, and that in all Particulars so regular, without much altering or varying the true Form and Position thereof; I say, without much altering and varying the true Form thereof, because, as I shall afterwards shew, it does really somewhat alter both the Form and Situation of the Head and Blaze, which would otherwise in probability appear of a somewhat different Shape.

What I understand by rarify'd and condensed, I shall afterwards manifest, when I come to the Explication of the Constitution of the *Medium*, that fills the Spaces between the solid Globular Bodies: For though it freely permits a Body to be moved through it, it cannot be thence argued, that it contains a less quantity of Body within the same Dimensions, but only that there is a less quantity of solid Body, or uniform and united Motion.

2. There is a Gravitation to and Levitation from the Sun.

Secondly, That there is a Gravitation towards, and a Levitation from the Body of the Sun: For as I have by many of the Observations shewn, though there be a Descent of the Steams from the *Nucleus* towards the Sun, yet I always plainly saw, that they quickly returned, and went contrary and opposite to the Sun, and that sometimes to a prodigious Extent.

3. This Gravitation and Levitatton extends to and beyond the Earth.

Thirdly, That this Gravitating rnd Levitating Power, in respect of the Sun, doth extend even to the Earth, and beyond it, as will necessarily follow from the Comet which appeared in the Year 1664, (to instance in no other) For 'twas evident, that the Motion of that Comet was in a Line, without the Orb of the Earth; and yet we found, that that Body was regulated in the same manner as all the other Comets, and that its Blaze was extended in opposition to the Body of the Sun, and, as I shall afterwards more particularly prove, was moved opposite to it.

4. A flaming Body may be beyond the Atmosphere.

Fourthly, That there may be a Fire or Flame, and a burning or flaming Body, in part of the Heavens far beyond the Atmosphere, nay much farther off from the Earth than the Body of the Moon it self; and consequently that there may be other Bodies of the same nature with the Earth, which may be much farther off from the Earth than the Body of the Moon, nay much farther off the Sun than either the Earth or Moon: And therefore it may be no great Absurdity to suppose, that the Body of the Moon may be of a Substance not much differing from the Substance of the Earth, and so may have many Proprieties, if not the same, yet probably not much differing from it.

5. The Power of Gravitation is extended far into the Æther, &c. The Æther the Cause of Gravitation.

Fifthly, That the Power of Gravitation is extended into the *Æther*, without the Atmosphere of Bodies, and consequently that the Atmosphere or Air is not the Cause of Gravitation, but rather the *Æther*, in which the Atmosphere or Air is but a kind of Dissolution, as Salt or Tinctures are dissolved in Water or other Liquors, and that from thence comes even the Gravitation of the Atmospheres to their incompassed Bodies; which we observe by many other Experiments made here upon the Earth: For 'tis evident that Bodies in a Receiver, exhausted or emptied of the Air by means of the exhausting Engine, or any other ways, have not less of Gravity towards the Perpendicular or Center of the Earth, than Bodies in the open and free Air; nay they are found to be proportionably

tionably heavier, by how much a Body of the Air, equal to them in bulk, has been found to be lighter than them; which is an Experiment that has been often try'd.

Sixthly, That the Air it ſelf is no farther the *Menſtruum* that diſſolves Bodies by Fire and Flame, than as it has ſuch a kind of Body raiſed from the Earth, as has a Power of ſo diſſolving and working on Unctuous, Sulphureous or Combuſtible Bodies: And this is the Aerial or Volatile Nitrous Spirit, which, provided it be ſupplied in the Body to be ſo diſſolved, as by Fire, will work the ſame effect, even without Air. This is obvious in Compoſitions made with Salt of Nitre and other combuſtible Subſtances, as in Gunpowder, and the like, which will actually burn without the help of Air, as may be tried with it under Water; nay in an exhauſted Receiver, as I have often tried, wherein the Effects are much the ſame, as if the ſame Accenſions had been made in the open and free Air; though where this Nitrous part is wanting, no Combuſtion, Diſſolution or actual Fire will be produced, be the Heat never ſo great. Whence we may deduce, *6. The Air the Diſſolvent of Bodies by Fire, ſo far as it has a Nitrous Spirit.*

Seventhly, That in the Steams that iſſue from the Cometical Body, there are two ſorts at leaſt of Particles or particular Subſtances: Namely, firſt a Nitrous, ſuch as is every where to be found in our Air, and is perhaps that part which may moſt properly be called the Vital part thereof, which ſupplies the *Menſtruum* to burning and flaming Bodies; and that which continues the Life, Heat and Motion of all Animals and Vegetables. Secondly an Unctuous or Sulphureous Body, that is to be diſſolved by it. Both which kinds of Bodies may be actually in the Star or ſolid Body, which I have ſuppoſed placed within the cloudy *Nucleus*, which may ſerve to continue the actual Fire once begun, and may both be rarify'd into the Halituous Steams that compoſe the cloudy or hazy Head and Blaze (which Particles, when emitted from the Body, may be ſeparated, and afterwards by convening together again, may produce an actual Flame) and make thoſe Flaſhings and Flarings, which I ſo often took notice of. *7. Two ſorts of Particles in the Steams of Comets; 1ſt A Nitrous. 2dly, A Sulphureous.*

That there may be ſuch kind of Effects produced, I would argue from Obſervations which are commonly made here in the Atmoſphere near the Earth. Every one has ſeen the Lightning and heard the Thunder here in the Air, and many have endeavour'd to give a Solution and Explication thereof. But though there be a vaſt variety of Opinions and Hypotheſes concerning it, yet to me they ſeem every one of them to have miſſed the right. I ſhall not trouble you to relate them here, ſince I have already declared my Opinion concerning them; nor ſhall I at preſent trouble you with ſetting down many abſurd Conſequences that would follow from ſuch their Hypotheſes, which would be quite incongruous to the manifeſt, if heeded, Appearances: But I ſhall only tell you what, from all the Obſervations I have made concerning it, I conceive Thunder and Lightning to be, which whether it be congruous to the *Phænomona*, and ſufficient to explain them, I leave to the curious Obſerver to judge. I have ſhewed already, that the Atmoſphere about the Earth doth abound with a ſpirituous Nitre, or Nitrous Particles, which are every where carried along with it; beſides which ſort of Nitrous Particles, there are alſo other Particles raiſed up into the Atmoſphere, which may be ſomewhat of the nature of ſulphureous, unctuous, or other combuſtible Bodies; as we ſee Spirit of Wine, Spirit of Turpentine, Camphire, and almoſt all other combuſtible Bodies, will by Heat be rarify'd into the form of Air or Smoak, and be raiſed up into the Air; all which, if they have a ſufficient degree of Heat, will catch fire, that is, be diſſolved and turned into Flame by the Nitrous Parts of the Air, as thouſands of Experiments might be brought to prove. There are alſo other ſorts of theſe ſulphureous Steams, which are raiſed up from ſubterraneous and mineral Bodies, which only by their coming to mix with the Nitrous Air (though they have no ſenſible Heat in them) will ſo ferment and act one upon another, as to proudce an actual Flame; which has been often found in Mines; and more eſpecially if any part of them be kindled, the whole Train of them, intermingled with the Air contiguous, will immediately take fire, like a Train of Gunpowder, and run from one end *An Explication of Thunder and Lightning.*

to the other of those Vapours, be they never so long, as I could prove by a Multitude of Relations from the Cole-mines and several other Mines. The Accension of which Vapours is so sudden, and with such violence and swiftness runs from one end to the other, as often to kill the Miners, to blow up their Props, Stays and Houses, and do as prodigious Effects as if a great quantity of Gunpowder had been fired in the Mine. Now Lightning here in the Air I take to be much of the like nature, that is to say, the Air or Atmosphere about the Earth is continually furnisht with the spirituous Nitrous Parts: Now the Heat of Summer, whenever very extraordinary (as 'tis always observed to be before Thunder and Lightning) raises up also out of the Earth a great quantity of sulphureous Vapours, which are of such a nature, as that meeting with the Nitrous of the Air, they work upon each other, and thereby begin a farther degree of Heat, which increases by certain Degrees so long, till it arrive at a certain pitch, at which pitch they actually fall on each other, and produce an actual Fire or Flame, which so soon as ever it kindles, whereever it be placed in the Train, it almost instantaneously fires the whole Train, and runs to the End with so great a Swiftness, that though I have observed the Progress of it at three or four Miles distance, as I have judged by the coming of the Sound to me, yet have I seen this Train kindle or pass at least a Miles distance in little more than the quarter of a Minute of time. Now the Progress of the Flashes or Dartings of Light out of the Comet do seem to be much of the like nature; and though the Progress of the Flash in the Comets be possibly a thousand times more swift; yet considering the vast difference there is between the Air and the *Æther*, I know not but that the Progress of the Accension of Flame in the Lightning may be accounted as quick through the thick *Medium* of the Air, as that of the Comet in the thinnner and more fluid *Medium* of the *Æther*.

This applied to the Comets flashing.

8ly, The Motion of Comets very rapid; therefore they are solid.

Eighthly, From the great Distance of the Comets, and the great Variation of Place they seem to make, we may collect that the Motion of them must needs be very rapid, and to equalize the Swiftness even of the Earth it self, if not much to exceed it; and consequently to continue that Motion so regular, one would rationally suppose it must be as solid as the Earth it self; or else that the *Æther* has very little, if any, impeding Power to the Motion of solid Bodies through it.

9thly, Yet the Parts of the Æther are denser.

Ninthly, That notwithstanding this, yet there seems to be reason to suppose, that there is a greater Density even of the Parts of the *Æther* it self; for otherwise it seems hard to conceive how there should be a Levitation of the flaming Parts, and a Gravitation in respect of the Sun, of the other more solid, as I shall afterwards prove more clearly by Consequences drawn, not only from the Form of their Motion, but from the more indisputable Motion of the Planets.

10thly, An Acceleration in levitating Bodies upwards.

Tenthly, That there seems to be a vast Acceleration in the Motion of Levitating Bodies (where the Motion is continued upwards) as well as there is of Gravitating Bodies, where the Motion is continued downwards, and towards the attracting Center: For though (as I have before mentioned) the exceeding swift Dartings and Flashings of the Light do rather seem to be made by a successive Accension, like a Train of Gunpowder (and, as I have supposed, if not proved, Lightning); yet to maintain such a Succession of Steams, there must needs be an exceeding quick Supply from the Head, even to the utmost Extremity of the Blaze: And it looks not unlike to a kind of actual Levitation, or a driving outwards of certain halituous Parts from the Sun, as if the Rays of Light of the Sun were carried with a local Motion rapidly swift, and in their Passage by the Star of the Comet, did carry with them such kind of halituous or fiery Steams. The often observing with my bare Eye these sudden Dartings of Light, which seemed to pass almost in a Second from the Head even to the End of the Blaze, did often make me consider, whether the Rays of Light might not thence be supposed to be moved away from the Sun with this exceedingly violent and rapid Motion; especially since there are some Observations of Mr. *Romer*'s about the Eclipses of *Jupiter Satellites*, which seem to make probable such a Theory. But whether that does well accord with other Appearances, and whether

ther it may be allowed in the Theory of Light I have ſuppoſed, I ſhall leave all Perſons free to judge. And as I deſire they would give me the liberty to ſatisfy my ſelf in trying to make a Solution of the Appearances that I have hitherto taken notice of by ſome Suppoſitions of my own, ſo I ſhall not endeavour to perſuade any of them to leave their own, or be of my Opinion, where the Appearances themſelves, that I have mentioned, or they ſhall obſerve, ſhall ſeem not to make it poſitively neceſſary: Since I doubt not but a more experienced, more thinking, and more judicious Man, may plainly diſcover what to me is as yet undetected.

For demonſtrating theſe 10 Particulars I have named, and ſeveral others conſequential upon them, I judge it neceſſary to demonſtrate, as plainly as I am able (by the ſmall Stock I have of Obſervations and Experiments, and ſome few Deductions I have made therefrom) *Four Particulars.* *Proofs of the 10 foregoing Particulars.*

Firſt, That the vaſt *Expanſum* of the World, that is, the whole Interſtice between the greater globular ſolid Bodies thereof, is a Body exceedingly fluid, and ſo fluid, as hardly to be able to hinder the Motion of any Solid through it, much leſs of a Body of any conſiderable Bulk or Magnitude. *1. The vaſt Expanſum is exceeding fluid.*

Secondly, That this exceedingly or indefinitely fluid *Medium*, though it do not at all, or at moſt very little, hinder the Motion of Bodies through it, is yet notwithſtanding the *Medium* by which the Communication of the harmonious or inharmonious Motions of the more ſolid Parts and Particles are communicated to others at a conſiderable diſtance; and that by means thereof both the Motion of Light is propagated outwards, or from the ſolid Body to all imaginable Diſtance in Radiating Lines or Orbicular Pulſes, with unimaginable Celerity: And alſo the Gravitation or Motion of Deſcent from all imaginable Diſtance towards the Radiating Body, of all ſolid Bodies, is cauſed and produced by the like Radiating Lines or Orbicular Pulſes reverſed, with an unimaginable Celerity and prodigious Power. *2. 'Tis the Medium by which Motions are communicated both of Light and Gravitation.*

Thirdly, That this indefinitely or exceedingly fluid Body may be, and is a *Medium*, in which a ſolid compound Body of proper Materials may be fired and kindled into an actual Fire and Flame, and may be continued in that State ſo long as the ſaid Materials ſhall laſt, and other Circumſtances do not hinder; and may have its Flame and Steams aſcend, and its more ſolid Parts deſcend. *3. A Body may burn in it.*

Fourthly, That the Motion of Aſcent and Deſcent herein is continually increaſed and augmented in a proportion more than duplicate downwards, and leſs than duplicate upwards, of the proportion of the Times; which Proportion ſhall be determined and demonſtrated. *4. The Proportion of theſe Motions.*

For the proving, or at leaſt making very probable of which four Proprieties of ſo vaſt a Body, and of the Parts of it at ſo great a Diſtance, and of a Body ſo altogether inſenſible to our Organs, any otherwiſe but by a Series of ſeveral Conſequences, it cannot be expected I ſhould produce a ſenſible and undeniable Demonſtration; and yet when the Coherence of all the Conſequences, that will neceſſarily and naturally flow from this Doctrine and Theory, ſhall be conſider'd, I hope it may produce other Thoughts and Arguments, in other Mens Minds, far more cogent than I am able to produce.

Now that I may not be miſtaken in my Expreſſions, and that the Words I make uſe of, which are commonly uſed, but by various Men are underſtood to ſignify various and very differing Notions, I would willingly explain in what ſenſe I underſtand them, and what Notions I would willingly have them to communicate, when made uſe of by me.

I conceive then the Whole of Realities, that any ways affect our Senſes, to be Body and Motion. By Body I conceive nothing elſe but a Reality that has Extenſion every way, poſitive and immutable, not as to Figure, but as to Quantity; and that the Body, as Body, is the ſame, whatever Figure it be of: As a Quart of Water is a Quart of Water, or a certain quantity of Body, though contained in a Globe, Cylinder, Cone, Cube, Quart Pot, or any other figured *Whatever affects our Senſes, is Body and Motion. Body what.*

contain-

containing Vessel: And as Body, it is indifferent to receive any Figure whatever; nor has it more Extension in one than in the other Vessel, nor can it have less; nor is it more essentially a Body, when solid, as Ice, than when fluid; that is, the Minims of it are equally disposed to Motion or Rest in position to each other; and therefore Body, as Body, may as well be, or be supposed to be indefinitely fluid, as definitely solid; and consequently there is no necessity to suppose Atoms, or any determinate part of Body perfectly solid, or such whose Parts are uncapable of changing position one to another; since, as I conceive, the Essence of Body is only determinate Extension, or a Power of being unalterably of such a Quantity, and not a Power of being and continuing of a determinate Quantity and a determinate Figure, which the Anatomists suppose. These I conceive the two Powers or Principles of the World, to wit, Body and Motion; Uniformity of Motion making a Solid, and Difformity of the Motion of the Parts making a Fluid, as I shall prove more at large by and by.

Motion what. By Motion I understand nothing but an Alteration, or Power of Alteration, of the Minims of a Whole, in respect of one another, which Power may be increased or diminished in any assignable Quantity; but the natural Ballance of the Universe is reciprocal to the Bulk or Extension, or to the Quantity of the other Power, Body.

These two Powers immutable, but by the Power that made them. These two I take to be two single Powers, which co operate in effecting the most of the sensible and insensible Effects of the World. Of the sensible Effects I am ascertain'd by sensible Experiments and Observations; and of the insensible I have a Probability from the Similitude, Harmony and Uniformity in the Operations of Nature.

Both these Powers I take to be the immediate Product of the Omnipotent Creator, and immutable in themselves, without a like Command of the same Power; and always to act in a regular and Uniform Geometrical or Mechanical Method; which Method by diligent Observations and curious Scrutiny may by natural and artificial Means be discovered, and, as I conceive, reduced under certain Rules, and Geometrically demonstrated. The doing of which I take to be the true end of the Science of Physicks, or of Natural and Experimental Philosophy; and all artificial Inquiries tending hereunto, I conceive to tend to the Advancement of the Knowledge of Art and Nature.

The first Principle, Matter. These are as it were the *Male* and *Female* of Nature, from the Co-operations of which the most of Natural Productions are effected. The first is, as it were, the Female or Mother Principle, and is therefore rightly called by *Aristotle* and other Philosophers, *Materia*, Material Substance, or *Mater*; this being in itself, abstractly consider'd, without Life or Motion, without form, and void, and dark, a Power in itself wholly unactive, until it be, as it were, impregnated by the second Principle, which may represent the *Pater*, and may be call'd *Paternus*, *Spiritus*, or hylarchick Spirit, as some call it; without whose Conjunction nothing, or no Alteration can be produced: For neither can Matter without Motion, nor Motion without Matter, produce any Effect. As for *Matter*, that I conceive in its Essence to be immutable, and its Essence being Expatiation determinate, it cannot be alter'd in its Quantity either by Condensation or Rarefaction; that is, there cannot be more or less of that Power or Reality, whatever it be, within the same Expatiation or Content; but every equal Expatiation contains, is filled, or is an equal quantity of *Materia*; and the densest or heaviest, or most powerful Body in the World contains no more *Materia* than that which we conceive to be the rarest, thinnest, lightest, or least powerful Body of all: As Gold, for instance, and *Æther*, or the Substance that fills the Cavity of an exhausted Vessel, or the Cavity of the Glass of a Barometer above the Quicksilver. Nay, as I shall afterwards prove, this Cavity is more full, or a more dense Body of *Æther*, in the common Sense or Acceptation of the Word, than the Gold is of Gold. Bulk for Bulk; and that because the one, *viz.* the Mass of *Æther*, is all *Æther*; but the Mass of Gold, which we conceive, is not all Gold, but there is an Intermixture, and that vastly more than is commonly supposed, of *Æther* with it: So that the Vacuity, as it is commonly thought, or erroneously supposed, is a more dense Body than the Gold as Gold. But if we consider the quantity of the whole Content of the one with that of the other, within the same or equal quantity

quantity of Expatiation, then are they both equally containing the *Matter*, or Body.

This possibly may at first hearing seem a little paradoxical, if not absurd; however I doubt not but that by the Sequel of my Discourse I shall be able to make it somewhat more plausible, if not positively and undeniably demonstrate it so to be.

The second Principle or Power, which is *Motion*, is of a quite differing nature, and may be rarified and condensed, diminished or increased, within the same quantity of *Body* or *Matter*, in any proportion assigned; that is, the same quantity of the 1st Power *Body*, or part of *Matter*, may receive any assignable quantity of the 2d, that is, any assignable Degree of *Motion*; and being possest of it, it may communicate or lose any assignable part of what it has, and still the Body, as Body, remain unalter'd and the same: For as it may be moved with any Motion, how swift soever it be supposed; so may it move with indefinitely slow Motions, and that so far, as that the next step one would suppose it must lose all its Motion, and remain in intire Rest, and unalterable of Position, as to the contiguous Body. *The second Principle, Motion.*

It may possibly be still demanded, what is *Matter*, and what is *Motion*? To which I can only answer, That they are what they are; Powers created by the Omnipotent to be what they are, and to operate as they do; which are unalterable in the whole, either by Addition or Substraction, by any other Power but the same that at first made them to be what they are; and what partial Alterations or Compositions are by them produced, they flow from that Omnipotent Wisdom, that ordered them so to do: And these are those which we call the Laws of Nature; which though at first glance they seem wholly unsearchable and incomprehensible, yet God has planted in Man a Faculty by which, I conceive, he has a Power of understanding and finding out, by and according to what Order, Rule, Method, or Law, they act, and produce the Effects that are produced by them. And this I conceive to be that we call Natural Knowledge, and our Advance in this Inquiry, I conceive to be that which we call the Improvement of Natural Knowledge; and the nearer we can approach from the lowest and most sensible Effects, to higher and higher Steps of Causes, the nearer shall we be to the highest and utmost pitch that human Nature is capable of arriving at.

I have in my Inquiries various and sundry ways attempted to ascend by the *Synthetick* Method, and as many ways attempted the contrary, or *Analytick* way, and shall therefore in some of my ensuing Discourses give some *Specimina* of each, which though they may have their Failings, and come short of what may be done by others, yet I hope they may appear to have been regularly and strictly prosecuted: And this I am now upon, though it should not prove the true, may yet be of some such use, as the Rule in Arithmetick called false Position, for the finding by the wrong Product what is more likely to be the true one.

Various have been the Attempts of several Philosophers, both antient and modern, to begin this *Analytical* way, which would be too tedious to repeat at this time; yet whether it be for that we have not a true, or at best but a very imperfect Account of what they were, we do not find that Satisfaction from the Product of them in the conclusion, which an inquisitive and strict Examiner would expect, the String and Series of the *Analysis* being broken and imperfect, and not carried on through all the Steps of Descent, as it ought to be; which will be more difficult to supply than the Effect will possibly be valuable, unless we had a more full Account of what were their first and fundamental Positions. And though even this has been an Undertaking not left unattempted by several of the more modern Writers, yet whether such Attempts have been altogether so successful as is desirable, I must leave to those that have examined them to judge.

Others there have been, and that much a greater number, who have gone the other way, and have been dabling in this or that particular Subject, and have been so blinded with some little things they have therein met with, that they presently square all the rest of Nature to their Rule. Such as these are too hasty in their Conclusions, and think to run away with that which they are far enough from attaining. The 4 Elements, the 3 Chymical Principles, Magne-

netiſm, Sympathy, Fermentation, Alkaly and Acid, and divers other Chimera's, too many to repeat; which having been embraced, nothing elſe will be heard, or go down with them; whereas, alaſs, Nature perhaps knows no one of theſe for a Principle in any ſenſe, much leſs in that which they underſtand it. Of which I ſhall ſay more elſewhere.

But to proceed, this Suppoſition of the two fundamental and primary Powers, to wit, that of *Matter*, and that of *Motion*, which I have here delivered, ſeems to me very conſonant to the Senſe I underſtand of the Hiſtory of the *Geneſis* of the World, delivered by *Moſes* in the firſt Chapter of *Geneſis*: And though the Words of that Hiſtory be by divers Authors very differingly explain'd and applied, yet by ſeriouſly conſidering of them, I conceive they may genuinely bear this Senſe alſo in which I ſhall here mention them.

A brief Interpretation of the beginning of Geneſis.

The words of the 1ſt Verſe, as render'd in our *Engliſh*, are: *In the beginning God created the Heaven and the Earth*: In the *Hebrew* 'tis, *the Heavens*; but the *Greek*, *Samaritan* and *Arabick* render it only the *Heaven*. The *Syriack* renders it, *the Being of Heaven, and the Being of Earth*: But the *Arabick* renders it thus: The firſt thing that God created was *Heaven* and *Earth*. Which Expreſſion does ſeem to ſignify the firſt Power that I have mentioned, namely, the *Matter* or *Mater*, the whole Subſtance of the Heavens and the Earth; that is, that Subſtance, which being afterwards informed and qualified by *Motion*, conſtituted the Heavens and the Earth. For it ſeems by the next Verſe to be for ſome time without the Impregnation of the ſecond Principle, *Motion*; for 'tis ſaid, *the Earth was without form, and void, and Darkneſs was upon the Face of the Deep*, or the Abyſs. The *Hebrew* is, *Deſertneſs and Inanity*. The *Greek* renders it *inviſible and incompoſed*. The *Targum*, *deſert and void*. The *Arabick* renders it, *covered with the Abyſs, and overwhelmed with the Sea*. And the Original, and all the Tranſlations, agree in the Darkneſs upon the Face of the Abyſs. All which Expreſſions ſeem to ſignify, that the *Mater* of Heaven and Earth was yet without any kind of *Motion* in it, but like that imaginary Entity we call Vacuity or Space; which was without any moving or acting Power in it, but had as yet only the Power of Expanſion, Extenſion, or Expatiation: For this is what we underſtand by the Notion of *Vacuum* or Space; and ſo is Darkneſs, namely, a Defect of the Motion of Light: For Light, as I have already by many Arguments and Experiments proved, is a Motion, and that a regular, uniform, and truly Geometrical Motion. So that the Senſe of the ſecond Verſe to me ſeems to be this, That the *Mater* out of which the Earth, or all the Solids in the World were afterwards made, was yet only a pure *Mater*, or extended Subſtance, and of the ſame nature with the Abyſs, which had not in it the 2d Power *Motion*; but was dark, without the Motion of Light, without Form; that is, without the Power of Motion, that makes Forms; deſert of Quality, Life, Action, or Diſtinction; wanting yet Motion, which maketh all the Diſtinction, Quality and Action that is in the World. Then follows the next Words, which ſeem to ſignify the Creation, or Infuſion of this ſecond Power *Motion*. *And the Spirit of God moved upon the Face of the Waters*. The Original is, *And the Spirit of God did move upon the Faces of the Waters*. The *Targum* is, *And a Spirit from the Conſpectu of God did blow in upon the Face of the Waters*. The *Samaritan* renders it, *And the Spirit of God was carried upon the Face of the Waters*. The *Syriack* renders it, *And the Spirit of God did incubare, or brood, upon the Superficies of the Waters*. The *Arabick*, *And the Winds of God did blow upon the Face of Water*. All which ſeveral Readings do ſeem to ſignify the Creation and Production of the ſecond Power, *Motion*. For firſt, 'tis moſt properly called a *Spirit*, ſignifying its Power of moving, by which Property only we know it. Next, it is ſaid to move, or be moved, or blown in or carried upon the Face or Superficies of the Waters. The *Mater* was now no longer dead, and unactive, and Earth, but it became a Fluid, ſignified by Water. For, as I ſhall afterwards ſhew, it muſt in this Place be ſo taken, and not only for the Subſtance Water, but that God joining the ſecond Power *Motion*, and impregnating the *Mater* with it, made every *Minim* of it to move with infinite Varieties of Motions: And ſo all thoſe which before lay ſtill, and changed not their Places and Poſitions in reſpect of one another, and were therefore called Earth, are now by this Inſufflation, Incubation, or acting of the Spirit of God upon the Superficies,

ficcies, become a perfect Fluid, or a Water. No two contiguous *Minims* yet agree in Unity or Uniformity of Motion. And hitherto seems to be the History of the Creation, or making of the two first Powers, *Matter* and *Motion*, *Body* and *Spirit*, or *Matter* and *Form*.

In the next place follows the Description of the two great Laws of Motion, which constitute the Form and Order of the τὸ πᾶν, or World. The first is that of *Light*, and the second is that of *Gravity*. *The two great Laws of Motoon, Light and Gravity.*

First for that of *Light*, which is the first regular Motion, or Rule of Nature, which is that regular Propagation of Motion, which, as I have formerly explain'd, extends it self instantaneously through the Whole of Matter. We find in the third Verse, *And God said, Let there be Light, and there was Light, and God divided the Light from the Darkness.* Whereby we find, that the first Regulation of Motion was the Principle of *Light*; which seems to signify, that this Propriety of the fluid Matter was then first implanted, by which the similar Parts of it were made fit to propagate the Pulse of *Light* to all imaginable Distance; and this Substance was distinguished from that other Substance, which would not propagate it, which was opaque and dark: For as yet we find neither the *Sun* nor *Stars* were made, nor the *Earth* it self formed but only a Qualification of Matter fit for the performing of those Functions, which were accordingly made distinct, and secondarily implanted: *And God said, Let there be an Expansum, or a Firmament, and let it divide the Waters from the Waters.* This seems to signify the second general and grand Rule of Natural Motion, namely, *Gravity*. For this Expansion or Firmament is said to divide the Waters from the Waters, or one Fluid from another; for so the Word *Maim* seems to signify. And this made all those Fluids which were of a Terrestrial Nature, to congregate or gather together into the Mass of the Earth, or Earths; and the other of a more Celestial Nature, to gather together in the Sun and Stars. And this Expansion or Firmament, which was the extensive Power of Gravitation, was that which caused those Effects. These two Powers seem to constitute the Souls of the greater Bodies of the World, *viz.* the Sun and Stars, and the Planets, both such as move about the Sun, and such as move about any other Central Body: And both these are to be found in every such Body in the World; but in some more, in some less; in some one is predominant, in others the other; but no one without some Degree of both: For as there is none without the Principle of *Gravitation*, so there is none without some degree of *Light*. And though some doe not shew its Effects in producing Light immediately, yet I shall make it probable that it has that Motion blended with others, which hinder it from producing Effects, but yet do not wholly destroy the Principle. And this I shall make the more probable, when I shall shew how both these Powers are but distinct Effects produced by one and the same Power, and that this Power is implanted in every such great Globular Body in the World. I could go on through the whole History delivered in this first Chapter of *Genesis*, but that I only aimed at present to shew, that nothing of what I have hitherto supposed, does any ways disagree with Holy Writ, but rather, that it is perfectly consonant to that, as well as it is to Reason, and the Nature of things themselves.

1. Light. *2. Gravity.*

I have often made use of the Words *Maximum* and *Minimum*, or of the Greatest and the Least; and because there are various Opinions concerning the Significancy of those Expressions, some understanding them in one sense, and some in another, I would willingly have it understood in what sense I make use of them. *Maximum and Minimum, in what sense taken.*

By the Words *Maximum* and *Minimum*, or the Greatest and the Least, I understand then only the greatest and the least Extension or Motion we have need to make use of in speaking or supposing, which will still be bounded: For Infinite or Unbounded cannot have an Idea formed in our Imagination or Memory, which must always have a bounded Idea, being material: And this bounded Idea, however by comparing and reasoning we may suppose it differing; yet it is never bigger or less in reality, than the biggest Appearance we have had of the Heavens, or the least Appearance we have had of a visible or other sensible Point. These Ideas therefore of *Maximum* and *Minimum*, made use of in Discourse and Reasoning, are compound Ideas, and consist of the simple Ideas of the sensible

Maximum

Maximum and *Minimum*, with a Proportion annexed. For, as much as the Idea of the *Maximum* does exceed the Idea of the *Minimum* brought in by the Sense; so much do we suppose the *Minimum* to exceed another *Minimum*, of which we would make a single Idea, but we cannot; but it will always be a compounded or comparative Idea; and so *vice versâ* of the *Maximum*. For neither can we form a simple Idea of any thing that is a Million of Millions of times less than the Idea of the least visible Point; nor can we form an Idea of a *Maximum*, which is Millions of Millions bigger than the imaginary bigness of the Heavens we see; but by Composition, and Comparison, and Proportion, we make the compounded Ideas, which suffice for a Material to be made use of in Reasoning. And when all comes to all, we do but reason upon the τὸ πᾶν in our own Repository or Memory, which contains certain Ideas, Forms, Pictures or Marks, we our selves have made of simple Sensations; which are originally begun from Motions without, but compleated, finished and disposed of within our selves, by the Power and Activity of the Soul; from whence proceeds that Difference which is to be found in the Imaginations and Reasonings of several Men: For the things of Nature are the same, and the Informations are conveyed by the same *Media*, and in the same Manner; yet partly the Organs of Men differ considerably in their Perfections; but chiefly the inward Parts of the Organ of Memory, and the natural or acquired Habits of the Soul in Imagination and Reasoning, are exceeding different. Some men have a more piercing Sight, and can distinguish a much smaller Point than others, possibly from the Tunicles and Humours of the Eye, their exceeding Clearness and Transparency, and Exactness of Figure; possibly also from the Fineness and excellent Structure of the sensible Part, and Optick Nerve, and Parts of the Brain serving to that purpose, and from the Habit, Use and Exercise of those Parts and Faculties: But still in the best, the *Minimum* and the *Maximum visibile* is limited, it can be no more than a Hemisphere of the Eye, nor smaller than a Point of the Eye, which to every Man is assignable; and whatever other Idea is formed to express a less or a bigger, is a compounded or proportionate Idea, and will be plainly discover'd so to be by any one that will but seriously so consider it.

But to leave this Digression, and proceed by various Enquiries in the Synthetick way, or by reasoning, and proceeding from sensible Observations and Experiments, to the more insensible Operations of Nature; I have already shewed Light to be a continued Pulse or Motion propagated through a Diaphanous *Medium* to all imaginable Distance *in orbem*; and by this means to continually agitate and make fluid, vivify and regulate the greatest part of the Universe. I have already shewed all its various ways of moving and crossing each other, and the harmonious Chime, as it were, of the Pulsations of several Luminous Points or Bodies, and therefore shall not here repeat them any further than only naming, As first, that Light makes all things sensible to the Eye; next, that such a Motion causes Heat, produces and contiues Fluidity and Solidity; producing Union and Separation; Union of homogeneous, and Separation of heterogeneous Bodies. These, I say, I have already pretty largely explain'd; and therefore I shall leave the further Explanation of it to a more proper Place, and proceed to the next Principle, *Gravity*, because I find that Principle to seem the more new and strange to some Persons; and I would willingly remove such Difficulties as occur, before I proceed, because otherwise there will be a hesitancy in all that follows.

Some Effects of the Motion of Light.

What is understood by Gravity.

By *Gravity* then I understand such a Power, as causes Bodies of a similar or homogeneous nature to be moved one towards the other, till they are united; or such a Power as always impels or drives, attracts or impresses Motion into them, that tends that way, or makes them unite. The Universality of this Principle, throughout the whole and every thing therein, I shall afterwards have more occasion to explain, when I come to the Effects of Nature in lesser Bodies. At present I shall only proceed to shew it in the greater Bodies of the World.

1. That there is such a thing.

First then, that there is such a Power in the Earth, in respect of terrestrial Bodies, I think no one will deny in the general. Some Disputes there have been, I confess, among Philosophers, concerning the Nature of the Power it self, and some concerning the Subject in which it is inherent: Some supposing it to

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be a *Spirit*, an *hylarchick Spirit*; others ſuppoſing it an *innate Quality*, or inherent tendency to the Center of the World, not as 'tis the Center of the Earth, but as it is the loweſt Place in the Univerſe, and fartheſt removed from the Heavens, and from the more Spirituous and moving Bodies; and ſo is ſuppoſed the worſt of Places, and made fit only to receive the Dregs of the Univerſe: And were the Body of the Earth there, or not there; yet thither would all theſe dull and earthy Bodies, that we now find deſcend, tend, and there remain. Others ſuppoſe this Power placed in the *Æther*, and that by the Rotation thereof making it tend outward, the more ſolid Bodies, which conſiſt of more bulky Parts than the *Æther*, are driven downwards. Others place it in the *Earth* it ſelf, which they ſuppoſe like a great *Loadſtone*, and to ſend forth certain Chains of uncous or hooked Particles, which pull down all Terreſtrial Bodies out of the Air, or from any higher to any lower Place: And many other ſuch Fictions and *Chimera's*, which ſerve only to inform us what kind of Notions and Imaginations thoſe Men had in their own Minds; but in no wiſe to inform us of what the Power is, or in what manner it operates. Only this farther we may collect from them all, that every one of them took it for granted, that heavy and terreſtrial Bodies were by ſome Power moved towards the Center of the Earth, whether their particular Notions concerning that Power were right or not.

Next, there have been as many differing Opinions concerning the Limits of this Power: Some extending it too far, and others as extravagantly too little: Some ſuppoſing, that wherefoever in the Univerſe a terreſtrial Body ſhould be placed, there it would have a tendency towards the Center of the World or Earth; and therefore that in the Creation, all the Terreſtrial Matter of the *Chaos* met together, and made up the Body of the Earth. Others, on the other hand, have been too penurious in limiting its Power to ſome few Miles; ſome to 50 Miles, others to a Boundary, that a Cannon well charg'd with Powder would be able to ſhoot a Bullet out of its reach. But though they are both enough miſtaken, yet they agree in this, that this Power of Gravitation does act at ſome diſtance above the Surface of the Earth. *Of its Limits upwards.*

Others differ again about the Modes and Limits of its working within the Body of the Earth below its Surface; but no one I have yet met with ſeems to me to have hit upon a right Notion concerning it; and yet all agree in this, that there is ſuch a Power ſomewhere placed, that does act regularly, and within ſome certain Limits. I could proceed farther to mention their Explanations; but I conceive they would be too long, and not much to my preſent purpoſe. *Of the Modes and Limits of its working below the Surface of the Earth.*

In the next place, this Power acts regularly and uniformly. I argue its Regularity or Uniformity of acting on all ſides or ſuperficial Parts of the Earth, from the Spherical Surface of the Sea; and that from the Shadow of the Earth in Eclipſes of the Moon, where the Picture or Shadow of it is found to be round: And therefore though I cannot without very much trouble here upon the Earth, be aſcertain'd of the Uniformity or Equality of the Power of Gravity working every way nearly towards the Center of the Earth; and though I cannot aſcend high enough, tho' I ſhould get to the top of the higheſt Mountain in the World, to have a certainty from Inſpection or Sight: Yet this alone, of the roundeſs of the Shadow in Eclipſes, is Argument enough to perſuade any unprejudiced Perſon from disbelieving it, as a Matter very unlikely; though it be not ſufficient to prove its Geometrical Roundneſs, which muſt be proved by other *Mediums*. Beſides, we find that it muſt be very near round, and conſequently have very near uniform Gravitation, from the general Obſervations of Navigators, who do find, that ſo many Leagues ſailed Northwards or Southwards, do alter a Degree of Latitude; which were the Gravitation not pretty near equal, it would not ſo happen. 'Tis poſſible, by very accurate trial, the Truth and Certainty thereof might be poſitively proved and determined; but 'twill require more than my Opportunities will reach unto at preſent, to do it, though I can ſhew how. It were deſirable however, that it were once for all accurately tried. *2. It acts regularly.*

The reaſon why I inſiſt ſo much upon this Argument of the Roundneſs of the Figure of the Earth, is, becauſe I take this Roundneſs to be as convincing an Argument as any, to prove that there is the like Power in every Globular Celeſtial Body, as there is in the Earth. For ſince all the Celeſtial Bodies, whoſe

Shape we are able to discover, are found to be of a Globular Figure, as is the Earth, and that several of them do turn round upon their *Axes* (as we find beyond doubt that the Sun and *Jupiter* do) were there not in them such a gravitating Power, all the loose Parts of their Bodies must be shot out from them, or thrown away like a Stone out of a Sling swung round, or the loose Parts sticking to a Wheel or Top, when whirled round; and consequently they must in a little time be dispersed and shattered to pieces. But no such Appearance has ever been observed: Therefore it is an Argument that there is such a Power in those round Bodies of the *Sun* and *Jupiter*, which keep those moveable Parts from flying off. For that the Sun has moveable Parts, is evident by the Discovery of our Telescopes, which shew us various sorts of Spots; which Spots, whether they be Clouds of Smoke, or more opaque Parts that rise out of the Body it self, and only float on a fluid part of the Body of the *Sun*, like the *Scoria* or Dross of red-hot melted Mettal, is not yet determined: And 'tis most probable they are of the former nature, by the various Circumstances that have been taken notice of; but be they which soever, yet the whirling of the Sun would throw them off, were there not such an attracting Power that kept them from receding, since 'tis evident they are loose from the rest of the Body. The like may be said for *Jupiter*, in whose Phases great Alterations have been observed by several; and Mons. *Cassini* judges some of those Appearances to be caused by some kind of Waters. The like I conceive may be said for the Body of *Saturn*, though our Telescopes have not yet certainly distinguish'd *Phænomena* sufficient to prove its Rotation.

I say moreover, that this Power is not only placed in the Earth, but that there is the like Power in every Globular Body in the Universe, whether Sun or Fixed Star, Planet primary or secondary, and in the Cometical Body included, as I have supposed, within the *Nucleus* or white Cloud appearing in the Head.

3. Its Power acts indefinitely upwards.

In the third place, I say, that this Power of Gravity, which is sufficiently evident on the Superficies of the Earth, and acts so regularly every where round the Surface of the Globes, is not suddenly extinguished, nor loseth its Power at a little height above us: But, as I conceive, it is extended to a vast distance upward, even indefinitely; and though it may be said to be sensibly finite, yet this sensible Boundary has its Limits prodigiously large; and when the Degree of its Power, which shall be called sensible, is stated, then these Limits also or Distance of such an imaginary Surface, may be Geometrically determined, and the Proportion of the Semi-Diameter of it to that of the Globe of the Body in the middle, exactly determined and demonstrated. I conceive further, that this Power thus extended, does act with various Degrees at several Distances from this Body, which Degrees I shall also endeavour to state, and, as I conceive, evidently demonstrate from my Hypothesis, founded, as I conceive, upon the *Phænomena* of Nature, and not taken up at random, or by chance. These my Conceptions (as being, I think, wholly knew, and not yet asserted by any Person whatsoever) may seem strange and extravagant, and I must be content to have them so esteemed, by such as may either have a Prepossession for some other Hypothesis, or shall not allow of the Arguments I shall bring to confirm them as sufficient for that purpose. It cannot, I suppose, be expected that I should try or shew Experiments at Distances sufficient to prove it experimentally and positively; and therefore all that I can bring is only this, that I find a certain Agreement and Coherence of this my Supposition with other Operations in Nature, and that hereby the Appearances of Nature's working are explain'd: Whereas I cannot find that by any other Hypotheses that have been hitherto made known, the *Phænomena* of the Heavens can be intelligibly and clearly solved, without the granting of many such Actions or Motions, as are very absurd, dissonant, and contrary to the natural Motions, Actions and Effects of Powers and Motions, which are within our reach to examine. Whence some of them, that they may give a Cause of the undoubted Appearances, have been fain to suppose understanding Beings, Spirits or Intelligences, to be the Movents or Causes of such Extravagancies. Others have supposed various sorts of solid Orbs, Orbits, Epicycles, and I know not what other Wheel-work, to make out the sensible Inequalities, and yet regular Periods; which being too gross, and

Several Opinions concerning the Motions of the Planets.

and contradicted by the Motion of Comets, others have rejected, but instead thereof, have supposed Magnetism, as *Kepler* and his Followers, who have to that end feigned a Friendly Side and an Enemy Side to be planted in the circumgyrating Celestial Bodies: And because the Moon always keeps the same Side very near, respecting the Earth, and so its Appearances contradicted this Supposition; therefore they supposed a *Nucleus* within the Moon, which had a differing Motion and Position in respect of the Parts of the Shell, or outward superficial Parts of the Moon which appeared. To help this yet farther, for this was not enough to do the business, they supposed a radiating Species to stand always stiff, like the Spokes in the Nave of the Wheel, and to turn round as the Body placed in the middle is turned; which radiating Species or Spokes, like a kind of Besom, sweep along the Planet with them, not so fast as they themselves are moved, but with a somewhat slower Pace; and that so much the slower, as the Body to be sweeped forward was farther distant. But beside this, another Actor is needed, and that is, a second sort of Spokes made of the Rays of Light; these also are supposed to help to sweep it on. Nay, besides all these there is another Help wanting, and that is, Magnetism, like that of the Dipping Needle; by which means there is feigned also to be a kind of Libration, sometimes of the Body, sometimes of the Orbit. And after all these and several other lame Helps supposed, we find they are fain to be most thrown aside, when they come to Calculation. Others, as *DesCartes* and his Followers, have supposed a Whirling of the *Æther* round each Star, or Planetary Body, and a swimming of the Planet that moves round it in this *Vortice*. But how uncertain Effects and Motions of the Planetary Bodies must this way be produced, any one that considers well the Hypothesis, will quickly find, and as readily conclude, that if this Hypothesis be true, there can be no Astronomy; besides, that were it granted, the *Phænomena* themselves could not be solved. It may still be said, that the disproving of all these will still be no Argument why what I have here supposed should be true.

But then it may likewise be farther urged, 1st, That this Hypothesis or Assertion which I have laid down, doth not create or suppose any new or unheard of Powers or Motions, but supposes only such as are altogether uniform and similar to Powers, Operations, Effects or Motions, which are within our reach and command, which we daily try, see, and find the regular working of.

My Arguments therefore to prove this Supposition, are only these. *Arguments to prove the Supposition.*

First, That what I here suppose in all Bodies, I can prove to be in some, and so suppose nothing absurd or impossible.

Secondly, That the Principles I ground it upon, are (according to the working of Nature in all things) the most simple and the shortest that can be: And 'tis generally asserted so to be by all Philosophers, and found by all inquisitive Searchers into Nature. *Natura nihil agit frustra, sed frustra fit per plura, quod fieri potest per pauciora.*

Thirdly, That Nature seems to take similar Ways for producing similar Effects; without granting of which we cannot reason or make any Conclusion from similar Operations. And then it would be no Absurdity to say, a Man grew out of the Earth like a Plant, or a Plant had Understanding and spoke.

Fourthly, That more or less of these Principles is to be found in every Body in Nature, but more remarkable in some of the Bodies in which I here suppose it, and that there is nothing that I have met with that does seem to shew a contrary or contradicting Quality in any one of them.

Fifthly, That from these most single and easy Principles of Body and Motions here asserted, there will follow such a Regulated Motion, as will *a priori* shew what are, have been, or shall be at any time assigned the true Places and Motions of the Celestial Bodies, consonant to the Appearances themselves: And this not in one, but in all, as I hope I shall shortly make more evident.

First

That Planetary Bodies have a Gravitation to them.

First then, that what I here suppose to be in all Celestial Globular Bodies, I can demonstrate to be in some, I think will readily enough be granted, when I prove that the Earth, on which we live, is one of those Celestial Bodies: And that Part I think I have proved by the Observation which I made of the Parallax of the Orb of the Earth to the bright Star in the Dragon's Head, which passes very near the *Zenith* of *London*; an Account of which I have already given in my Attempt to prove the Motion of the Earth, which Attempt (how *trivial* soever it may be supposed, yet considering, that without some such Proof we were condemned to the worst Place in the Universe, and so thought unfit and unable to understaud any thing of Celestial Bodies) has given Mankind one Argument at least to believe somewhat better of their Mother Earth and themselves than they did before, *viz*. that she hath *Origo Cælestis*, and that we our selves are *Incolæ Cælestes*. And so being granted able, at least, to consider, examine and reason about the Nature of the Earth on which we live, we are at the same time granted to be able to consider, examine and understand the Nature of some Celestial Body. This being granted, all the *Ptolemaick* solid Orbs immediately vanish, and all the ingenious Clockwork which has since that time been added to his. For since we are assured by this Observation, that the Body of the Earth is moved round the Sun once in a Year, and that the Earth swims or is incompassed with a fluid Air only, or a more fluid *Æther*, and that the other Planetary Bodies are moved about the Sun in the same manner as the Earth, and have the same Passions and Affections as the Earth hath of acceding towards and receding fromwards the Sun, of moving swifter and slower, according to several Distances from that Body, of turning round upon their *Axes*, of carrying peculiar lesser Planets along with them, which move about them as the Moon doth about the Earth, of eclipsing and being eclipsed by those Bodies, of being inlightned by the Beams of the Sun, and of being dark where that Light cannot shine, and the like; why should we any more suppose it necessary that the other Planets should have solid Orbs to guide their Motions, than we find the Earth it self, which is one of them, really hath? not now to urge the Arguments drawn from the Motions of Comets. This *trivial* Observation then was necessary to introduce us into the *Expansum* of Heaven, and to manifest to us how great a Voyage we make in a Year, and what we also do in the space of twenty four hours, and to inform us what Opportunity we have of surveying and knowing more of the World than before we thought our selves capable of. And though the Notion was perhaps fully understood and believed long before the other of *Ptolemy* was broacht; yet being only a Probability, there could be no positive and undoubting Assent given unto it, without some such Experiment or Observation as I have formerly produced. The Earth then being found to be a Planetary Body, it will be no difficult matter to prove, that it hath that Propriety which we call Gravity; that is, that all Terrestrial Bodies, or such Bodies that seem to be part of it, or that are of a like nature with it, are continually moved, or have an Endeavour to move towards the Center of the whole, which Endeavour is called the Gravity of such Bodies: And consequently a Planetary Body is proved to have Gravity, and 'twill not be difficult to prove the same in all the other.

An Inquiry into the Cause of Gravity. Some of its Proprieties enumerated.

It remains only to enquire what is the Cause or Principle of this Gravity, and what invisible or insensible Power it is that causes this Endeavour. Various have been the Attempts of several to explain it, but no one, that I have yet met with, to me seems satisfactory; nor would they make out the *Phænomena*, tho' all they have supposed, how extravagant soever they be, should be granted; whatever the Power be that doth thus cause Bodies to move towards the Center.

1st, It is wholly insensible by any other Means than by the Effects. There are no hamous Particles underneath to be discover'd to pull down the Body, nor any hammer Particles above to beat it down. A Body is not less heavy though there be never so thick, nor never so dense a Body placed between that and the Earth to break the Chains, or above it to hinder the Strokes of the Hammers or striking Particles; nay though included every way within the densest Body; as the middle Parts of a great Stone, or Piece of Mettal, weigh as much when whole, as when the same is broken in pieces.

2dly, The

2dly, The Endeavour of Gravity acts or tends always towards the Center of the Globe of the Earth, as far as any Obſervation has been made. This is generally granted and believed by all, though I doubt whether it hath been ever proved; for though I believe it nearly probable to be ſo, yet I am not aſſured of it by any Experiment yet ſo much as attempted to be made. The beſt way that I know how to prove it, is, to meaſure the parts of a Meridian upon the Earth from Pole to Pole, and compare them with Celeſtial Meridional Altitudes: For if they every where correſpond and anſwer one another, then the Perpendicular Line is true in all thoſe Places; but if otherwiſe, not. And till this be done, we are not by any certain Experiment aſſured, that the Body of the Earth it ſelf is perfectly Globular; for it may be ſomewhat either of an Egg-form, the longeſt Diameter being in the *Axis*, or elſe of a Turnep-form, the longeſt Diameter being in the Equinoctial. Nor is the Shadow of the Earth eclipſing the Moon, ſufficiently diſtinct to determine this Point. This Gravitating therefore to a Central Point, though it be probable, is not yet poſitively proved by any Obſervations hitherto made, nor is it very eaſy to be made to ſufficient exactneſs. But though we have no Experiment here made on the Earth, that does poſitively evince it; yet this fetcht from the other Planets, may do ſomething towards it: Namely, that moſt of the reſt of the Planets (ſome of which are certainly bigger than the Earth it ſelf, and, as I but now mentioned, have the ſame Qualifications) are obſerved to be very near Globular. Here by the by, I cannot but take notice, that there are in Philoſophy many things that are generally taken for granted, which yet when we ſeek for the grounds of thoſe Opinions, none certain are to be found, and thence all that is built upon them muſt be uncertain. For inſtance, in Experiments that have been made to prove the Magnitude of a Degree, 'twill be inſufficient to prove the Magnitude of the Earth, till by comparing ſeveral made in ſeveral Latitudes, they are all found to agree, and ſhew the ſame Quantity: For if the Earth be Oval, as there ſeems to be good reaſon to ſuppoſe, then the Length of a Degree in one Latitude will not be equal to the Length of a Degree in another Latitude, and the Perpendicular of Gravity will not always point to the Center of the Earth. For if the Principle or primary Cauſe of Gravity, which I conceive an internal Motion in the Earth, be every way uniform, and ſo cauſe an equal Attraction to the Center, then any other Cauſe that alters the Diſpotions of Bodies to receive this Power, or that ſuperinduces another Power that in ſome parts of the Earth has a greater Renitency againſt the Power of Gravity than it hath in other Parts; then the uniform Effect which Gravity alone would operate, will be altered by the adventitious Power. Now the Diurnal Rotation of the Earth doth ſuperinduce ſuch a Power; for the Parts near the Equinoctial muſt have an Endeavour outwards, or from the Center; whereas the Parts nearer the Poles muſt have leſs, and ſo much the leſs, by how much the nearer they approach the Poles: And this Renitency, as it will be directly oppoſite to Gravity under the Equinoctial, ſo will it be in all other Parts oblique unto it. Wherefore from the conſideration of theſe two Cauſes, there ſeems to be a probability that the Perpendicular does not always and every where point to the Central Point of the Earth, how generally ſoever that Opinion be received which aſſerts the contrary; and may poſſibly deſerve ſome further Enquiry, as opportunity ſhall offer; and there muſt want a Demonſtration till this Queſtion be determined. And by the way 'tis very remarkable, that by comparing of former with later Obſervations of the Magnitude of a Degree, the Earth ſeems to have continually grown leſs. But of theſe and ſeveral other Remarks I ſhall ſpeak more, when I come to read concerning the Earth it ſelf: I ſhall therefore return to the conſideration of Gravity in general. This believed Roundneſs of the Figure, ſhews Gravity to act regularly in every part of the Earth's Superficies, otherwiſe it could not be nearly round.

3dly, This Gravitation and Levitation extends to and beyond the Earth.

In the 3d place then, the tendency of Grave Bodies reſpects the middle Parts of the Earth, though theſe Central Parts be carried with a very ſwift Motion from Weſt to Eaſt by an annual Motion about the Sun. And therefore 'tis probable that it carrys with it the Principle or Power that acts; and thence, that it muſt

muſt there be ſought for. This will need no other Proof, its Motion being already proved by the Perpendicular Obſervation.

4*thly*, Gravity is a Power which at all times acts equally; that is, a Body which remains the ſame, will always be found to have the ſame weight. This I conceive, none will doubt, but yet 'tis not very eaſy poſitively to prove it; for Scales cannot examine it, becauſe if the gravitating Power alter, the Counterpoiſe will be affected as well as the Weight; nor can it be try'd with my Philoſophical Scales made by a Spring, becauſe it may be ſaid, the Alteration is in the Spring, and not in the Weight. The only way that I conceive it may be try'd, is by the Deſcent of Bodies, compar'd with the time of their deſcending a certain Space, or becauſe that will be very nice, by the Vibrations of a Pendulum, whoſe time and number of Vibrations may be ſtinted: But here alſo will come ſome Objections, that there may be other Cauſes of altering the Velocity of the Vibrations, beſides Gravity, as the ſhrinking and ſtretching of the Rod; the thickning or thinning of the Air or Medium in which the Pendulum moves, unleſs it be in *Vacuo*, and the like. Yet I conceive theſe and others may be obviated, and the Matter determined, if that were neceſſary; but another Argument hereafter to be mentioned of the Moon, will better clear it.

5*thly*, Gravity is obſerved to accelerate the Velocity of deſcending Bodies with equal Accelerations in equal times. This hath been ſufficiently proved by falling Bodies and Pendulums, to certain Degrees pretty near, but not exactly. And therefore in the

6*th* place, Gravity is a finite Power, and acts with a determinate Degree of Force; that is, the Gravitating Power can never accelerate any Body beyond its own Velocity. That it is finite, we eaſily find from the Power we have of throwing or ſhooting Bodies upwards, which could not be, did not the Power of the Arm, Bow or Gun exceed it: And comparative to other Powers of Nature, 'tis weak.

7*thly*, That it acts on all Bodies promiſcuouſly, whether fluid or ſolid: So that the ſame Body which can be made fluid or ſolid, provided nothing be added to it or taken from it, will have, in both Forms, the ſame weight *quam proxime*.

8*thly*, The Bodies moſt receptive of it are ſuch as have their Particles of the greateſt bulk and of the cloſeſt Texture. This the whole Series of grave Bodies will ſufficiently manifeſt; and I ſhall afterwards prove, when I come to ſhew the Texture of Body, what it is that cauſes Bodies to be grave or heavy, and what makes them light, and that 'tis not the quantity of Matter contained within the ſame Space, but the Modification of that Matter, and the Receptivity it hath of Uniform Power.

9*thly*, I cannot find by any certain Experiment, that grave Bodies do ſenſibly decreaſe in Gravity, tho' further removed from the Surface of the Earth; which was the Intent of an Experiment I formerly tryed at the top of the Steeple of St. *Paul*'s and at *Weſtminſter-Abby*, and may now again be repeated with much more conveniency and greater advantage at the Column on *Fiſhſtreet-Hill*. For by counterpoiſing two Weights in a curious Pair of Scales, firſt at the top of the Steeple, and then letting down one of the Weights by a Wire of two hundred and four Foot in length, the Counterpoiſe remaining at the top in the Scale, the *Æquipondium* remained; whereas if the Gravity of the Body had increaſed by Approximation to the Earth, the Weight let down to the bottom muſt have weighed the heavier. But though the Difference were inſenſible in ſo ſmall an height, yet I am apt to think ſome Difference may be diſcovered in greater heights, and by ſome more curious ways than thoſe I then uſed, even in that height: For I ſhall in my following Diſcourſes plainly ſhew, from the Theory thereof, that there is neceſſarily a Difference, and that the Power of Gravity does decreaſe at farther and farther Diſtance from the Center of the Earth, and conſequently that the Line of a projected deſcending Body is not truly Parabolical, but Elliptical, though

though it ſhould be made *in vacuo*, where the Impediment of the *Medium* could make very little or no Alteration.

Having enumerated ſome of the moſt remarkable Proprieties of Gravity, we come in the next place to conſider what may be the Cauſe thereof.

And firſt, I believe I ſhall not need to ſay much againſt the Opinion of *Intelligent Matter*, which ſuppoſes every part of Matter to act underſtandingly; for that being ſuppoſed, all Philoſophy is vain, and there needs no farther Inquiry into Nature.

And ſecondly, I have as little to ſay to its Couſin-german Opinion, *viz.* the *Regimen* of an *Hylarchick Spirit*.

And 3ly, The *Epicurean* Atoms ſeem to me to give as little of Explanation almoſt as either of the former.

And 4ly, For the *Peripatetick* Doctrine of tendency to the Center of the Univerſe, beſides that the Foundation is falſe, the Earth being proved not to be in the Center, 'tis not yet underſtood what the tendency is.

5ly, The *Carteſian* Doctrine, and that of Mr. *Hobbs*, are both inſufficient, becauſe they do not give any reaſon why Bodies ſhould deſcend towards the Center under or near the Poles.

6ly, Nor will the *Magnetiſm* of *Gilbert* or *Kepler* ſerve; for, as I ſhall afterwards ſhew, that is a Propriety diſtinct from Gravity, and of quite another nature.

What the Cauſe of Gravity is.

It muſt therefore be ſomewhat elſe differing from all theſe, which by reaſon of its acting by the means of ſome very inſenſible Body, it will be very hard to demonſtrate, yet not altogether impoſſible. We find then that a Propriety ſomewhat like this is to be found in the Attraction of the Magnet and Iron. Another ſomewhat like it is to be found in Amber, Jet, Glaſs, Chryſtal, Diamonds, and ſeveral hard Bodies upon Rubbing: And more inſtructive yet to this Inquiry is the Experiment of Mr. *Newton*, of rubbing a Plate of Glaſs, which is laid over ſome ſmall bits of Paper, or other light Bodies, at ſome diſtance, by which Rubbing the Papers are made to riſe up towards the Glaſs, and ſtick faſt to it. Now in all theſe Experiments there is a ſenſible Attraction of Grave Bodies to the reſpective attracting Bodies, or at leaſt a Motion of thoſe Bodies towards one another; though in all, the *Medium*, that cauſes this Endeavour of Motion, be inſenſible. Some have ſuppoſed for Amber, that the ſame being a very unctuous Body, certain ſtringy unctuous *Effluvia* are ſent out, which ſticking to the light Bodies, are drawn into the Amber again, and ſo bring back with them the light Bodies. But this is very hard to be ſuppoſed of Glaſs or Chryſtal, and leaſt of all of a Diamond, which yet will have a conſiderable Electricity, as 'tis called, upon Rubbing; Beſides, 'tis evident by Mr. *Newton*'s Experiment, that the greateſt Electricity of Glaſs is at the very time when it is hardeſt rubbed, which ſhould be the time when theſe unctuous Strings ſhould be ſent out; 'tis neceſſary therefore that ſome other Medium muſt be found than theſe unctuous and ſtringy Emanations.

If we farther conſider of theſe Experiments, we ſhall find that there is in all theſe a neceſſity of an internal vibrative Motion of the Parts of the Electrick Bodies; and that ſo ſoon as ever that Motion ceaſes, the Electricity alſo ceaſes: We may therefore conclude, that there may be ſuch an internal Motion of the Parts of ſome Bodies, as may cauſe an Electrical Virtue in them, whereby they will be able to draw, with ſome ſmall Degree of Power, ſome Bodies to them.

I have already here produced ſeveral Experiments, whereby I have ſhewn how mechanically to produce ſuch an Attraction towards the acting Body. The firſt was that of a Body placed upon a wooden Rod, the one End of which was kept in its place by a Spring, and the other was ſtruck by a Hammer, whereby it plainly appeared, that at every Stroke the Body was moved on the Rod towards the Hammer that ſtruck. Here the *Æther* was reſembled to a Solid. By the ſecond Experiment, where a Ball poiſed in Water deſcended toward the ſtriking Part, I ſhewed how the ſame Effect might be done by a fluid Medium, as in the other was done by a Solid. In the third was ſhewn how a Fluid alſo might be

See more Experiments in the Author's Life.

be affected by a like Pulse; for that the Water it self, by means of a vibrative Motion in the Parts of the Glass, acquired a Motion towards the vibrating Parts. I should have proceeded, if not interrupted, to have experimentally proved the Effect of this Power in *Media* much more insensible. The Obviousness possibly of these and such like Experiments may make them be looked upon as slight and trivial; and the Paucity of them, for that they come not in by whole Shoals, but are only caught singly, may make them not regarded. But as the Miracle was not less of the single Fish catched by a Hook, with the Tribute in his Mouth, than of the Shoals which were ready to sink the Vessels, and brake the Nets: So some one plain but pertinent Experiment, apply'd with Judgment, may be more significant than thousands of such as are pompous, amusing, and excite Admiration. And I am satisfied that more Discoveries in Nature may be made by the most plain, obvious and trivial Experiments to be everywhere met with, than by the far-fetcht and dear bought Experiments which some seek after.

Nor is this way of working at a distance, by means of the internal Motion of the Particles of the Body; so strange a thing in Nature, that we need much to insist upon these few Experiments to prove it. For if we consider the *Totum Sensibile* in Nature, we shall find it to be little else than what is this way produced. I have already, I think, fully proved in Light and Colour, the Object of Sight, that the Motion which is produced in the Eye, proceeds from an internal Motion made in the Sun so many thousands of Miles distant, or from the same in some Stars so many thousand times as much farther off. I could also as easily prove, that Sound in the Ear, which is a real Motion in some part thereof, is produced by the internal Motion of the Parts of the Bell some Miles perhaps distant. Somewhat like to this may also be said of the Smell, and of the other Senses; but the Instances of the first two will be sufficient; especially the latter is the most evident; and that because both the Motion in the Bell, and the Motion in the Ear, or some other Body there placed, is discovered by the other Senses, namely, by the Sight and Touch, as well as by the Ear.

These Particulars I could more largely explain by particular Experiments, and plainly evince, that the Motions of several Bodies at a distance, are caused by the internal Motion of the sounding Body; and that this Power of moving is every way propagated by the ambient *Medium*, which excites in solid Bodies at a distance, a similar Motion. I could farther also prove, that every one of these distinct internal Motions of Bodies, as that of Light, and that of Sound, have distinct and differing *Mediums*, by which those Motions are communicated from the affecting to the affected Body: And so I conceive also that the *Medium* of Gravity may be distinct and differing both from that of Light, and from that of Sound. I conceive then, that the Gravity of the Earth may be caused by some internal Motion of the internal or central Parts of the Earth; which internal and central Motion may be caused, generated and maintained by the Motion of the external and all the intermediate Parts of its Body: So that the whole Globe of the Earth may contribute to this Motion, as it will happen to a Globe of Glass or solid Mettal, to any part of which no internal Motion can be communicated, without at the same time affecting the whole with the same Motion. And I shall most plainly and evidently prove, when I come to the Explication of Magnetism, that this is undeniably performed and effected by this means.

The Hypothesis of the Cause of Gravity.

Suppose then that there is in the Ball of the Earth such a Motion, as I, for distinction sake, will call a Globular Motion, *whereby all the Parts thereof have a Vibration towards and fromwards the Center, or of Expansion and Contraction; and that this vibrative Motion is very short and very quick, as it is in all very hard and very compact* Bodies: *That this vibrative Motion does communicate or produce a Motion in a certain Part of the* Æther, *which is interspersed between these solid vibrating Parts; which communicated Motion does cause this interspersed Fluid to vibrate every way* in Orbem, *from and towards the Center, in Lines radiating from the same. By which radiating Vibration of this exceeding Fluid, and yet exceeding dense Matter, not only all the Parts of the Earth are carried or forced down towards the Center; but the Motion being continued into the* Æther, *interspersed between the Air and other kinds of Fluids, it causeth those also to have a tendency towards the Center; and much more any sensible Body whatsoever, that is any where*

where placed in the Air, or above it, though at a vast Distance; which Distance I shall afterwards determine, and shew with what proportioned Power it acts upon Bodies at all Distances both without and within the Earth: For this Power propagated, as I shall then shew, does continually diminish according as the Orb of Propagation does continually increase, as we find the Propagations of the Media *of Light and Sound also to do; as also the Propagation of Undulation upon the Superficies of Water. And from hence I conceive the Power thereof to be always reciprocal to the* Area *or Superficies of the Orb of Propagation, that is duplicate of the Distance; as will plainly follow and appear from the consideration of the Nature thereof, and will hereafter be more plainly evinced by the Effects it causes at such several Distances.*

This propagated Pulse I take to be the Cause of the Descent of Bodies towards the Earth. But it way perhaps seem a little strange how the Propagation of a Motion outward should be the cause of the Motion of heavy Bodies downwards. To make this the more intelligible, I shall mention an Observation very commonly known amongst Tradesmen; and that is, the driving of a Hammer or Axe upon the Helve, which to do the easiest way, they commonly strike the End of the Helve, holding the Helve in their Hand, and the Axe or Hammer at the lower End hanging downward, by which means they not only make the Axe to go on upon the Helve, but make it ascend, if they continue striking, even to their very Hand. To apply which Observation to my present Theory, I say, that the *Medium* of Propagation is the Helve, and the Axe or Hammer is the grave Body that descends: So that at every Stroke that is given by the Globe of the Earth to the propagating *Medium*, one Degree of Velocity of Descent is given to the Grave Body, which is as it were the Axe. Now according to the Velocity of this vibrative Motion of the Earth, so must the Power it communicates be stronger or weaker. Suppose for instance, there should be 1000 of these Pulses in a Second of Time; then must the Grave Body receive all those thousand Impressions within the space of that Second, and a thousand more the next, and another thousand the third Second; so that in equal Times it would receive equal Degrees of Acceleration. And if a Second of Time were again subdivided into a thousand Moments of Time, the Body would receive one Degree of Acceleration in the first moment, one more in the 2d, a 3d in a 3d, and so onwards: So that the compounded Acceleration would be as one the first Second, three the next Second, and five the next, and so onwards; according as it is observed in the Motion of descending Bodies.

The Medium *that propagates this Motion, I suppose to be one part of that which permeates most Bodies, which we call by the general Name of* Æther, *and thence it proceeds that the Motion is communicated to every part thereof: And so the* Momentum *of every Body becomes proportioned to its Bulk or Density of Parts, difform to the fluid* Medium *that communicates the Pulse.*

The Objections that I expect against this Hypothesis may be some such as these.

1*st*. How does it appear there is any such Motion in the internal Parts of the Body of the Earth? For who can descend thither, and if they could, how should they find it, it being from the Hypothesis supposed not within the reach of Sense?

To this I answer, that though this be hypothetical, yet that there is some such Motion in those Parts, I shall prove clear enough, when I come to the Explication of Magnetism. In the mean time, there is nothing absurd or contradictory to the rest of Nature. The solidest Body in the World can receive an internal Motion of its Particles from an outward Impression; as has been found in Diamonds, which upon Rubbing would shine, and upon so rubbing would become Electrical, and attract Bodies to them; as I observed in the Diamond which was formerly shewed this Society by Mr. *Henshaw*. Besides, that it is receptive of internal Motion, is farther evident by the splitting or cleaving of a Diamond by a smart Stroke; which is well enough known to our Jewellers and Lapidaries. The hardest Chrystal, Porphyrys, Agates, Flints, *&c.* that I have yet met with, will receive an internal Motion, as may be plainly argued from the Tone they give upon being briskly struck. The hardest of Mettals always give the best and longest Sounds, and consequently are the less hindred by the ambient *Medium. The Author breaks off here abruptly.*

The following DISOURSE *is a Lecture of Light, which I found among the Authors Manuſcripts: And tho' I found by another Paper that it was read before the foregoing Lectures of Light; yet I judged it would not prove unacceptable for the Experiments related in it; from which it will appear, that the Picture of the Sun tranſmitted through a ſmall Hole into a dark Room, does not answer to what it ought to be by the received Laws of Opticks; and alſo that the Rays of Light do not proceed in ſtrait Lines, as he endeavours to ſhew by Experiment. I ſhall not venture at any Deductions, but leave that matter to the more intelligent Reader.*

R. W.

Experiments the beſt way to find out Truths.

THERE is no means in the World for the attaining the true Knowledge of things more certain and more inſtructive, than the accurate Obſervation and ſtrict Examination of them by Trials and Experiments. And though, I confeſs, it is a much ſpeedier and more eaſy way to collect and underſtand what is already known, to read and ſtudy ſuch Notions of them as are already deliver'd in Authors treating of that Subject; yet, as 'tis that way quickly attainable, ſo you will as quickly find your ſelf at a *non plus ultra* in your Information, and much fuller of Doubts and Queries as to a perfect Knowledge of the thing you ſeek, than poſſibly you were, when you firſt enter'd upon that Inquiry. For the more you are informed, the more able you are to inquire for and ſeek after what is conſiderable to be farther known concerning that Subject; and that Knowledge is much more apt to ſlip out of the Memory, and be forgotten: Whereas that Knowledge which is attained by a Man's own Obſervation and Study, as it always remains fixt in his Memory, ſo it ſo thoroughly informs his Imagination with a true and right Idea of the thing he inquires into, that he is able thereby readily to ſolve many Doubts and Difficulties that may at firſt occur to him; and it puts him in a capacity of pertinently inquiring farther into the Nature and Cauſe of the thing he ſeeks after. And let me tell you, whoſoever has a Knowledge of things made up only of what he finds in Bocks of that Subject, ſhall find it to be very little, confuſed and imperfect; eſpecially if he comes to converſe with ſuch as have experimentally and ſagaciouſly enquired thereinto. And in very many caſes he will not only find his Knowledge little, confuſed and imperfect, but notoriouſly and dangerouſly falſe and erroneous: So that this kind of Knowledge, inſtead of leading and directing of him in the right way, oftentimes ſeduces him, and hurries him into the broad Way of Error and conceited Ignorance. I could give you many Inſtances of this Truth in Phyſicks, nay even in Mechanicks, whoſe Principles ſeem moſt obvious; and ſhew you, that for want, I ſuppoſe, of accurate Trials and Experiments, ſeveral Axioms, which have been received and builded on as Truths, both by all the antient and modern Philoſophers and Mathematicians, are yet notwithſtanding by ſome few Trials and accurate Obſervations, found notoriouſly falſe: But theſe I ſhall reſerve for ſome other Opportunities. I ſhall now rather chuſe to give you an Inſtance in another Subject.

I have formerly endeavoured to explain ſeveral things concerning the Nature and Eſſence of Light, which I ſhall not now repeat; but having ſtill many Doubts in my own Thoughts concerning the ſame, I have made it my aim, according as I had opportunity, to examine and inquire farther into the Nature thereof, by ſuch Obſervations and Experiments as I judged might be any ways helpful to the Manifeſtation thereof. And herein I have not been altogether unſucceſsful, having diſcovered ſeveral Proprieties therein, whereof before I had no Notion or Information.

To this purpoſe I prepared a Room fit for Trials of this nature, by ſo perfectly ſtopping all ways by which the Light could find its Entrance into the ſame, that the whole remained perfectly dark; at leaſt ſo much, that though a

Man

Man ſtaid a long time in the ſame, yet the Eye could not perceive any Light. For though that in many caſes be not abſolutely neceſſary, yet in moſt 'tis generally very convenient, and fit to make the Trial more accurate and certain. For as in a Mixture of divers Liquors, 'tis very difficult to diſtinguiſh and determine the true Taſte of any one of them; ſo the Effects and Properties of any one Ray is more obſcurely perceived, when it is blended and mixed with the Effects of a thouſand others. In this darkened Room I provided ſuch Conveniency for admitting or excluding the Rays of Light, that I could let in what quantity of Light I pleaſed, and in what manner; and thereby had the opportunity of finding ſeveral Proprieties thereof, which are not otherwiſe diſcoverable. Having then thus darkened a Room, by a very ſmall Hole through a Braſs Plate in part of the Shutter, I let through the Light of the Sun, which by degrees ſpreading it ſelf, ſeemed to make up a Cone, whoſe *Apex* was in the Hole, and whoſe Baſe was on the Paper expoſed to receive the ſame at a diſtance. In this Image of the Sun thus painted on the Paper, it was very obſervable that the Middle thereof was very much brighter than the Edges, and that there was a kind of dark *Penumbra* that went round about the Limb of the ſame, about a 16th part of the Diameter of the Circle; the which *Penumbra* could be no ways aſcribed either to the leſſer Light of the Parts of the Sun near the Limb thereof; or to any thing defective in the make of the Hole or Paſſage through which it was admitted; but to ſome other Cauſe, or Propriety of Light, which I ſhall hereafter explain. Having obſerved this, at about the diſtance of two Inches I let in another Cone of Light, and receiving the Baſes of them upon a Piece of Paper, at ſuch a diſtance from the Holes, as that the Circles did interſect each other; I did manifeſtly obſerve, that there was not only a *Penumbra* or darker Ring incompaſſing the lighter Circle, but a manifeſt dark Line or Circle, which did manifeſtly appear even where the Limb of the one interfered with the Limb of the other.

A new Property of Light diſcovered.

As in the Figure, where *a b c g h*, *a d c k l* repreſent the Baſes of thoſe Cones of Light, whoſe middle Parts *ii ii oooo*, appear brighter; but the Parts thereof next the Limb, *e e e e*, *u u u u*, appear much darker, with a kind of *Penumbra*, or Faintneſs of Light; and the extream Circumference, or terminating Lines of each, appear perfect dark Strokes; nay though the parts thereof *a b c* and *a d c* intermix with the brighter Parts of the other Baſe, as at *b* and *d*. Examining the bigneſs of this Baſe with the diſtance of it from the *Apex* or Hole, I found it no ways anſwer to that Proportion it ought to have, ſuppoſing the lateral Rays from oppoſite Parts of the Limb of the Sun's Disk, did interſect each other in the above-mentioned Hole, and did proceed on by ſtrait Lines to the Paper or Baſe; but according to the various bigneſſes of the Holes, and according to the various diſtances of the Receiving Papers from thoſe Holes, ſo were the Proportions of the Diameters of thoſe Circles to their Diſtances varied: Which in Aſtronomical Inquiries will produce no ſmall Errors, if not carefully prevented by proper Remedies. I proceeded farther to make Experiments concerning the Nature of Light; and holding an opacous Body between the Hole or *Apex*, and the Baſe or Paper, I obſerved that there was, notwithſtanding all the care I uſed to exclude other Light than what came in by that ſingle Hole, a certain faint Light caſt even into the Shadow of the Body; and in that part of the lucid part of the Baſe, which was not ſhaded by the opaque Body, there was a certain *Faſcia* or *Zone* of Light which went parallel along with the terminating Line of the Shadow of the opacous dark Body; the which Zone of Light was manifeſtly much lighter than any part of the lucid Baſe beſides. Nay this lucid Zone did not only croſs the Circle of the Baſe, but did manifeſtly proceed and extend it ſelf a good way beyond the lucid Circle of the Baſe, ſtriking pretty far into the incompaſſing opaque *Medium*. To make this more evident to you by a Scheme, let O repreſent the Hole in the Shutter of the Window, through which the Light of the Sun is let paſs: Let C O N repreſent the Cone of Light transmitted, and P A the Paper upon which the Circle or Baſis of the Cone is caſt: Let B B repreſent the opaque Body interpoſed between the Hole and the Papers, and S S T T the Shadow thereof upon the Paper. That which I obſerved was this: The Shadow of the opaque Body B B was ſomewhat all over inlightned, but ſeem'd moſt inlightned towards the Edge thereof. Several Per-

Plate 2. Fig. 7.

Plate 2. Fig. 8.

ſons

ſons that were preſent, and ſaw and diligently obſerved theſe *Phænomena*, conceived and objected, that the lucid *Zone*, or brighter part, which edged the Shadow of the opaque Body, was produced by ſome kind of Reflection from the Side of the ſaid Body by which the Light paſſed; it being indeed a round Body, and ſo ſome of the Rays might poſſibly reflect, ſo as to fall upon the lucid Zone: But I could ſee no reaſon why it ſhould not as much inlighten any other part of the bright Baſe or Figure of the Sun on the Paper; for the ſhading Body being only a round Piece of Wood, not bright and poliſht, nor of ſo certain a Reflection, as to direct the Rays that fell on it exactly to a determinate Place, I could not conceive any reaſon why that ſhould produce ſuch a lucid Zone. Others ſuppoſed that it might proceed from ſome Reflection of the Braſs Hole through which the Light was admitted into the Room. But to obviate both theſe Objections, and to inquire farther into the Nature of this *Phænomenon*, I placed inſtead of the Cylinder of Wood, a very ſharp and ſmooth edged Razor, ſo that the Edge of the Razor was that which caſt the ſtrait Line of Shadow which divided the lucid Baſe; from which there could be no Reflection, at leaſt ſo very little, that if we do ſuppoſe a Flatneſs or Breadth in the Edge thereof, it could not amount to a 500th part of the breadth of the lucid Zone; and conſequently there could be no imaginary Reaſon drawn from the Reflection thereof to ſolve the *Phænomena*: And it was believed that the Appearance would have been conſiderably differing, but upon trial thereof, the ſame *Phænomena* were as obſervable as before, without any ſenſible Variety. The ſame Appearance alſo was viſible, when inſtead of the Razor, a piece of Paſtboard was uſed for an opaque Body. And to obviate the other Objection, inſtead of the piece of Braſs placed in the Shutter, which by a Hole in it let in the Light, there was placed a piece of Paſtboard, with a ſmall black Hole burnt through it: But upon trying over all the aforeſaid Experiments with it, we found the very ſame Appearances as when the Light paſſed through the piece of Braſs. So that upon the whole matter it was very manifeſt, that it was ſome new Propriety of Light much differing from the common Rules and Laws thereof deliver'd in Optical and Phyſical Writers. Having diſcovered theſe Proprieties, I proceeded farther to examine into the Nature of Light, by placing the Razor as before, ſo as to divide the Cone of Light into two Parts, the tranſmitting Hole remaining as before: And I placed the Paper (expoſed to receive the Circle of the Baſe) ſo as that none of the enlightned part of the Circle fell thereupon, but only the Shadow of the Razor or opaque Body; and to my wonder, I found a very brisk and viſible Radiation ſtriking down upon the Paper, of the ſame breadth with the Diameter of the lucid Circle, or at leaſt (if the Shadow did not divide the Circle into two equal Parts) as big as the Subtenſe made on the ſaid Circle by the Shadow; and this Radiation always ſtruck perpendicularly from the ſaid Line of Shadow, and did not only extend ſo far as the bredth of the remaining part of the Circle; but like the Light or Tail of a Comet, extended more than 10 times that length, and in probability more than a 100 times; nay, as far as I could find by many Trials, the Light from the Edge did ſtrike downards into the Shadow very near to a Quadrant, though ſtill I found, that the greater the Deflection of this new Light was from the direct Radiations of the Cone, the more faint they were.

It was hereupon objected by ſome, that this Deflection of the Light was to be aſcribed either to the Reflection of the Particles of Duſt flying to and fro in the Air of the lucid Cone, or to ſome kind of Tranſparency and Refraction in the Edge of the Raſor.

But to obviate theſe Objections, I took care firſt ſo to hide that part of the lucid Cone that was between the Hole and the Razor, that little or nothing thereof could come to ſhine on that part where the Radiation appeared: And next by changing the Sides of the Razor, I placed the thick Back thereof inſtead of the Edge: So that if there were any thing aſcribable either to the Tranſparency, or Figure and Superficies thereof, all thoſe Proprieties might be altered, and conſequently the Effects producible thereby: But upon all the variety of Changes and Alterations and Examinations of it, this way and that way, I found the Effects and *Phænomena* the ſame; ſo that it was manifeſt, that the Effect was aſcribable wholly to a new Propriety of the Rays of Light, and not at all to any

The Effect wholly to be aſcribed to a new Property of Light.

any Reflection or Refraction, or any other common Propriety of Light.

I proceeded yet farther to examine into the Nature of Light, and finding that there were several brighter Parts of this Radiation into the Shadow, and others that were darker and more obscure, and that they did all strike perpendicularly into the Shadow; and finding also that these brighter and darker Parts would be moved to and fro, and disappear, and other new ones appear, according as I moved and slipt the Razor or shadowing Body to and fro: After several Trials I found, that wheresoever there was a part of the shadowing Body more high than the rest of the Superficies, there the Radiation into the Shadow was brighter and more strong; and wheresoever there was a Notch or Gap in the said Superficies, there a darker Stroke or Radiation would be: Insomuch that if I fixt upon the Side of the shadowing Body, a Piece of Lead, or the like (whether reflecting or not reflecting Body, 'twas the same thing) there would strike a brisk Radiation from the Shadow thereof into the Shadow of the opaque Body perdendicularly to the Line of Shadow. If the Superficies or Bulk of the Knob was considerably big, the Radiation would strike perpendicularly to the Sides thereof; so that if the shadowing Body were circular, it would strike towards a Center; and if it were concave, it would strike with Radiations, as it were, from a Center: If it were a sharp Angle, or Corner, it would strike by a Line dividing the Angle into two equal Parts. This also, after several Examinations and Trials thereof, by varying Experiments, I found to be ascribable to a new Propriety of the Rays of Light, and not at all to Reflections or Refractions, or any other commonly known Propriety of Light. *These Radiations of Light might be moved.*

Proceeding farther to make Observations of the bigness of the Figure of the Sun, painted by the Rays of Light admitted through the small Hole in the Brass Plate, upon the Table or Paper exposed to receive them; I observed that the Limb of that Figure was always much darker than the middle Parts, and that it was not only darker, but ragged, and not neatly and distinctly defined, by reason of a kind of *Penumbra* which fringed the edge thereof. Comparing this *Penumbra* with the bigness of the Hole in the Plate through which the Light was admitted, I found that it was considerably broader than that, sometimes five or six times as broad; so that I was sufficiently satisfied that it could not proceed from a *Penumbra* caused by the bigness of the Hole upon the common Principles, that is, from the Supposition of the Rays from every point of the Sun proceeding in strait Lines: For had that been supposed, the *Penumbra* could not have been broader than the Diameter of the admitting Hole, as it will be made very evident, if we examine the Progress of the Rays Geometrically, supposing them to move always exactly in strait Lines.

Let SN in the 9th Scheme represent the Diameter of the Sun shining through the Hole HO, and painting upon the Table TT the round Figure of the Sun, whose Diameter suppose is DI, terminated by the Rays SOI and NHD, proceeding from the Extreams of the Sun's Diameter SN, to the opposite Sides of the Hole HO. Draw then from the Extremes of the Sun's Diameter S and N, two other Rays, SM and NE, passing by the corresponding Sides of the Hole H and O, and terminating at the Table or Paper at M and E; which last Rays, with the preceding, will cut off from the shining Circle of the Sun MI and ED. And because of the vast Distance of the Body of the Sun from us, those Rays which we have here drawn diverging, will notwithstanding be Physically and sensibly parallel; and consequently the breadth of the *Penumbra* MI and DE, must be equal to HO the Diameter of the Hole, by the 34 *pr. 1st Euclid.* the Paper or Table being supposed parallel to the Diameter of the Hole HO; or if we will proceed according to the strictness of Geometry, the Breadth of the *Penumbra* MI will be so much greater than the Diameter of the Hole HO, as the Distance SI is to the Distance SO. For as SI is to SO, so is MI to HO, by the 4th of the sixth of *Euclid*; the which Proportion being, as to the greatest accurateness of Sense, a Proportion of Equality, it follows that the *Penumbra* of the Disk must be equal, as to all sense, to the Diameter of the Hole; and to make the *Penumbra* double to the Diameter of the Hole, the Distance of the Hole and Paper must be equal to the Distance of the Sun from the Hole; that is, as SI is double to SO, so will MI be double to MO. It follows therefore that this extraordinary *Penumbra* can no way be ascribable to the common Principles of Plate 2. Fig. 9.

Light, but to some new Propriety, whereby the Light doth deflect from strait Lines, contrary to what is hitherto asserted by Optick Writers. Nor will the bright Zone which I mention'd, be explicable by any of the common Rules of Opticks: For according to the common Principles of Opticks, all the Parts of the shining or light Picture of the Sun, which lie between M and E, must be equally inlightned; that is, supposing the Light to proceed only by right Lines: For every Point between E and M will be inlightned by an equal Space of the Diameter of the Sun. From the Point E of the Sun draw the Line EHL; then shall LN represent such a part of the Diameter of the Sun, as can at once inlighten the Point E through the Hole. Then take any other Point in the Picture of the Sun between M and E, as suppose the Point C, and from the Point C draw two Lines touching the Extreams of the Diameter of the Hole H and O; that is to say, CHB and COA, terminating at the Points B and A of the Sun; I say, that BA shall be equal to LN. For since SN, HO, and TT are Parallels, HC will be to BC, as HE to LE. But as HE to LE, so is HO to LN; and as HC to BC, so is HO to BA. Therefore as HO is to LN, so is HO to BA; and consequently BA and LN are equal; and consequently every Point of the Picture of the Sun painted by the Rays on the Table TT, between the Points E and M, ought to be equally inlightned by the Rays passing through the Hole HO; since every of them is inlightned by an equal part of the Diameter of the Sun's Disck, which is contrary to the Observations that I have made; and therefore the Rays of the Sun which cross each other in the Hole of the Shutter HO, do not proceed on in strait Lines, but deflect, some this way, some that way, as I shall hereafter more at large declare, when I shall shew divers other strange *Phænomena* of Light, both in Direct, Reflected and Refracted Rays; whereby are produced Colours, Light and Heat, and various Pictures of the Objects without: For according to this or that Variety of the quantity of Light admitted, so would the Effects be exceedingly differing as to Light, Heat and Colours. And I also further observed, that the widening or streightning of the Hole would alter the *Penumbra*, and that a smaller Hole would make a larger *Penumbra*, which is contrary to the common Principles of Opticks: For if the Rays went in strait Lines, the bigger the Hole were, the bigger would be the *Penumbra*. These things I have deliver'd to you as briefly and succinctly as I could. The other *Phænomena*, God-willing, I shall hereafter deliver to you more at large.

" IN reference to the foregoing Experiment of Light, I found a Paper to this " purpose. On the 18th of *March* 167$\frac{4}{5}$ Mr. *Hooke* read a Discourse con- " cerning the Nature and Properties of Light, in which was contained several " new Properties of Light not observed, that he knew, by any Optick Writers: " These were, That there is a Deflection of Light differing both from Reflection " and Refraction, and seeming to depend upon the unequal Density of the con- " stituent Parts of the Ray, whereby the Light is dispersed from the Place of " Condensation, and rarify'd or gradually diverged into a Quadrant. 2dly, He " observed that this Deflection is made toward the Superficies of the opacous " Body perpendicularly. 3dly, That in this Deflection of the Rays, those Parts " of diverged Radiation that are deflected by the greatest Angle from the strait or " direct Radiations are faintest, and those that are deflected by the least, are " strongest. 4ly, That the Rays cutting each otehr in one common *Foramen*, " do not make the Angles *ad Verticem* equal. 5ly, That Colours may be made " without Refraction. 6ly, That the true bigness of the Sun's Diameter cannot " be taken with common Sights. 7ly, That the same Rays of Light falling " upon the same point of the Object, will turn into all sorts of Colours only " by the various Inclination of the Object. 8ly, That Colours begin to appear, " when two Pulses of Light are blended so well and near together, that the " Sense takes them for one.

The two following Fragments of Gravity *and* Magnetism, *I found amongst some other loose Papers, which I suppose the Reader will accept of, tho' he should judge them of little worth.* R. W.

Of

Of GRAVITY.

ALL ſolid Bodies take in and emit Fluids for their Suſtentation.

All ſuch fluid Bodies have ſomewhat of Solidity in them, when admitted, but are emitted more fluid.

The Sun and Stars continually emit; they muſt therefore admit, otherwiſe a *Vacuum.*

The Earth, Planets, Moon, and Secondary Planets, admit, therefore muſt emit; otherwiſe Penetration; neither poſſible therefore a Circulation.

All Animals and Plants ſenſibly admit and emit.

Of Minerals. The Magnet admits and emits. Electrical Bodies the ſame; and the ſhining Diamond.

All Bodies are in motion: Motion and Body equipollent.

Similars work moſt powerfully on each other.

Similar Bodies join together more eaſily.

All Solids have a tremulous Motion, as Bells, *&c.*

The tremulous Motion of Solids work on or move the incompaſſing Fluids, and comminute, grind or divide the included or interſperſed.

All Fluids by degrees without this Comminution, become more ſolid, Part agreeing with the Part in Motion, as Saline Liquors, Waters, Air, *&c.*

Coherence nothing but Similitude of Parts and Motions.

Where the Motion of the denſer prevails, Coagulation; where of the fluid, Diſſolution.

The more fluid, the quicker the Motion is; the more ſolid, the more ſlow.

The vibrating Motion of all Globular Bodies is from the Center to the Superficies, and *vice verſâ.* This ſhewn by the Bell, Water in a Glaſs, *&c.*

The Motion to and fro at the Center infinitely ſwift, becauſe condenſed conically.

The comminuted Parts receive a rapid Motion according to their Smallneſs, ſhewn by the Burning Glaſs, *&c.*

They muſt recede or be emitted with that Velocity. Their Receſs every way equal.

The Earth turbinated and roaſted by the Sun; whilſt Equinoctial Parts contract, Polar recede.

This Receſs not at once, but ſimilar; whence a circular vibrative Motion, or Pulſe of Gravitating Matter. This confirmed by Magnetiſm, Bell, Water in a glaſs, *&c.*

Central Parts of the Earth poſſibly fluid.

Heat or Exceſs of Motion ſhakes the Parts of Solids ſo, as to make them Fluids, which is when a minute Fluid can get between.

Thence more eaſily diviſible by Supreme Fluid, which is Fire.

Supreme Fluids always recede from the Center radiating; leſſer Fluids follow in their place.

Of

Of MAGNETISM.

AFter the Explication of Light and Gravity, I come in the 3d place to the Explication of Magnetiſm. Magnetiſm then is a certain Power in the Body of the Earth, or any other Celeſtial Globulous Body, by which a certain Motion is produced in an appropriate *Medium*, that affects or moves certain Bodies capable of receiving the Impreſſions thereof according to determinate Laws.

The Power in the Body of the Earth is the vibrative Motion of the internal Parts thereof from North to South, and from South to North.

The *Medium* appropriate for receiving and communicating this Motion, is an Æthereal ſubtil Matter, which penetrates and pervades, and fills the Interſtices of all Terreſtrial Bodies.

The Bodies capable of receiving Impreſſions or Motions from the Motion of this *Medium*, are thoſe we call Magnetical, *viz.* Loadſtones and Iron, *&c.* which are homogenious or uniſonous, or equally great with the Magnetick, or ſo vibrated Parts of the Body of the Earth.

The Cauſe of this Motion is firſt from the Circular Motion of the Body of the Earth, or other Globe upon an *Axis*.

And ſecondly, the Obliquity of this *Axis* to the Plain in which it is moved, with a Motion of Lation.

This imperfect Fragment is all I find of this Hypotheſis, tho' there are other Matters relating to Magnetiſm ſcattered in his Diſcourſes. R. W.

This Diſcourſe

This Discourse gives an Explication of a Glade of Light first observed in the Heavens by Dr. Childrey, *about the* Vernal Æquinox, *and by Mons.* Cassini *and others. This Lecture was read before the* Royal Society, June *the 3d* 1685.

DOctor *Childrey*, at the End of his *Britannia Baconica*, which he pulished in the Year 1660, containing several very curious Observations made by himself and others, has this Advertisement to the Curious and Ingenious. There is a thing which I must needs recommend to the Observation of Mathematical Men, which is, that in *February*, and for a little before, and a little after that Month (as I have observed several Years together) about 6 in the Evening, when the Twilight hath almost deserted the Horizon, you shall see a plainly discernable way of the Twilight striking up toward the *Pleiades*, or Seven Stars, and seeming almost to touch them. It is to be observed any clear Night. There is no such Way to be observed at any other time of the Year, that I can perceive, nor any other Way at that time to be perceived darting up elsewhere. And I believe it hath been and will be constantly visible at that time of the Year: But what the Cause of it in Nature should be, I cannot yet imagine. So far the Doctor discoursing with this Gentleman about a Year or two after this Publication, he could not then think of any Cause of it, unless perhaps it might be some extraordinary Reflection of the Sun Beams, caused by some part of the Western Ocean; but could not be positive, but doubted whether this might be a Cause or not. This Tract of Dr. *Childrey*'s was translated into *French*, and printed in the Year 1667, as appears by the *Miscellanea Curiosa Academiæ Naturæ Curiosorum*; and by that means the Advertisement was spread in *France*, and the rest of *Europe*. In the 11th Journal *des Scauans* of the Year 1683. we have an Account of a Sight the most rare that has been observed in the Heavens, described by Mr. *Cassini* thus. " A Light, like that which blanches the Milky Way, " but more clear and shining in the middle, but more faint towards the Ex- " treams, was expanded over those Signs which the Sun was shortly to pass " through. I began to see it at the *Royal Observatory*, the 18th of *March St.N.* " two Days before the *Æquinox*, upon the occasion of turning the Telescope " (with which I had been viewing the Changes of *Saturn*) to see the 1st Star " of *Aries*, which is composed of two, distant only the Sum of their Dia- " meters. I saw this Constellation, and that of *Taurus* more light than ordi- " nary, about ¾ after 7 of the Clock, which was ½ an hour after the Evening " Twilight. The West End of this Light was terminated by Horizon-Clouds " about 3 Degrees high, the Breadth of the clearest part was about 8 or 9 " Degrees: It was extended obliquely near the *Zodiac*, and sheer'd by the North " side of the two brightest Stars in the Head of *Aries*, comprehending all the " Body. It extended in Length over the 7 Stars, and ended insensibly in the " Head of *Taurus*. That part of the Heaven was so very clear, that Stars of " the 6th and 7th Magnitude could be plainly seen, even in the middle of it, " which was the brightest, as is sometimes seen in the Tails of Comets. But " 'twas too great for the Tail of a Comet, tho' it respected the Sun, and descen- " ded behind the Clouds, without altering its Situation among the Stars. It " continued to appear for some Days, but alter'd not its Position, tho' it grew " fainter by degrees. The 26th of *March* (*St. N.*) which was the last " Night he then saw it) it seemed to be moved somewhat more towards the " North than at first, which some Observations of it in *April* following farther " confirmed. I pass over his comparing of it to other *Phænomena*, because I " take them to be of another nature. As for the Cause of it, he takes it to be " either from the Head of some Comet hid under the Sun's Rays, which yet he

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Mr. Cassini's *Observations.*

" doubts to aſſert, becauſe of its Breadth, or from the Sun's Body it ſelf; but " determines nothing. He takes its Diſtance to be great, approaching towards " the Fixed Stars, above the Planets, becauſe it chang'd its Place ſo very little " in the time it appear'd.

In the *Nouvelles des Livres* of *March* laſt, is inſerted a Letter of Mr. *Choüet*, Profeſſor of Philoſophy at *Geneva*, giving a further Account of the Obſervation of it at that Place the laſt Spring, *viz.* 1684. by Mr. *Fatio de Duillier*, to this effect. " That 'tis a great Light, like the Tail of ſome Comet, whoſe Head " is abſconded in the Sun's Rays, appearing ſometime in the Weſt, ſometime in " the Eaſt, after and before the Twilight, but always near the Sun. 'Tis al- " ways near the Plain of the Ecliptick, and reſpects the Sun. The End next " the Sun is about 14 Degrees broad, at about 40 Degrees from the Sun, and " from thence goes about 30 Degrees farther, diminiſhing in Breadth and Bright- " neſs, and ending in almoſt a Point. It is brighteſt through the middle, yet " even through that ſmall Stars may be ſeen.

This admirable Appearance, ſays he, was firſt obſerved by the Illuſtrious *Caſſini* in *March* and *April* 1683, where Mr. *Fatio* was preſent and aſſiſtant in the Obſervation: And returning to *Geneva*, he obſerved it in *March*, but was much ſurprized to find it again by chance in *Feb.* 1684. which made him frame the following *Hypotheſis*, *viz.* that he was in part of the ſame Opinion with Mr. *Caſſini*, that the Light was cauſed by ſome more reflecting or refracting Parts expanded into the *Æther* in that place which conveyed the Sun's Beams to our Sight: But differ'd alſo from him, 1ſt, In that Mr. *Fatio* ſuppoſes it ſpread about the Sun's Body moſt about the Plain of the Ecliptick, extending far beyond the Orb of *Venus*, and even almoſt to the Orb of the Earth. 2ly, In that he ſuppoſes this Luminous Matter about the Sun not to be a Globe, but only a tapering Circle in the Plain of the Ecliptick: So that it is much thicker near the Sun, where it doth to a great thickneſs incloſe him; but as it ſpreads further and further from it, ſo it grows thinner. 3ly, That this Matter is carried round about the Sun by the Motion of the Heavens, in the Plain of the Ecliptick, and terminates at the Orb of *Venus*.

To make out which *Hypotheſis*, he affirms to have ſeen the like Glade of Light in the Morning before the Twilight in *September*, and both before the Morning Twilight, and after the Evening Twilight in *December*. But this I do not find obſerved by any one elſe.

But theſe Hypotheſes, tho' ingenious, do not give ſo ſatisfactory an Account of this Appearance, as I conceive; eſpecially the firſt, which is indeed not limited enough to make it deſerve the Name of an Hypotheſis; and for the 2d, I conceive no reaſon why it ſhould not every Night and every Morning that is clear, and without much Moonlight, be viſible round the Year; eſpecially in the Torrid Zone, where the Ecliptick riſes more perpendicular. Which I do not find hath been noted, nor does it appear every Year: For I my ſelf (for two or three Years after I firſt ſaw the beforemention'd Advertiſement of Dr. *Childrey*, which was, as I remember, in 1662, 1663, and 1664) looked diligently for it, but found it not. And Dr. *Childrey* himſelf told me, that he had never found it at any other Time of the Year: However it will be very well worth looking after.

The Author's Opinion of its Cauſe.

Comparing all theſe Obſervations together, my Conjectures are, that this Appearance is cauſed by ſome *Effluvia* from the Body of the Earth it ſelf, produced by the near Approach of it to the Sun, when in and near its *Perihelium*, which *Perihelium* being about the 5th or 6th Degree of *Taurus* for the Sun's Place, or of *Cancer* for the Earth's Place, is on the 16th or 17th Day of *December*. By which Approach of the Body of the Earth to the Sun, I conceive that a more than ordinary Rarifaction is made of the Parts of the *Atmoſphere*, and the Dimenſions thereof accordingly extended to a much greater diſtance than at any other times of its periodick Revolution: And the annual Motion being then alſo proportionably increaſed in Swiftneſs, many of the more than ordinarily rarify'd Parts of this *Atmoſphere* may be for a time converted into a kind of *Æther*, and be thereby intimately mixed and united with it, and ſo be left by the ſwiftly moving Ball in the Vicinities of its Paſſage through the *Æther*, where for ſome time after it may remain perfectly incorporated with the Parts of the *Æther*: But the extraordinary Heat reflected from the Body of the Earth, having

ing left it for some time, these Aerial Vapours begin to lose that Form, and condense again into a Substance somewhat like the rarify'd Air, out of which they had been generated by the Coaction of the *Sun* and Earth. Which Condensation makes them of a differing Transparency from the rest of the *Æther*, and thereby capable both of reflecting and refracting the Rays of the Sun passing that way, and so make them to become visible to the Earth in that place of its Orbit where they had been left, and so continue, till by Degrees they be dispersed and scatter'd into a greater space or quantity of the *Æther*, and at length wholly disappear. To make this the more conceivable, and also more sensible and probable, I could produce an Experiment in more sensible and tangible Bodies, that would perfectly represent all the Particulars remarkable in these Observations, making use of Fire to represent the Heat of the *Sun*, of *Water* to represent the *Air* or *Atmosphere*, and of *Air* to represent the *Æther*; whereby the same *Phænomena*, at least very similar, would be plainly visible, respect being only had to the proportionate Differences between the Bodies representing and represented, and the Times of producing the Changes necessary to exhibit the mention'd *Phænomena* both of the one and the other Observation. But that I think will not be necessary, since none that has made any Observations at all, can be ignorant of them. 'Tis known to all, that Heat, whether of the Sun, Fire, or an Animal Body, will make Water so incorporate with the Air, as to waste away into it, without being at all visible, or altering the Transparency of it, as we every moment are sensible of it in our Breathing. 'Tis as well known likewise, if the Air be very cold into which we breath, the Vaporous Parts will presently condense, so as to become visible. 'Tis as well known also, that such Vapors, if the Air be warm, do spread themselves into the circumjacent Parts of the *Æther*, and will by degrees be wholly lost and dispersed. 'Tis likewise known, if such a reaking Body be moved through the Air, it will leave the Air through which it passes, infected by it; which Infection will spread laterally, and be broader than the Line of Motion. And the like may be said of all the other *Phænomena* necessary to make a sensible Representation of this notable Appearance.

Supposing then that this is the Cause of this Appearance, the Reason will be plain, why it appears at that Place, at that time of the Year, of such a breadth at the West end, and so sharp at the East; why of such a Length, why 'tis brightest in the middle, why fainter towards the Edges, why extended in or near the Plain of the Ecliptick, why it varies this way or that way, why it keeps its place among the Stars so long, and the like; which I am ready to explain more fully, if any Doubt.

Against this Hypothesis several Objections may be made, as

First, If this were the Cause of this Appearance, the *Atmosphere* of the Earth, and consequently the moist or watery part thereof would in time waste and be consumed, and so the World would be unfit for the Uses it was designed, of nourishing Vegetables and Animals. *Objections against the Hypothesis answered.*

To which I answer, that it may possibly be true, that the Moisture of the Earth may have always for the time past, and may also at present, and for the future, proceed to waste; and consequently the Earth may have grown drier, and continue so to do. There is sufficient ground to believe, that a great part of the Land that is now dry, and a considerable height above the Level of the Sea, hath been in former Times covered by the Sea, which the Shells now found do sufficiently evidence; and by what means it comes to be so, is not so well known or proved. There are other Parts, as *Palestine*, which have in former Times been much more succulent and fruitful than they are at present, being now Rocky, Sandy, and Barren.

But secondly, To supply this Wasting, it may be alledged, that the continual Gravity of the Earth doth make the heavier Parts thereof to get lower, and closer together; and thereby the Watery and Aerial Parts, that have fill'd the former Cavities and Interstities thereof, may be squeezed out into the Sea and *Atmosphere*: And so as the Body of the Earth may have by this means shrunk, and

and be grown lesser and shrivelled; so the Watery and Atmospherical Parts about its Surface, may in some proportion to its present bigness be supplied.

Thirdly, 'Tis not unlikely, but that, as the extraordinary Heat of the Sun upon the Earth, when it is in its *Perihelion*, may for a time convert some parts of the *Atmosphere* into *Æther*, and the extraordinary Swiftness of the Earth may leave them behind; so the lesser Heat of the Sun upon the Earth, when in its *Aphelion*, may suffer the Parts of the *Æther* to be converted into Air, and by the slower Motion of the Earth in that part, be taken hold of and carried with it, and afterwards be further converted into Water, and so repair what was lost in the *Perihelion*. I shall not mention that we find further, that Waters do petrify, and petrify'd Substances again revert into watery, that being more proper to another Head.

Secondly, It may be objected, That if this were the true Cause, why should not the like happen to the other Planets, as particularly to the Moon, whose Glade would be seen every New Moon, especially in *November*, *December*, and *January*.

To this I answer,

First, That 'tis not undeniably proved, that any of the primary Planets have Water, or Atmosphere about them; and so though they may have as great or greater Vicissitudes than the Earth in respect of the Sun; yet this Tail would not be produced without an Aerial or Atmospherical Substance fitly prepared to receive these Changes. And for the Moon, 'tis most probable it hath none, and if it ever had, may have been thus wasted, and be now grown dry and rocky.

But secondly, Supposing they really have the same Substances about them, as the Atmosphere is about the Earth, and that such a Tail should be really produced by them; yet for two Reasons they could not be seen by us. The first is from the great Distance of them from our Sight in the Primary Planets; and secondly, the direct View of such a Tail, if it were produced by the Moon: For the Moon moving about the Earth, the Eye on the Earth must always look upon such a Tail or Stream transversly, and so being but thin, cannot be seen: But in this of the Earth, the Eye looks upon it endways; and so, though rare of it self, yet the Length of it being turned towards the Eye, it appears much the more dense, and becomes visible in a dark and clear Evening.

This *Phænomenon* I thought the more worthy consideration, because it was first discovered and published to the World, by an *English* Gentleman, and because, that if the Reason thereof be what I have here supposed, it may help to give an account of abundance of other *Phænomena*, whose Causes have been ascribed to very differing Principles and Agents.

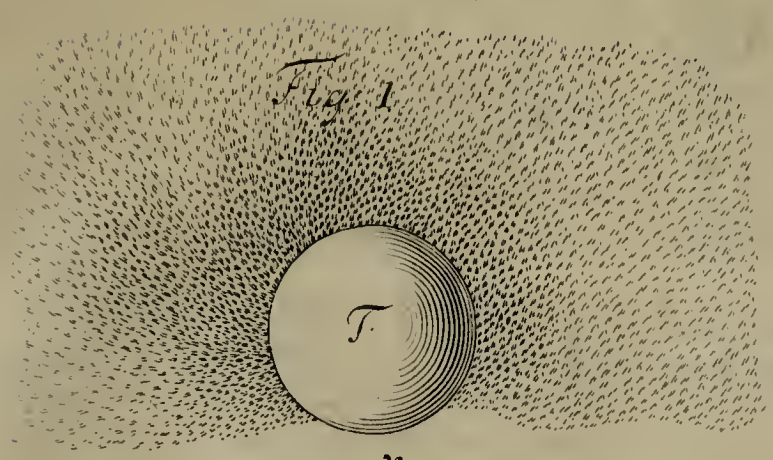
I propounded the last Wednesday an *Hypothesis* for the Solution of that *Phænomenon*, that appears in the West after the Twilight, like the Tail or Glade of a Comet. And having since met with several other Objections against it, besides those I then answer'd, I thought it might not be impertinent to give a further and more compleat Explication of it; and that the rather, because I find that several of them have proceeded from a mistaken Conception of the Theory it self.

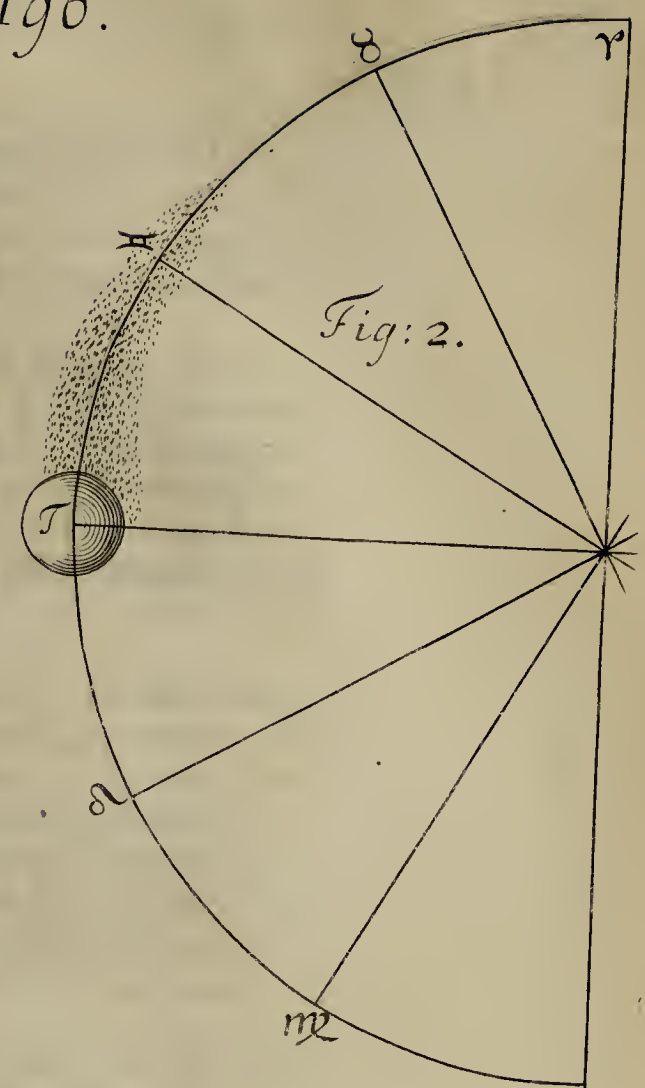
I shall therefore explain all those Particulars more exactly by Schemes and Delineations, which may serve to give a more perfect Idea thereof.

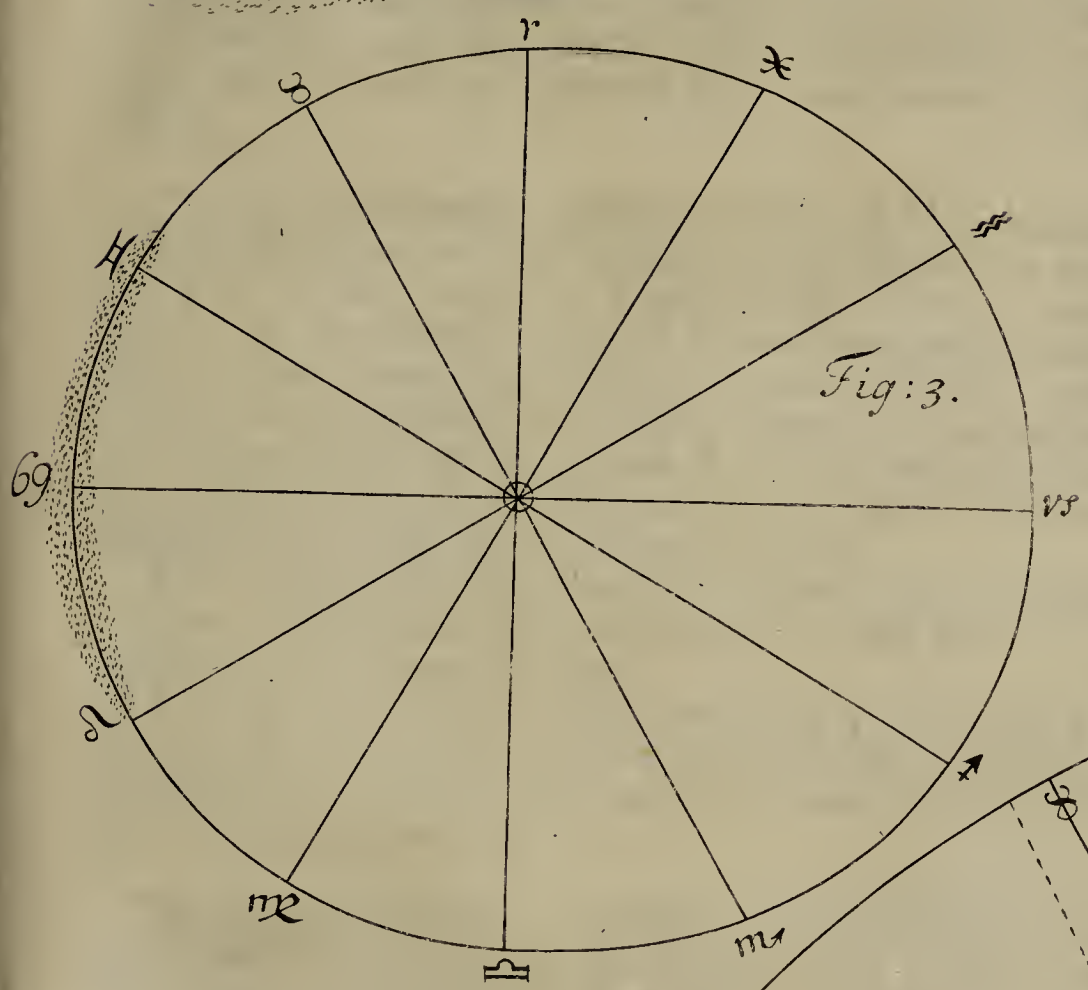
Plate 3. Fig. 1. The first represents the Ball of the Earth encompassed with an Atmospherical Shell or Cover, composed the greatest part of *Æther*, but tinctured by rarify'd Particles of Water, Vapours or Air, which are still more rarify'd and expanded, and fewer; and the nearer to the Nature of the *Æther*, the further they are distant from the Surface of the Earth.

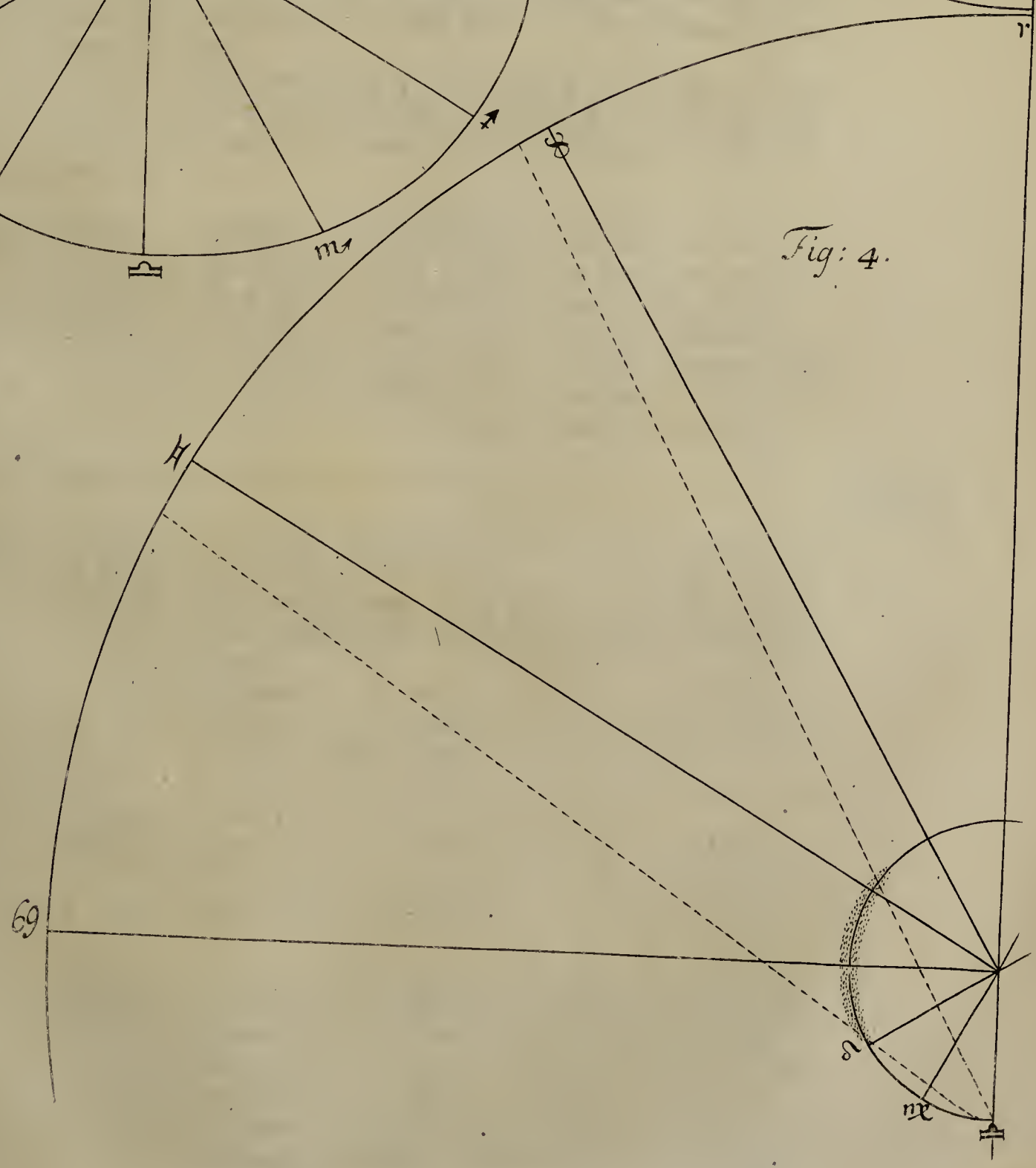
Fig. 2. The second represents this enveloped Ball moving by its annual Motion in a part of its proper Orbit or Line about the Sun, and so passing through the Body of the *Æther*, which I suppose altogether stagnant, and not moving round with it

Plate the Third Page 196.









it in a *Vortice*, as *Des Cartes* ſuppoſed; but quieſcent, according to that Theory of Celeſtial Motions which I long ſince have explained and ſhewn to this Society, which deduces the Cauſe of their periodick Motions from an impreſt direct Motion, and an attractive or protruding Impulſe towards the Center of the Sun.

By means of the ſwift Motion of which Body thro' this ſtagnant *Æther*, I conceive there may be ſome of the higher and more rarify'd Parts of the *Atmoſphere* left behind, and not carried along with it, they being for that time more intimately united to the *Æther*; but that thoſe Parts, after they have for ſome time been ſeparated, may alter or loſe their Rarefaction, and ſo become for a time viſible to the Eye upon the Earth, now removed at a great diſtance from them.

The third repreſents the ſame in the Orbit of the Earth about the Sun, ſhewing this Subſtance left in that part of the Orbit which neareſt approaches the Body of the Sun, where its Power and Heat is more intenſe, and where the Motion of the Body of the Earth is much more rapid than in other Parts of its Orbit. From which two Cauſes, I conceive, the Earth leaves an Impreſſion or Sign of its way through the *Æther*, ſomewhat like the Froth left in the Wake of a Ship paſſing ſwiftly through the Water, which may be ſeen by one looking from the Poop of the Ship a good way behind, like a white Line, and has ſometimes in a dark Night appeared to ſhine.

Nor is this the only Inſtance; for I conceive there are very few, if any, here preſent, who have not ſeen the ſhining Line left behind by the Meteors called Falling Stars, or Star Shootings.

This alſo repreſents the Poſition or Angle of it in reſpect of the Sun, as alſo the Length of it, and the manner how that End of it which is next the Sun, ſpreads, and the other End is ſharp, and how the middle becomes more bright and conſpicuous than the reſt.

The 4th repreſents the ſame Orbit of the Earth drawn in ſmall, and ſo manifeſts the Reaſon why that part of the Orbit appears to the Earth in *Virgo* and *Libra*, amongſt the Fixt Stars of the Conſtellation of *Aries* and *Taurus*.

The right underſtanding of this Theory will plainly ſhew a Reaſon why it had ſo little, if any Parallax at all; which made *Caſſini* ſuppoſe it higher than the Planets, and *Chouet* that it was about the Sun: For by the Scheme it plainly appears, that it muſt be for the moſt part of it further diſtant than the Sun.

The chief Objections that I have ſince met with are theſe. *Other Objections anſwered.*

1. How the *Æther*, which is ſo exceeding thin and fluid a Body, can detain or ſtop any part of the Atmoſphere in the Tranſit of the Earth, and why the Gravity of the Earth, which carries along with it the Moon, according to my Theory, which is ſo vaſtly much more diſtant, ſhould not be able to carry with it all the Parts of the Atmoſphere.

2. Tho' the *Æther* ſhould thus retain part of the Atmoſphere, as I ſuppoſe, yet why this retained Subſtance ſhould not appear ſooner, and how it ſhould continue ſo long after, without being wholly diſperſed into the *Æther*.

3. Why this Separation, or marked Way, ſhould be left only when the Earth is in its *Perihelion*, and not all the Year, in every part of its Orbit.

4. Why this Glade ſhould not appear the ſame every Year, ſince the Earth moves the ſame Trace through the ſame *Æther*; and ſo at the ſame Times or Places of its Orbit, it has the ſame Influences both from the Sun and the *Æther*.

To the firſt I anſwer, That tho' the *Æther* be exceeding fluid, yet both from Obſervation and Experiments it affords ſome Reſiſtance to Bodies moved through it. Firſt by Obſervation it has been, I think, always found that the Tail, Blaze or Glade of Comets, has not been exactly directed or pointed from the Sun, but hath always had an Inclination backwards, that is, towards the Place from whence the Comet is moved, as I have publiſhed in my Obſervations concerning Comets; the Blaze of a Comet in this ſomewhat reſembling the Aſcent of the

Flame of a Candle, when it is moved sideways through the Air. But secondly, by experiment we find, that though the Motion of a *Pendulum in vacuo* will be much more free, and last a considerable time longer than the Motion of a *Pendulum in pleno Aëre*; yet even this will in some short time also lose its Motion, and stand still, as I have manifested to this Society by former Experiments purposely made. 3ly, Tho' the gravitating or attracting Power of the Earth be able to retain and carry the Moon along with it in its annual Orbit, the Moon being a Body of a vast Bulk of Solidity, compar'd to the Fluidity and small Resistance of the *Æther* through which it moves: Yet, as I shall afterwards prove in my Theory of Lunar Motions, the Impediment of the *Æther* hath a very considerable Influence upon it, and produceth very sensible Effects, tho' they are ascribed to differing Causes. But on the other hand, the Solidity of the Parts which serve to exhibit this *Phænomenon*, are so very small, and so near approaching to the Nature of the *Æther*, that the Stagnancy of the *Æther* hath a considerable Influence and Effect upon them.

For answer to the 2d Objection, 1st, I say, that I suppose it when separated from the Atmosphere, to be so near of the same Nature of the *Æther* with which it is mixed, that it discovers not its essential Difference, till it hath been for some time separated from the Atmosphere; but then when the Reflective Influence of the Earth hath been for some time wanting to it, it doth by degrees re-assume its preceding Form, and by degrees revert into the Form of Air, Vapours or Water, and so becomes of a differing Nature from the *Æther*, and serves to reflect the Rays of the Sun towards the Earth.

2ly, The Nearness of its Qualification to the *Æther*, makes it more slow in altering its Form. Of this we have Instances enough in the Atmosphere in a dry Season, as at this present, when though the Air be plentifully charged with watery Vapours and Exhalations, yet they continue for a long time in the form of the Air, being not discoverable from the more permanent Body of the Air it self, by any difference of Refractiveness, till by some other Cause unknown, they be converted again into the Form of Water in small Globules, or Drops, and so appear in form of Clouds, many of which Drops uniting into one, form a Drop of Rain, and so fall down to the Earth. This unknown Cause seems to be sometimes extraordinary Heat, whereby one part is converted into Lightning, upon which another presently reverts into Water or Rain, and falls down in Thunder Showers. At other times it seems to be extraordinary Cold, as one may judge by the falling down of those Drops in the form of Ice, as in Hail Showers.

Of Rain.

3ly, If we consider the vast height from the Surface of the Earth, to which the Parts of the Atmosphere ascend, which exhibit the Twilight, which *Cardan* believes to be almost 800 Miles, tho' *Ricciolus*, and others more moderate, suppose it not above 100 Miles high; we may easily assent, that some of those Parts may be left in the *Æther*, considering the Stagnancy of the *Æther*, and the exceeding great Swiftness of the solid Globe of the Earth through the same. But then if we consider the Parts of the Atmosphere not Refractive, they may be supposed very much more elevated, even to the height of a Diameter of the Earth. But if they are supposed less than 50, which the most moderate allow, yet they will be high enough to be left behind by the swiftly moving Ball of the Earth.

To the Third Objection, why this Train or Stream should be left when the Earth is in its *Perihelium*, and not as well at all other Times and Places of its Revolution, I answer, That there being a manifest difference of a Cause, 'tis rational enough to suppose there may be a sensible difference of Effect. 'Tis by other ways proved that the Earth is in that part of its Orbit nearer the Sun, and that its Motion is then and there proportionably swifter; if then we can observe a different *Phænomenon*, 'tis rational to ascribe it to that different Cause, till a more certain be found. Now that such a Cause may have some considerable Influence, I shall produce an Observation of the before-mentioned Dr. *Childrey*, in the same Book, *viz.* his *Britannia Baconica*, pag. 97 & 98. "I forgot (says he) to say, that several great Inundations speak "in favour of my Opinion touching the Moon in *Perigeo*, her greatning the "Tides

Moon's Influence on Floods.

" Tides; for I can assure you, that for that great Flood *Anno* 1532. *Novemb.* 5.
" on which was made this Distick.

Anno ter deno cum sesqui mille Novembris
Quinta stat salsis Zelandia tota sub undis.

" That in the Year 1551 and 1552, *Jan.* 13th; that horrible one 1570, on *All*
" *Saints* Day, the first of *November*; and that notable one 1605, *Jan.* 30th,
" the greatest that ever was known in *Severn*, and so fatal to *Somersetshire*,
" *Glocestershire*, and *Monmouthshire*; they were all when the Moon was in
" *Perigeo*, as he that lists to calculate, or search the *Ephemerides* for those
" Years, will find. And the same Doctor, in the beginning of his Book, adds an Advertisement of an Observation he made before that Book was quite printed off, *viz.* " That on the 1st of *November* 1660, between 10 a Clock at
" Night, and 5 next Morning, happen'd an unusual shifting of the Tides in the
" *Thames* at *London* ebbing and flowing three times, as 'tis reported, in that
" space; which, says he, was when the Moon was almost in the very place of
" her *Perigæum*.

To which let me add one Observation more to the Doctor's, That all these *Phænomena* hapned when the Earth was very near its *Perihelium*, and within the Limits of this supposed Luminous Glade or Wake, as I may call it, of the Earth; and 'tis not impossible but that this greater Nearness of the Body of the Earth to the Fire of the Sun, may make it emit more copious, and other natured Steams than at other times, when not so much roasted by the Heat of the Sun.

As to the 4th Objection, why this should not appear every Year the same; I answer, that there may be many Causes or Reasons to make one Year considerably differ from another, as is sufficiently manifest by the Variety of Weather of one Year from another. But to determine positively what is the Cause, does require a greater number, and more exact Observations than have been hitherto made of it.

Having understood that there yet remains one Objection against the *Hypothesis*, I have proposed for solving the Glade of Light appearing in the West in *February*, *March*, and *April*; and that is, against the Stagnancy of the *Æther*, and its staying of Atmospherical Parts within it from following the Motion of the Earth. I shall thereupon mention two *Phænomena*, which I conceive, when they are well considered, will give some probable Argument for this Opinion; and those are two of the same Kind or Nature, but observed at different Times and Places. The first I shall mention, tho' the last in time, was the *Fax* or *Lampas Volans* observed after Sun-set the 1st of *March* 1676, at *Fau*--- by *Petrus de Lauina*; at *Rome* by Monf. *Auzout*; at *Florence* by *Matthias del Arpi*; at *Venice* by *Jo. Jacob Hertz*, and in several other Cities of *Italy*; in all which it was seen also by very many others, and at the same time also was observed in the Lower Parts of *Germany*, as at *Triers* by the *Jesuits* there; Places very far distant one from another; yet the Time and Manner of Appearance in all was much the same. It seemed to rise out of the North East, and to pass by the Meridian to the South Western Parts of the Heavens, near the same Tract that the Sun had gone that Day, and disappeared behind thick Clouds, where with a mighty Noise it was supposed to be blown to pieces and dispersed. It appeared about the bigness of the Full Moon, and left behind it a Tail about 3 Diameters, of a reddish Flame at first, but turning bluish towards the last. It lasted about a Minute or two. Its Noise at last was like the Noise of an Earthquake at a distance, and made the Glass in the Windows shake. From the comparing of several Observations, 'twas supposed about 90 Miles high, and near a Mile in Diameter. The several Authors that have writ concerning it, have explicated it by an Hypothesis very different from mine. My Conceptions of it are these.

of a Lampas Volans.

First, That it was a vaporous Steam much of the same nature with that which makes Lightning raised into the Superior Parts of the Air by means of its own innate

innate Heat and Rarefraction, which might possibly proceed from some subterraneous Operation in some Parts of the East lying far distant from *Italy*, as *China*, or some other Part where there might be some Earthquake, or possibly some Irruption, by which it might be sent out in great plenty, and forced up with great Power and Swiftness, that remaining there some time, it might from the Cold or want of Heat of those higher Regions, by degrees be condensed and conglobated nearer together, and by the Operation of the more Æthereal part of the Atmosphere, be prepared for Accension; and so being kindled, it would continue some small time before it set fire to the middle Parts thereof, at which time it seemed to imitate the Noise of Thunder afar off. Now that Particular for which I mention it, is the way of its apparent Motion, which was said to be much the same with the Sun that Day, rising Eastward, and passing by the Meridian towards the West. This, I conceive, was caused by the Diurnal Motion of the Earth, whereby the Parts where it was seen being moved very swiftly towards the East, *viz.* about 12 or 14 Miles in a Minute, the higher Parts of the Atmosphere in which it was kindled, being left behind, it appeared as if it had been carried by a swift Motion of its own from East to West. And by reason, I suppose, that even that part of the Atmosphere was moved a little towards the East, thence was the Appearance of the Tail or Blaze it had that way, of about 3 times its own Diameter: Which will, I conceive, give a probable Cause of its apparent rapid Motion, and very well agree with the Hypothesis I lately mentioned.

And the same *Hypothesis* will solve a like *Phænomenon*, which, as well as I can remember, was some 10 Years before observed, both here in *England*, and in *Holland*. It was seen by Sir *Robert Murray*, if I misremember not, and by Mr. *Shortgrave*, and I think also by Mons. *Hugens* in *Holland*. It was as big as the *Italian* Meteor, and was judged to be of an exceeding great height in the Atmosphere, being seen at Places so far distant at the same time. It appeared first about the North East, and passed by the North West, not rising, as I remember, so high as 10 Degrees above the Horizon. For supposing that in the same manner to be left behind by the swiftly moving Parts of the Earth, the *Phænomena* will be very naturally solved; and therefore deserve, I conceive, to be taken notice of in the History of Nature.

An

An Account of Dr. Isaac Vossius's *Hypothesis of* GRAVITATION, *with some* Animadversions *thereupon.*

HAving perus'd a Discourse of the Learned Dr. *Vossius*, wherein he endeavours to explain the true Reason and Cause of the *Gravitation* of Bodies towards the Center of the Earth, I thought it might not be unacceptable to give an account of my Thoughts concerning it, it being a Subject well worthy the consideration of this Society, there having not been to this day any one *Hypothesis* given by any Writer, that is sufficient to solve the *Phænomena* thereof, or to explain the Multitude of Effects produced by it, much less to demonstrate the Power and Limits thereof, concerning which I have heretofore somewhat more largely discoursed in this Assembly. I shall not now spend time in the enumeration of the various *Hypotheses* of several other Authors, but confine my self only to the consideration of that which is propounded by this Worthy and Ingenious Person. He conceives then, that the sole reason why heavy Bodies descend towards the Center of the Earth, and why light Bodies ascend from it, is the Diurnal Rotation thereof upon its *Axis*, and wonders that it was never found out before, even by those who patronized the *Copernican Pythagorick* (or, as he affirms, the *Chaldean* and *Egyptian* Opinion, long before *Pythagoras*) of the Motion of the Earth. The Reasons he assigns, why this Motion must infallibly and necessarily produce this Effect, is because heavy Bodies having an inaptitude to Motion, do therefore endeavour towards the Center, where there is none, or the least that can be. This he explains by two sorts of Experiments tried or observed by him; the first is that of a *Vortex*, or Whirl of Water in a large Tub, the second that of a large Top. By the first, he says, he found that the Water being put into a swift Circular Motion, all those Bodies which were heavy, and sunk to the bottom, were drawn to the middle, and the heaviest of them got nearest to the Center, and those less heavy were removed farther and farther off, according to their proportionate Degree of Gravity, as Lead would get nearest, Iron next, then Stones, or other less heavy Bodies. On the other side, such Bodies as were lighter than the Water, and so swam upon it, would recede and fly off to the Sides of the Tub. The like *Phænomena* he observed also in Whirlwinds of the Air. His second Experiment of the Top, he produces to answer some Objections which are usually made against the Motion of the Earth, and so will consequently be against this *Hypothesis*: For 'tis usually, says he, objected, that if the Earth move, then all such Bodies as are loose upon it, would be so far from growing more heavy towards the Center, that they would all of them be rather thrown off into the Air or *Æther* with a great violence, and tend outwards or upwards from it, since 'tis plain, that a Body put into a Wheel, and turned swiftly round, has a tendency from the Center, and not at all to it. For, saith he, tho' it be true, that a Wheel turned thus perpendicularly, do's cause the heavy Body to recede; yet if the Wheel were moved Horizontally, as a Top is, with its *Axis* erect, and at right Angles with the Plain of the Horizon, it would not. But I conceive both these Arguments are *gratis dicta*, as are all the Conclusions deduced therefrom, and the *Phænomena* they exhibit are to be ascribed to quite different Causes to those he assigns. For first, as to Whirl-winds and *Vortices*, 'tis clear, that by the violent Circumrotation of the Air or Water, the Endeavour of those Bodies is to recede from the Center of that Rotation, and by that means there is less Resistance in the Center for Bodies, whether heavy or light (for both will move towards it) to get into it; but the lighter much easier than those that are heavy, as 'tis common to see small Whirles of the Wind to gather together Leaves and Straw, and light Dust, and raise them up into the Air; but Stones and heavier Bodies are not at all

Of Spouts at Sea.

ſtirred by it. And for the ſame reaſon, I ſuppoſe, it is, that large and violent Whirlwinds upon the Sea do cauſe the Water to riſe up from the Sea, and aſcend upwards, and the Clouds on the other hand to deſcend downwards into the Center, now made almoſt like an empty Pipe by the receſs of the Air in whirling round, as is obſerved in the Spouts at Sea; which quantity of Water ſo raiſed, ſuddenly falls again, ſo ſoon as the whirling Motion ceaſes. Now, as in Whirlings of the Air, the Water riſes in the *Axis* or middle, ſo 'tis very obvious in Whirl-pools of Water, the Air deſcends, and fills that Cavity that is deſerted by the Water in the middle. But neither of theſe afford any Argument, as I conceive, of *Gravitation* to the Center of the Earth: For 'tis not here the fluid *Medium* that is whirled round faſter than the ſolid Body of the Earth, but this Body is whirled round faſter than the Air; and that is ſuppoſed to be the reaſon why the Winds in the *Torrid Zone* do for the moſt part move from the Eaſtern Parts of the Earth towards the Weſtern, making that Wind they call a Trade Wind. Now both Monſ. *Des Cartes*, and Mr. *Hobbs* have been of this opinion, that the Diurnal Motion of Rotation might be the cauſe of this Tendency of Bodies to the Center of it; but neither of them have explained the manner how, ſuppoſing the *Æther* to be the moſt compact Body, and ſo to be thrown off by this Rotation, and thence the more ſenſible and tangible Bodies of the third Element to be forced towards the *Axis* of Rotation: They have not, I ſay, explained how theſe lighter Bodies come to tend towards the Center; for granting what they ſuppoſe, thoſe Bodies would not tend to the Center of the Globe, but to the Center of each Parallel Circle of Latitude, and conſequently under the Pole there would be no Tendency at all. Now tho', 'tis true, it would be a hard matter to confute them, to aſſert experimentally a Gravitation at the Pole; yet 'tis evident enough in all other Degrees of Latitude, that the Tendency is not to the Center of the Parallel of that Latitude, but always towards the Center of the Globe. Again, if the Rotation of the *Æther* were the Cauſe of this Tendency towards the Center, and that this Rotation were differing from the Rotation of the Earth, that is, either faſter or ſlower, which ſeems to be the Cauſe ſuppoſed in the firſt Experiment of the *Vortex* of Water; then falling Bodies would not deſcend in a Line tending to the Center, but in ſome Oblique Line, either inclined towards the Eaſt or the Weſtward of it. If, on the other ſide, it were from the ſwifter Rotation of the Body of the Earth, as ſeems to be hinted by the 2d Experiment of the humming Top, then would falling Bodies not deſcend and fall perpendicularly, but to the Weſtward of it in the ſame Parallel of Latitude. Again, whereas Dr. *Voſſius* ſays, that a Vertiginous Motion, whoſe *Axis* is perpendicular to the Horizon, does not throw off Bodies from it, as the Motion of a Wheel, whoſe *Axis* is parallel to the Horizon; 'tis clear by Experiment that it doth, in the ſame manner, which may be plainly ſeen, if Water be dropt upon the top, whilſt in that turbinated Motion; for it will diſperſe it every way with great violence. And as to the ſtanding ſtill of the Top upon its End, when it is ſo violently moved round upon it, and of its running away with a great Swiftneſs ſo ſoon as its Sides touch the Ground, I conceive the Reaſons of both are ſo plain, that I need not inſiſt upon them. Again, whereas Dr. *Voſſius* lays great ſtreſs upon the Perpendicularity of the *Axis* of the Earth to the Plain of its annual or progreſſive Motion. It is evidently otherwiſe; for the *Axis* is always declined 23 ½ Degrees from that perpendicularity. So that I fear we are yet to ſeek for the true Cauſe of Gravity, as well as we are of the Degrees of its Power, and the Limits of its Extent: For tho' there have been many that have ſuppoſed its Power not to extend beyond the Air or Atmoſphere, and upon that have given the reaſon of the Suſpenſion of Water in the Clouds, and of the flying of Kites, and other Fowl, to a great height into the Air, and the like; yet 'tis very evident by many Arguments I produced in my Lectures about the Comet, that the Power thereof is not limited within ſo ſmall an Extent, but rather that it hath a ſtrong and powerful Effect, not only as far as the Moon, but vaſtly far beyond it; and that it is one of the moſt eſſential Properties of all the large Globular Bodies of the Univerſe.

Of

Of Dr. Dee's *Book of Spirits.*

Tho' this Discourse be of a quite differing nature from all the other Subjects treated of in this Book, yet I thought it would not be unacceptable for the newness of it, since it gives a quite different Explication of that unusual sort of Treatise of Dee's *Converse with Spirits, from all other Interpreters. This Paper was bought by a Gentleman in the said Book, at the Auction of* Hook's *Library, who was pleased to send it to me. To him therefore myself and the Reader are obliged for this Tract. To which is added an Account of* Dr. Dee *and his Studies, transcribed by Dr.* Hooke *out of Mr.* Ashmole's Theatrum Chemicum.

HAving lately met with a Book, which though it hath been published now above 30 Years, I never had the Curiosity to examine further into, than upon opening here and there to read some few Lines, which seeming for the most very extravagant, I neglected any further Inquiry into it: Yet having not long since met with a small Pamphlet of the same Author, intituled, *A Letter, containing a most brief Discourse Apologetical, with a Plain Demonstration and Fervent Protestation for the lawful, sincere, very faithful and Christian Course of the Philosophical Studies and Exercises of a certain studious Gentleman, an antient Servant to her Most Excellent Majesty Royal:* Written to the Most Reverend Father in God, the Lord Arch-Bishop of *Canterbury*, Primate and Metropolitan of all *England*, and one of her Majesty's most Honourable Privy Council, *&c.* And subscribed by *John Dee:* Wherein, besides his Protestation before Almighty God, upon the peril of his Soul's Damnation, if he lied, or took his Name in vain therein, that with all his Heart, with all his Soul, Strength, Power and Understanding (according to the measure thereof which the Almighty had given him) for the most part of his time from his Youth hitherto, he had used, and did still use, good, lawful, honest, Christian, and Divinely prescribed Means, to attain to the Knowledge of those Matters which were meet and necessary for him to know, and wherewith to do his Divine Majesty such Service, as he had, did or should call him unto during his Life, for advancing his Honour and Glory, and for the Benefit and Commodity Publick of this Kingdom, so much as by the Will and Purpose of God should lie in his Skill and Ability to perform, and of his Profession of being a Christian. Besides this Profession (I say) I found it contained a Catalogue of most of his Works, either published before that time, or then in Manuscript; by the Titles whereof he seeming to be an extraordinary Man, both for Learning, Ingenuity and Industry, I had a desire to peruse the Book with a little more Attention than I had formerly Thoughts of; to see if by the Contents thereof it might have contained any of those Subjects, which he, in the said Apologetical Discourse, had asserted himself to have written concerning. Nor was I frighted from this my Purpose, either by the six pretended Conjurers prefixt to the Title, *Mahomet*, *Apollonius Tyaneus*, *Kelly*, Friar *Bacon*, *Paracelsus*, and Dr. *Dee* himself; nor by the Title, viz. *A true and full Relation of what passed for many Years between* Dr. John Dee *(a Mathematician of great Fame in Queen* Elizabeth *and King* James, *their Reigns) and some Spirits, tending* (had it succeeded) *to a General Alteration of most States and Kingdoms in the World*, &c. Since I conceived both these to have been the Ingenuity of the Publisher, to make the Book sell the better: No, nor thirdly by the long and frighting Preface of the Publisher, Dr. *Merick Casaubon*, who certainly did believe him, the said *Dee*, to be a Conjurer or Witch, and to have dealt with the Devil all along through the whole Course of this Relation of his Travels into *Germany*, *Poland*, and other Parts of *Europe*; he understanding the same all along

along in the plain literal Sense, as indeed most Readers have, and do as yet conceive of it, as he, besides what he hath said in his Preface, doth more particularly shew in his Contents of the several Sections of it, and his several Notes dispersed here and there in the said Book. But proceeding to peruse the said Discourse, I upon the first View and Consideration of the 3 Copper Sculptures prefixed, immediately conjectured what the Subject of the Book was likely to be, which by divers other Circumstances afterwards I was more confirmed in, as I shall by and by shew.

But first, it may seem needful that I premise some Discourse Apologetical for my self,

First, for perusing a Book supposed to be a Book of Conjuration, and dealing with the Devil and his Imps.

Next, For discoursing in this Place concerning a Book which has been published so many Years, and past under the Censure and Judgment of most Learned Men, and so is at best but stale, and what every body knows, or may have known already.

3dly, That it contains a Discourse of a Subject so much beside the Design of the Institution of this Honourable Society; this seeming to have nothing to do with the Improving Natural Knowledge.

4thly, For that it seems not to have relation to the History of Nature or of Art, and so falls not within the Limitation of the Subject of this Lecture.

5thly, For my Presumption in interposing my Conjectures and Sentiments concerning the Subject Matter of the same, after it hath been censured by such Eminently Learned and Judicious Men, as Bp *Usher*, Dr. *Casaubon*, and others.

As to the first of these, I found in the very Title Dr. *Merick Casaubon*'s Opinion specified to be, that the Relation was real (as to the Point of Spirits) and that a sober Christian might make several good Uses of all: And in the Preface it self the Doctor hath very much inlarged upon this Subject, and says in the first Page of his Preface, that he was the more confirmed in his Sentiments concerning it, when he was told at first by those that knew very well, that the most Reverend, Pious and Learned Arch-Bishop of *Armagh*, then lately deceased, upon reading the said Book before his Death, had declared himself to the same purpose, and wished it printed. His first Use is for an Argument against Atheists, and such as do not believe Spirits and Devils. 2dly, Against Enthusiasts, who altogether depend upon new Revelations, zealously and fervently praying for such Inspirations and extraordinary Assistances, saying, that this Business of Prayer and Praising is a Business, as of great Comfort, so of much more Danger and Delusion than many do believe; upon which account he tells many strange Stories. 3dly, For to deter Men from presumptuous unlawful Wishes and Desires; and thence of making use of Witches, Conjurers, Astrologers, and Fortunetellers, and all Books of those Subjects, which he conceives were the Cause of Dr. *Dee*'s Delusion: So that I was satisfied there could be no great Danger or Harm in the looking farther into the Contents of it. But more than this, I conceived it not reasonable altogether to depend upon the Opinion and Sentiment of others concerning it, when the Book was by, to give Testimony of it self; for that divers Books have been condemned for supposed Crimes, of which yet, upon further Inquiry, they have been found innocent, and to have quite a differing Design from what they seemed at first sight to intend. Witness the *Steganographia* of the Abbot *Trithemius*, which was to fiercely accused of Conjurations by *Carolus Bovillus* his Contemporary, by *Wierus* his Follower, also by Cardinal *Bellarmine*, *Antonius Passerinus*, and by most others since, who understood not the Art and Ingenuity of the Book; but others more judicious and knowing have vindicated and cleared him from those Calumnies, and proved the Art and Ingenuity of the Book, as above all other, *Gustavus Selenus*, or *Augustus* Duke of *Lunenburgh*, pag. 37. *Ut profanum Vulgus ab occulte scribendi hac Arte arceret, atq; adeo quibusdam Terriculamentis absterreret, ingeniosissimus noster Abbas, eam Magiæ, vulgo invisi & odiosi Nominis specie venditavit, quasi infernalium Spiritum ope, dirisq; Incantationibus, sub horrido confragoso, atq; ad terrorem pene confecto idiomatismo res perageretur, quem Scopum non obscure*

ſcure innuit in duabus ad Electorem Palatinum Philippum Præfationibus. Addamus nos ipſum porro tali involucro ingenuum Ingenii Luſum cogitaſſe, in gratiam Eruditorum artem hanc filo Ariadnes fido adepto addiſcentium. Ludit enim ſub Nomine Spirituum ad Literas, quibus occulte aliquod Negotium alteri ſignificatur; vel quod illæ ſunt Animi & Spiritus noſtri indices voluntatem noſtram abſenti quo vox non penetrat, fideli & mirabili modo perferentes; vel quod inter plures literas (quæ pro occultando inſtituto in Epiſtola aliud Thema tractante tranſmittenda adhibentur) iſtæ, quibus quaſi aliud agendo Secretum alteri indicatur, uti Spiritus, Vita & Anima; cætera vero eo non pertinentes, pro Mortuis habendæ ſint. And ſo he proceeds to ſhew the Reaſon, why he calls ſome of thoſe Spirits Dukes or Princes, others Captains, others miniſtring and ſubſervient; and in ſhort, detects the whole Artifice of the whole Book, which had nothing of that Deſign for which the illiterate and unskilful Readers did generally condemn it.

But ſecondly, As to the Staleneſs of the Book, it having been now printed and publiſhed about 32 Years, I anſwer, that as to my ſelf, tho' I had often ſeen the Book, and heard many Diſcourſes of it, and of its Contents, yet as to my own knowledge of it, it was perfectly new, and poſſibly it may be ſo to a great many others, conſidering the Subject of the ſame, and the manner of the Delivery thereof, which indeed ſeems to be (bating ſome Parts that relate to a kind of Hiſtory of *Dee*'s particular Affairs and Tranſactions with ſome Great Men) a Rapſody of incoherent and unintelligible Whimſies of Prayers and Praiſes, Invocations and Apparitions of Spirits, ſtrange Characters, uncouth and unintelligible Names, Words and Sentences, and Relations of incredible Occurrences. So that wherever you open and begin to read, you may find cauſe enough in a very little time to throw it aſide and neglect it, till you have quite forgotten what you then met with, as it happen'd to me, who had in that manner ſeveral times ſeen and read here and there a few Paragraphs.

But next I anſwer, that there are many Books that have been a long time printed; nay ſome ſo long, that they are many of them almoſt quite loſt, and very hardly and rarely to be met with, which yet deſerve to be looked into, and an account given of, as much as many new Books, which now almoſt every Day are brought forth into the World; upon which Subject I need not inlarge, becauſe I believe I may have many others of the ſame Opinion: For there are many things which are now produced for Novelties and new Diſcoveries, which yet may be found to have been long ſince publiſhed, and either have not been taken notice of, or through Length of time have been forgotten and loſt, as if they had never been. Again, there are many Books, that have ſlipt into the World at ſuch times, as no body, or very few, at leaſt, have taken notice of them upon their firſt coming, by reaſon they were of Subjects then not much regarded, or in vogue, or when Mens Minds were taken up or more concerned for other Subjects, or Matters of greater import, which by the Time of the Printing might poſſibly be the Fate of this very Book, which probably at another time would have made more Noiſe, and, it may be, have met with more Notice, if not alſo more Oppoſition. And it has been the Fate of many good Books to be neglected for ſome time after their firſt Publication, which yet in time come to be better look'd into, and the Uſefulneſs of them underſtood, and then to begin to be prized, as I underſtand was the Fate of Mr. *Purchas* his Pilgrims and Pilgrimage, and ſeveral others.

As to the 3d Objection that may ſeem to need an Apology, namely, the *Heterogenity* and Unfitneſs of the Subject for the Conſideration of this Society, as being reputed a Treatiſe about Supernatural Effects or Productions, I muſt confeſs, that if it be to be underſtood according to the plain literal Meaning, it would be truly ſo; but whereas I conceive the true Meaning and Deſign of the whole to be quite another Matter, I think it may be as properly referred to the Improvement of Natural Knowledge to underſtand it, as of any other Book that has plainly and expreſly treated of the Hiſtory of Nature and Art. For I take it to be a concealed Hiſtory of that kind, which may alſo apologize for my treating of it upon this occaſion in this Lecture.

It may alſo ſerve for my 5th Apology: For tho' I confeſs it may ſeem to ſavour of too much Confidence, to differ from the Sentiments of moſt Men concerning it; yet ſince what I propound is not poſitive, but rather as Queries to

be resolved by such as have better Abilities and Opportunities to solve them than I have, and that I am ready to submit to such well-grounded Determinations. I hope my Attempt in this kind will not appear to exceed the Limits of the Charter of *Philosophia libera*, nor be repugnant to the Doctrine of *Nullius in Verba*: For whatever may seem rational to others to judge of the said Book, to me, I confess, it seems to be designed to comprehend another Meaning than what is plainly legible in the Words of it, which possibly many others that have read it, may have no Suspicion of; neither may they have ever seen or considered the Cryptography of *Trithemius*, or any other Author on the like Subjects. *Non omnia possumus omnes.* Thus much by way of Apology.

To come then to the Book it self. Upon turning it over, and comparing several Particulars in it one with another, and with other Writings of the said Dr. *Dee*, and considering also the History of the Life, Actions and Estate of the said Author, so far as I can be informed, I do conceive that the greatest part of the said Book, especially all that which relates to the Spirits and Apparitions, together with their Names, Speeches, Shews, Noises, Clothing, Actions, and the Prayers and Doxologies, *&c.* are all *Cryptography*; and that some Parts also of that which seems to be a Journal of his Voyage and Travels into several Parts of *Germany*, are also *Cryptographical*; that is, that under those feigned Stories, which he there seems to relate as Matters of Fact, he hath concealed Relations of quite another thing; and that he made use of this way of absconding it, that he might the more securely escape discovery, if he should fall under suspition as to the true Designs of his Travels, or that the same should fall into the hands of any Spies, or such as might be imployed to betray him or his Intentions; conceiving the Inquisition that should be made, or Prosecution, if discovered, would be more gentle for a Pretended Enthusiast, than for a real Spy.

What his Designs or Business with the Emperor, the King of *Poland*, and others, was, is hard to determine, *i. e.* first whether he were sent upon some private Message by the Queen, or any of the then Ministers of State, to inquire into and discover the secret Designs or Actions of that Court, is hard now to determine; but 'tis likely. For in his Apology he alledges, that the Lord Treasurer had by the Queen's Order written to the Arch Bishop, to signify that he went beyond Sea by her good Favour and License; and we find also that the Queen did send several Letters and Messengers to call him home, and that upon his Return the Queen received him kindly at *Richmond*, and that she used to call at his House at *Mortlack*, and shewed herself courteous to him upon all occasions, and against *Christmas* 1590, sent him 200 Angels to keep his *Christmas*, and 100 Mark for the same purpose 1592. We find also, that in his Return for *England*, he presented the Landgrave of *Hesse* with 12 *Hungarian* Horses; which seems too much for any Man in a private Capacity. And when he returned, he left *Kelly* with the Emperor, who for several Years after kept Correspondence with Dr. *Dee* here, which might possibly continue to execute the same Design; *Kelly* being now grown Sir *Edward Kelly*, and the Emperor's Chymist. And in probability Dr. *Dee* might have sufficiently furnished him with *Cryptography* enough to send what Intelligences he pleased, without suspition, which was easily conceived under any other feigned Story. I will not determine whether this were his Business, I say, or whether it might not be upon his own account, to see if he could make a Fortune under the Emperor by means of Chymistry, or Mathematicks, or Astrology, or Mechanicks, all which I find by his Writings he was well versed in, and especially in the Business of Opticks, and Perspective and Mechanick Contrivances; an effect of which I conceive his Chrystal, or Angelical Stone, or *Chrystallum Sacratum*, as he terms it, to have been, for that it was of a considerable bigness, and was placed upon a Pedestal, or Table, which he calls a Holy Table, which might contain the *Apparatus* to make Apparitions, when he had a mind to be seen in it, as likewise to produce Noises and Voices, if there were occasion. All which might be done by Art, as has been shewn, both formerly by *Roger Bacon*, and of late by the Echoing Head. He likewise pretended to the Philosophers Stone and *Elixir*, for which I take *Kelly* to be his Engine. I find also, that he affirms to have had 2 Ounces of the *Pouder of Projection*, which, as Mr. *Ashmole*, in his Notes upon the *Theatrum Chymicum*, published by him 1652, says, was so rich in Virtue (being

One

One upon 272330) that they at first lost much by making Projections for Trials, before they found out the true height of the Medicine. He was likewise well versed in *Cabalistical* Learning and *Cryptography*, as appears by the Title of a Treatise written by him upon that Subject, and by that Book which he seems to have prized so much, and calls the Book of *Enoch*, which I take to be of no other use, than for *Cryptography* and *Cabalisms*. I will not determine, I say, whether his Design might not be by these and some other such Ingenuities (as particularly a Glass, which he mentions, *Pag.* 256. (the Secret of which he opened to Dr. *Curtz* the Emperor's Physician) for *Battering* in a dark Night, *&c.* which what he means by it I understand not; but Dr. *Curtz* told him that Conclusion would be very acceptable to the Emperor. He had also written Six Books *deSpeculis Comburentibus*, Two Books of the *Astronomical Ring*, or *Ring Dial*, and two Books also of *Clockwork*) to find Entertainment and Encouragement from the Emperor. But I do rather conjecture, that he was employed by Queen for some private Affair of State, and that he made use of these his Inventions, in order to obtain the freer and more unsuspected Access to the Emperor; which having not succeeded as might have been expected, he was recalled, and returned into *England* in *Nov.* 1589. That a great part of this Treatise is *Cryptography*, I conceive is very probable from these and divers other Considerations: First, for that he took such care to preserve the Book of *Enoch*, which I conjecture to contain the Methods and Keys of what was concealed in this Book. Next, for that the Method and Manner thereof is so like to that of *Trithemius* his *Cryptography*, that I conceive (were it worth while) it would not be difficult to decipher a great part of it, by analogy thereunto. Now tho' at that time the Key or Method of that Book were not so well and commonly known, yet I do not doubt but this inquisitive Man had got Knowledge of it in his Travels and Enquiries in *Germany*, possibly when he presented his *Monas Hieroglyphica* to the Emperor *Maximilian* 1564; and possibly it might be upon the same account, that he made choice of this way of Invocations and Revelations to conceal his Meaning, that I shewed before *Trithemius* had done in his. *Trithemius* also pretended to Revelation, as may be seen in the History of his Life, tho' not so frequent as this Author has done in this Book, at least if the Sense thereof be understood literally; but that I conceive to be nothing but the outward Form, Appearance or Dress of the Substance and Subject of the Book, which lay absconded from common Discovery under that Mask or Disguise; tho' yet I am apt to believe he had some artificial Contrivances to perform this also, when he saw cause. Thirdly, for that there are very many plain Instances of *Cryptography*, both by changing and putting some Letters for others, and Numbers for Letters, and Numbers also for Words, and Tables for disposing or placing Letters according to several Orders and Methods, to be seen in the Book it self: And the Book which he calls the Book of *Enoch*, seems to be nothing else. Besides, the Words that he sets down, as delivered by his Spirits, are many of them inarticulate, according to the commonly accepted Sounds or Pronunciation of those Characters they are written with, and therefore were not put to signify those Letters. It would be too long to give Instances out of the Book it self of these Particulars, and 'tis needless, since they are so very many and frequent in every part of the Book. He hath likewise divers Polygonal Figures, as I conceive, for the same purpose, and many other such Indications of *Cryptography*.

And to conclude for the present, any one that does without prejudice peruse the *Libri Mystici Apertorii Cracoviensis Sabbatici*, pag. 115. will see a hundred Arguments to convince him of the Probability, if not Certainty of this my Conjecture: And some other time I shall give some other Arguments, which may possibly give fuller Satisfaction. But I would not detain too long upon this Subject.

Out

Out of the Theatrum Chemicum Britannicum, *collected into one Volume, with Annotations. By* Elias Ashmole *Esq*; London, *printed* 1692, 4*to*.

PAG. 480. [Mr. *Ashmole*'s Notes.] As touching Dr. *Dee*, he chiefly bent his Studies to the Mathematicks, in all Parts of which he was an absolute and perfect Master; witness his Mathematical Preface to *Euclid*'s *Elements*, wherein are enumerated many Arts of him wholly invented (by Name, Definition, Property and Use) more than either the *Grecian* or *Roman* Mathematicians have left to our Knowledge; with divers Annotations and Inventions Mathematical added in sundry places of the said Book, together with several Pieces of Navigation Perspective, and other rare Mathematical Works of his in Manuscript.

His Epistle prefixed to *John Field*'s *Ephemerides* 1557. *de Usu Globi Cælestis*, to *Edw. 6. de Nubium, Solis, Lunæ, & reliquorum Planetarum, &c. Distantiis, &c.* to *Edw. 6. Astronomical and Logistical* Canons to calculate *Ephemerides* by; *de Stella admiranda in Cassiopeæ Asterismo*; an Advice and Discourse about Reformation of the Vulgar Year; speak him a Learned *Astronomer*.

Lastly, He was a good *Astrologian*, and a studious Philosopher: His 300 *Astrological Aphorisms*; his 120 Aphorisms *de prestantioribus quibusdam Naturæ Virtutibus*; *Monas Hieroglyphica*; *Speculum Unitatis* (being an Apology for our famous Friar *Bacon*); his *Cabbalæ Hebraicæ Compendiosa Tabula*, with many others, afford no small Evidence to the World.

All which, and many more in several kinds of Learning, as History, Heraldry, *&c.* written by him before the Year 1583. Some time he bestowed in Vulgar *Chymistry*, and was therein Master of divers Secrets; amongst others he (*Dec.* 28. 1519.) revealed to one *Roger Cook*, the great Secret of the *Elixir* (as he called it) of the Salt of Metals, the Projection whereof was one upon a hundred. His great Ability in *Astrology*, and the more secret Parts of Learning (to which he had a strong Propensity and unwearied Phansy) drew from the Envious and Vulgar, many rash, hard, and lying Scandals upon his most honest and justifiable Philosophical Studies, and many times forced him, out of the Bitterness of his Soul (which was even crucified with the Malice of impudent Tongues) most seriously and fervently to apologize: Nor could he enjoy Tranquility in his Studies, but was oft disquieted and vexed with the sower Dispositions of such as scandalized most injuriously both him and them: Insomuch that (1581) the Year he went beyond Sea, his Library was seized on, wherein were 4000 Books, 700 of them Manuscripts. (*A Caveat for all Ingenious and Eminent Philosophers to be more wise than to keep any dear or excellent Books in their own Houses.*) And 'tis most probable that at this time his *Speculum Unitatis* might fall into some Hands that would never since suffer it to see Light; which might occasion the Learned *Selden* to say [in the Preface to *Hopton*'s *Concordance*] this Apology was long since promised by him, but intimating it was never writ. *Anno* 1592, [*Novemb. 9.*] Mr. Secretary *Walsingham*, and Sir *Tho. George*, were sent to his then Dwelling house at *Mortlack* (by virtue of a Commission) to understand the Matter and Causes for which his Studies were scandalized; and for some things in the like nature, was he necessitated to send his Apologetical Letter to the Arch-Bishop of *Canterbury*.

These kind of Persecutions were still multiplied upon him, and he sometimes personally aggrieved by them: For about the Year 1594, he was under some Restraint, which occasioned him to write to the Lady *Scudamore* [*Oct.* 28. 1594.] to move the Queen, that either he might declare his Case to the Body of the Council, or else under the Broad Seal have Liberty to go freely where he pleased.

———'Tis generally reported, that Dr. *Dee* and Sir *Edward Kelly* were so strangely fortunate, as to find a very large Quantity of the *Elixir* in some Parts of the Ruins of *Glastenbury* Abby, which was so incredibly rich in Virtue (being one upon 272330) that they lost much in making Projection by way of Trials, before they found out the true height of the Medicine. And no sooner

were

were they Masters of this Treasure, then they resolved to travel into foreign Parts, when falling into acquaintance with one *Albertus Lasky*, a *Polonian* Prince, which came into *England* in the beginning of *May* 1583, on the 21st of *September* following, they, their Wives, Children and Families, went beyond Sea with the said Prince. And whether they found it at *Glastenbury*, as is aforesaid, or however else they came by it, 'tis certain they had it: For at *Trebona* in *Bohemia*, whither they were come to dwell [*Sept.*4. 1586.] Sir *Edward Kelly* made Projection with one small Grain thereof [*Dec.* 9. 1586.] in proportion no bigger than the least Grain of Sand, upon one Ounce and a quarter of common *Mercury*, and it produced almost an Ounce of most pure Gold. This was done to gratify Mr. *Edward Garland* and his Brother *Francis*, and in their Presence; which *Edward* was lately come to *Trebona*, being sent thither to Dr. *Dee* from the Emperor of *Moscovia*, according to some Articles before brought by one *Thomas Symkinson*. I also find this Note of Dr. *Dee*'s, *Jan.*9. 1586. *Donum Dei* 2 Ounces, *E.K.* Moreover, nearer the later *Testimony*, I have received it from a credible Person, that one *Broomfield* and *Alexander Roberts* told him, they had often seen Sir *Edward Kelly* make Projection, and in particular upon a Piece of Metal cut out of a Warming-pan, and without Sir *Edward's* touching or handling it, or melting the Metal, only warming it in the Fire, the *Elixir* being put thereon, it was transmuted into pure Silver. The Warming-pan, and this Piece of it, was sent to Queen *Elizabeth* by her Ambassador, who then lay at *Prague*, that by fitting the Piece into the Place from whence it was cut out, it might exactly appear to be once part of that Warming-pan. The aforesaid Person hath likewise seen in the hands of one Mr. *Frye* and *Scroop*, Rings of Sir *Edward Kelly*'s Gold, the Fashion of which was only Gold Wire twisted thrice about the Finger; and of these fashioned Rings he gave away to the value of 4000 *l.* at the Marriage of one of his Servant-Maids. This was highly generous; but to say truth, he was openly profuse beyond the modest Limits of a sober Philosopher.

During their abode at *Trebona* they try'd many Chymical Experiments, to see whether they could make that Jewel they possest; (The particular Account of their Operations I need not here relate.) yet I cannot hear that ever they accomplisht any thing: Only I find the 27th of *April* noted by Dr. *Dee* with several Expressions of Joy and Gladness, as, *Hæc est Dies quam fecit Dominus*: Again, *Misericordia Dei Magna*; and lastly, *Omne, quod vivit, laudet Dominum.* And to testify what they meant, he writes upon the 30th Day following, *Mr.* Edward Kelly *did open the Great Secret to me, God be thanked.* While they lived at *Trebona*, Sir *Edward Kelly* went divers times to *Prague*, and the 15th of *Jan.* 1587, he went into *Poland*, but returned the 9th of *February* after. And 'tis probable these Journies were made in quest after some famous Chymists. Things were not carried here so privately, but Queen *Elizabeth* had notice given her of their Actions; whereupon she used several means by Letters and Messages to invite them back into *England*, where it was believed she had so far prevailed, that Mr. *Symkinson* and Mr. *Francis Garland*'s Brother *Robert* coming from *England* to *Trebona* [*Dec.* 8. 1587.] supposed they had been ready to come over to *England* upon the Queen's Letters formerly sent them. And tho' Sir *Edward Kelly* staid behind, yet Dr. *Dee* left *Trebona* [*May* 1. 1589.] and came for *England*. But whether occasioned by some Unkindness received from Sir *Edw. Kelly*, or falling out of their Wives, or Sollicitation of Queen *Elizabeth*, or all of these concurring, I am not yet certain. Not unlike but each of these might contribute to their Separation. For that there was some great and wonderful Unkindness past from Sir *Edward Kelly*, appears by his sending for Dr. *Dee*, the beginning of *Jan.* 1588, under shew of Reconciliation, and discovering more than ordinary Intimacy and Complacency about that time; which fair Shews the Good Doctor notes with these Prayers, *God lead his Heart to all Charity and Brotherly Love.* As also Letters sent by Dr. *Dee* to Sir *Edward Kelly* and his Wife the end of *March* following, requiring at their hands mutual Charity; which [*May* 9.] after, upon Mrs. *Kelly*'s receiving the Sacrament, she gave her Hand to Dr. *Dee* and his Wife in token of Charity. But it seems things were not cordial, but only outward: For the 6th of *September* following, the Lord Chancellor coming to *Trebona*, the Rancour and Dissimulation was more evident to him, and it seems grew up to a greater height than he could bear. And thereupon he thought wisely to avoid the

further Danger by leaving *Germany*, which occasioned him [*Jun.* 4. 1589.] to deliver to Sir *Edward Kelly* the Powder, the Books, the Glass, with some other things, and thereupon received his Discharge in Writing under his Hand and Seal. While these Discontents continued, several Letters past between Queen *Elizabeth* and Dr. *Dee*, whereby perhaps he might promise to return. At length it so fell out, that he [*March* 1. 1589.] left *Trebona*, and took his Journy for *England*. The 9th of *April* he came to *Breame*, and had not staid there 3 Days, but the Landgrave of *Hesse* sent Letters of civil Complements to him, and within 3 Days after Dr. *Dee* presented him with his 12 *Hungarian* Horses, that he bought at *Prague* for his Journy. Here (*June* 27. 1589.) the Famous *Hermetick* Philosopher, Dr. *Henric Kunrath* of *Hamburgh* came to visit him. The 16th of *Novemb.* he went thence to *Stade*, where he met with Mr. *Edward Dyer* going Embassador for *Denmark*, who the Year before had been at *Trebona*, and carried back Letters from the Doctor to Queen *Elizabeth*. He was a great Correspondent of Dr. *Dee*'s, and as earnest a Searcher after the Stone. The 23d of *Nov.* following he arriv'd at *Gravesend*, having been out of *England* 6 Years, 2 Months, and 2 Days; and the 9th of *Dec.* presented himself to the Queen at *Richmond*, where he was favoured with a kind Reception.

Being settled again at *Mortlack*, the Queen used to call at his House to visit him, and shewed her self very courteous to him upon all occasions. Against *Christmas* 1590, she sent him 200 Angels wherewith to keep his *Christmas*, and 100 Marks against *Christmas* 1592. She likewise sent him word by Mr. *Thomas Candish*, to do what he would in Alchymy and Philosophy, and none should controul or molest him: And not unlike, by the Queen's Example, divers Personages of Honour at Court frequented his Company, and sent him many Gifts from time to time; amongst others Sir *Tho. Jones* most nobly offer'd him his Castle of *Emlin* in *Wales* to dwell in free with all Accommodations.

His Favour was fair at Court, the Queen her self bad him find out something for her to bestow; yet all the Preferment he gained was (*Dec.* 8. 1594.) the Grant of the *Chancellorship* of St. *Paul*'s; and the 27th of *May* 1595, his Patent past the Great Seal for the *Wardenship* of *Manchester*, whither he, his Wife, Children and Family came the 14th of *Feb.* 1596. and the 20th Day following was installed, and in this Wardenship, (wherein he had the Unhappiness to be often vext with the turbulent Fellows of that College) died, deserving the Commendation of all Learned and Ingenious Scholars, and to be remembred for his remarkable Abilities.

After Dr. *Dee* came to *England*, as is before remembred, Correspondence was still maintained between him and Sir *Edward Kelly*, in Letters sent by Mr. *Francis Garland* and others (and some Expectancy of Sir *Edward*'s coming over (*Dec.* 23. 1589.) Mr. *Thomas Kelly* his Brother putting the Doctor in hopes thereof likewise.) But at length Sir *Edward* was clapt up close Prisoner by the Emperor (for he had so unwarily and openly managed the Secret, that it had given the Emperor occasion to carry a strict eye over all his Actions, out of a desire to be Sharer with him in his good Fortune) yet it seems the Emperor set him at Liberty (*Nov.* 4. 1593.) and Dr. *Dee* had notice of it the 5th of *December* after. And tho' he began to grow into the Emperor's Favour, in hopes to be entertained into his Service (for so he certify'd Dr. *Dee* by Letters in *August* 1595.) nevertheless he was clapt up again into Prison, and attempting to make his Escape out of a high Window, by the tearing of his Sheets, which were ty'd together to let him down, he being a weighty Man, fell and broke his Leg, and thereof died. This is one Report of his Death. Others there are, but Dr. *Dee* mentions none at all, of the manner thereof, only this: *Nov.* 25. 1595. *News that Sir* E. K. *was slain.*

Note, *That Two Presses being employed in Printing these Tracts, has caused a Chasme in the Pages.*

LECTURES

Lectures and Discourses

OF

EARTHQUAKES,

AND

Subterraneous Eruptions.

EXPLICATING

The Causes of the Rugged and Uneven Face of the EARTH;

AND

What Reasons may be given for the frequent finding of Shells and other Sea and Land Petrified Substances, scattered over the whole Terrestrial Superficies.

THE Treatise our Author mentions in the beginning of this Discourse I have not had the happiness to meet with among his Papers; possibly he might formerly have read some Discourses upon these Subjects, but if so they are lost, as I am satisfied some other valuable Papers are; if not, I know not well what he means, except some Hints in his Lectures of Light, and at the end of his Tract of Comets; Tho' I am rather of Opinion some of the following Papers were wrote before that of Comets: But of this Matter I can affirm nothing positively. This Discourse more particularly relates to the rugged and unequal appearance of the Earth's Surface, which he here endeavours to solve by successive Earthquakes and Inundations. I shall not (were I able) attempt to prepossess the Reader, nor longer detain him from the Authors own Discourses; only desire it may be observed, that the following Papers were read at several distinct times to the Royal Society, *and upon that Account not so methodically digested as they would have been had they been published by himself.*

R. W.

A Discourse of Earthquakes.

The Introduction to the following Discourse, giving some account of its Design.

I Have formerly endeavour'd to explain several Observations I had made concerning the Figure, Form, Position, Distance, Order, Motions and Operations of the Celestial Bodies, both as to themselves, and one with another, and likewise with respect to the Body of the *Earth* on which we inhabit. But conceiving it may more nearly concern us to know more particularly the Constitution, Figure, Magnitude and Properties of the Body of the *Earth* itself, and of its several constituent Parts, I have endeavour'd to collect such Observations and Natural Histories of others, as may serve to give some Light toward the making a compleat Discovery of them, so far as the Power, Faculties, Organs, and other helps that Nature has furnish'd Man with, may assist us in performing and perfecting thereof.

The Subject is large, as extending as far as the whole Bulk included within the utmost limits of the Atmosphere: And 'tis not less copious and repleat with variety, as containing all the several Parts and Substances included within those Limits, namely, The aerial, watery and earthy Parts thereof, whether Superficial or Subterraneous, whether Exposed or Absconded, whether Supraterraneal, Superterraneal, or Subterraneal, whether Elemental or Organical, Animate or Inanimate, and all the Species and Kinds of them, and all the constituent Parts of them, and the Composits constituted of them; of which also there will fall under Consideration, the Artificial as well as the Natural Causes and Powers effective of things; then their Generation, Production, Augmentation, Perfection, Vertue, Power, Activity, Operation, Effect, Conservation, Duration, Declination, Destruction, Corruption, Transformation, and in one word, the motion or progression of Nature sensibly exprest, or any other ways discernable in each of those Species. Which Subject, if we consider as it is thus represented, doth look very like an Impossibility to be undertaken even by the whole World, to be gone through within an Age; much less to be undertaken by any particular Society, or a small number of Men. The number of Natural Histories, Observati, ons, Experiments, Calculations, Comparisons, Deductions and Demonstrations necessary thereunto, seeming to be incomprehensive and numberless: And therefore a vain Attempt, and not to be thought of till after some Ages past in making Collections of Materials for so great a Building, and the employing a vast number of Hands in making this Preparation; and those of several sorts, such as Readers of History, Criticks, Rangers and Namesetters of Things, Observers and Watchers of several Appearances, and Progressions of Natural Operations and Perfections, Collectors of curious Productions, Experimenters and Examiners of Things by several Means and several Methods and Instruments, as by Fire, by Frost, by Menstruums, by Mixtures, by Digestions, Putrefactions, Fermentations and Petrifactions, by Grindings, Brusings, Weighings and Measuring, Pressing and Condensing, Dilating and Expanding, Dissecting, Separating and Dividing, Sifting and Streining; by viewing with Glasses and Microscopes, Smelling, Tasting, Feeling, and various other ways of Torturing and Wracking of Natural Bodies, to find out the Truth or the real Effect as it is in its Constitution or State of Being.

To these may be added Registers or Compilers, such as shall Record and Express in proper Terms these Collections; add to these Examiners and Rangers of Things, such as shall distinguish and marshal them into proper Classes, and denote their Excellencies or Gradations of differing Kinds, their Perfections or Defects, what are Compleat, and what Defective, and to be repeated, and the like.

So

So that we see the Subject of this Enquiry is very copious and large, and will afford Work enough for every Well-willer to employ his Head and Hands, to contribute towards the providing Materials for so large a Fabrick and Structure, as the great quantity of Materials to be collected do seem to denote. However, 'tis possible that a much less number may serve the turn, if fitly qualified and done with Method and Design, and it may be much better and easier.

When this mighty Collection is made, what will be the use of so great a Pile? Where will be found the Architect that shall contrive and raise the Superstructure that is to be made of them, that shall fit every one for its proper use? Till which be found, they will indeed be but a heap of Confusion. Who shall find out the Experiments, the Observations, and other Remarks, fit for this or that Theory? One Stone is too thick, or too thin, too broad, or too narrow, not of a due colour, or hardness, or grain, to suit with the Design, or with some other that are duly scapled for the purpose: This Piece of Timber is not of a right Kind, not of a sufficient Drineſs and Seasoning, not of a due length and bigness, but wants its Scantlings, or is of an ill Shape for such a purpose, or was not fell'd in a due time: 'Tis Sap-rotten, or Wind-shaken, or rotten at Heart, or too frow, and the like, for the purpose for which 'tis wanted.

The Use of pre-design'd Theories, and Modules of Enquiry.

I mention this, to hint only by the by, that there may be use of Method in the collecting of Materials, as well as in the use of them, and to shew that there may be made a Provision too great, as well as too little, that there ought to be some End and Aim, some pre-design'd Module and Theory, some Purpose in our Experiments, and more particular observing of such Circumstances as are proper for that Design. And though this Honourable Society have hitherto seem'd to avoid and prohibit pre-conceived Theories and Deductions from particular, and seemingly accidental Experiments; yet I humbly conceive, that such, if knowingly and judiciously made, are Matters of the greatest Importance, as giving a Characteristick of the Aim, Use, and Significancy thereof; and without which, many, and possibly the most considerable Particulars, are passed over without Regard and Observation. The most part of Mankind are taken with the Prettiness or the Strangeness of the Phænomena, and generally neglect the common and the most obvious; whereas in truth, for the most part, they are the most considerable. And the greatest part of the Productions of Nature are to be seen every where, and by every one, though, for the most part, not heeded or regarded, because they are so common. I could wish therefore that the Information of Experiments might be more respected, than either the Novelty, the Surprizingness, the Pomp, and Appearances of them.

Of figured Stones.

The obviousness and easiness of knowing many Things in Nature, has been the Cause of their being neglected, even by the more diligent and curious; which nevertheless, if well examined, do very often contain Informations of the greatest value. It has been generally noted by common, as well as inquisitive, Persons, that divers Stones have been found, formed into the Shapes of Fishes, Shells, Fruits, Leaves, Wood, Barks, and other Vegetable and Animal Substances: We commonly know some of them exactly resembling the Shape of Things we commonly find (as the Chymists speak) in the Vegetable or Animal Kingdom; others of them indeed bearing some kind of Similitude, and agreeing in many Circumstances, but yet not exactly figured like any other thing in Nature; and yet of so curious a Shape, that they easily raise both the Attention and Wonder, even of those that are less inquisitive. Of these beautifully shaped Bodies I have observed two sorts: First, some more properly natural, such as have their Figures peculiar to their Substances: Others more improperly so, that is, such as seem to receive their Shape from an external and accidental Mould.

Of Chrystals, and the like Stones, shot into Figures.

Of the first sort, are all those curiously figured Bodies of Salts, Talks, Spars, Crystals, Diamonds, Rubies, Amethysts, Ores, and divers other Mineral Substances, wherewith the World is adorned and enriched; which I at present omit to describe, as reserving them for a Second Part, they seeming to be, as it were, the Elemental Figures, or the *A B C* of Nature's working,

working, the Reason of whose curious Geometrical Forms (as I may so call them) is very easily explicable Mechanically: And shall proceed to the second sort of Bodies.

Of these are two kinds; either first the very Substances themselves converted into Stone, such are Bones, Teeth, Shells, Fruit, Wood, Moss, Mushrooms, and divers Vegetable and Animal Substances: Or secondly, such other Mineral or Earthy Substances, as Clays, Sands, Earths, Flinty Juices, *&c.* which have filled up, and been moulded in divers other Bodies, as Shells, Bones, Fruits, *&c.* but especially Shells. These, according to the Representations they bear of other Bodies, have received divers Names; of which *Aldrovandus*, *Bauhinus*, *Imperatus*, *Wormius*, and others, reckon a great number: Such are, *Cornu ammonis sine armatura*, *Helicoides*, *Hoplites*, *multiplex obscure lucens*, *muricatum*, *cristatum*, *cristatum pertusum*, *striatum Campoides*, *Campoides Echinatum*, *Caprinum cornu*, *Cornu Arietinum*, *Sceleton Serpentis*. *Conchites bivalvis striatus*, *Mytulus biforis*, *cinerius rugosus*, *Coclites*, *Chama lapidea*, *lævis*, *rugata*, *Ostracites*, *Pectenites*, *Bucardia*, *Strombites*, *Belemnitæ*, *Cornu fossile*, *Glossopetræ*, *Astroites*, *Entrochos*, *Colonetta*, *Lapis judaicus*, *Fungites*, *fungus saxeus*, *Lapis Indicus*, *Brontias*, *Brontias favogineus*, *Ombria*, *Ovum anguinum*, *Lignum petrifactum*. Of these I shall describe some few, because every one has not the Opportunity of seeing and examining them. *Of Petrifactions.*

As to the figured Stones or Petrifactions here mention'd, I found only one Sheet of the Descriptions of several of the Cornu-Ammonis *sort, with some of the* Echini, *or Helmet-stones, which Descriptions follow: As for the Designs of them, they were, I know not by what means, not to be found amongst his Manuscripts; but by the Favour of Dr.* Sloane, *into whose Hands they happily fell, I procured them for the Graver; to whom the World and my self are obliged for this, as well as for other more valuable Communications. The Five first Tables were design'd by Dr.* Hook himself; *and tho' he has not perfected the Descriptions of them all, yet I have procured them all to be graved, supplying in some measure my self those Figures which were left undescribed by him. The Two last I drew my self from some figured Stones I happen'd to meet with, not far from* Bristol, *some Years since; about which time I gave the Designs to Dr.* Hook, *together with a Particular Explication of the Figures; but by Misfortune did not keep an exact Copy of what I then gave him, which, amongst others of his Papers, is lost. I have endeavoured to supply this, as well as I now can, as the Reader may see by a short Account of a Letter I then sent him, with these Draughts; which I have so far presumed upon the Readers Acceptance, as to insert after the Explications of the Author's own Draughts.*

R. W.

I have designed 15 several sorts of Snail rather than Snake-stones, call'd by some Authors *Cornua Ammonis*, or *Sceleta Serpentum*, all of them, both of different Substances and various Shapes; but yet all of them agreeing in these Proprieties, that they were made of a Tapering or Pyramidal Body, coil'd up together, so as that the Tip or Point of it was in the Center, and the Base outmost; next that, in the coiling up, the Axis of this Pyramidal Body kept exactly in the same Plane. 3. That all of them were ridged or furrow'd with Rings, Furrows, or Proturberances and Depressions, which respected the Center of the Spiral, for the most part, but were moulded and rang'd each of them different ways, all of them very regular, and exceedingly ornamental. 4. That in the coiling the lesser and inner Parts sunk, as it were, always into the inside of the greater encompassing Part. 5. That all of them had Diaphragms, or separating Valves, whereby the Parts might oft-times be easily separated. 6. That the *Fimbriæ*, or Edges of these Diaphragms, were in most of these Stones very visible; in others of them, where they were somewhat more obscure, they might be made apparent, by scraping or rubbing away the outsides of them. 7. That these *Fimbriæ* or Edges appear'd on the Surface, like the Out-lines of some curious Foliage, a Specimen of some of which I have given in the 3d and 10th Figures. This,

upon Examination of them, I found to proceed from the Fulness of the Edges of the Diaphragms whereby the Edges were waved or plaited somewhat in the manner of a Ruff. 8. That most of them were covered with a very curiously polish'd, as well as curiously carv'd Surface, some of them shining like burnish'd Brass, as those of the 1st and 2d Figures; others like Brass, tarnish'd black, but rubb'd smooth; others of them like transparent Horn, as the 12th Figure; others like Coperas-stones; others like a coarser sort of white Marble; others like black Marble. 9. That from these polisht Surfaces one might oftimes easily pick off a Substance exactly resembling the plaited shining Substances of a Shell; and this did very visibly in many of them cover the internal stony Body, with a Coat two or three times as thick as a Snail's Shell. 10. That the biggest end of these Spiral Bodies was always imperfect without any determinate Figure. 11. That many of these Spiral Bodies seem'd, as if they had been broken and shatter'd, and had grown together again in an irregular Posture. 12. That many of them were compounded of several Substances, the Spaces between the Diaphragms being sometimes fill'd with one kind of Substance, sometimes with another, and sometimes they were found empty, only all the sides of the Diaphragm were cover'd with a kind of Tooth-Sparr. 13. There were many of these which were at first included in Stones, out of which they might easily be separated, so as to leave a perfect Impression like themselves; but in most of those incompassing Bodies, the Impression was bigger than the impressing Body, by the thickness of a thin Shell, which seemed to have been heretofore the Cause of both Impressions, but was worn away and decay'd by the Injury of time; they differ'd one from another chiefly in these Particulars: First, That the Bases or Planes supposed to cut these spirall'd Bodies at right Angles, with the Circumference and Plane thro' the Axis, were of different Figures; as that of the first Figure was much like that of a common Nautilus, being somewhat like the Figure of a Turkish Crescent; but the Diaphragms were not smooth and plain like those of a Nautilus, but full and ruffled like the Leaves of Sea-wrack, and several other luxuriant Vegetables, and that (which appear'd by the Foliage visible on the Surface) the Diaphragms were much thicker and closer together: This on the outside was like polish'd Silver, but the inside of a Substance not much unlike blue Slate, but closer, harder, and heavier. That of the 3d Figure was of a Figure, as if the former had been press'd quite flat; so that instead of the round Back in the 2d Figure, this has a Back terminated with a sharp Edge, as in the 4th Figure, 'tis all over almost cover'd with a shining Substance not unlike a Substance we call Alchimy, or whited Brass; on this the Foliage of the Edges of the Diaphragms is very visible, one of which I have described in its posture, as at *a*, and 3 others of them, that the Curiosity of them might be the more visible, I have described by the help of a Lens in the 5th Figure. Somewhat like to this is that of the 6th Figure; but that instead of an edged Back, this is hollowed or furrowed not unlike the Wheel of a Pully, with two protuberant Ridges on either side, as is visible in the 7th Figure; the Surface is undulated like the former two, but somewhat more manifestly, the Fashion of which Waves are not unlike the Ribs of wicker Screens, 2, 3, 4, and sometimes more of them uniting at last together into one more conspicuous Rib which crosses the Center; the other side of this was broken so that the Diaphragms and several hollow Cavities between them were to be seen, 'twas of a Substance somewhat like the Rust of Iron. That of Figure the 8th was of a Substance somewhat like *Portland*-stone, but closer and harder. The transverse Section of it was much like the former, as may be seen in the 9th Figure: The Back of it was gutter'd and knobbed very like a *Japan* Nautilus, one of which I have in Mr. *Colwall*'s Gift: The Ribs also, or Furrows of the Side were not much unlike, only they were somewhat finer wrought with Knobs or Buttons, as may be perceived by the Figure. The Knobs and Surface of the 10th was somewhat like this, but that they were a little more gross, as is visible by the Figure; this was of the Colour of a Bone that has been long buried in the Ground, and of a stony Substance almost as hard as a Flint; the outward Shell that seems to have cover'd it, was quite worn away, and all the Partitions

or


Tab: I.a p: 283.
fig: 7.
Fig: 8.
fig: 9.
Fig: 12.
Fig: 26.
fig: 24.
fig: 25.
fig: 6.
fig: 15.
fig: 14.
fig: 16.
fig: 17.
fig: 22.
fig: 23.
fig: 19.
fig: 18.
Fig: 1.
Fig: 3.
fig: 4.
fig: 13.
fig: 2.a
fig: 5.
fig: 11.
Fig: 10.
Fig: 29.
Fig: 27.
fig: 21.
fig: 28.

or Edges of the Diaphragms were most conspicuous, the transverse Section you have in the 11th Figure. The Snail-stone describ'd by the 12th Figure was of pellucid Pebble, and look'd almost like Horn; that this had Diaphragms also, is evident by the end of it, which is bounded by one, as may be seen by the 13th Figure, which shews also the transverse Section of it. It had a Spine or Quill *a*, coiled about the back of it; the biggest part of which was broken off, and only the hollow part of the Quill of the Shell was left, as at *b* in the 12th: But at *c* the Quill was intire, and the Substance that fill'd the hollow of it, was transparent Pebble like the rest of the Stone; the incompassing Shell was much worn away, only in some Parts of it 'twas visible enough.

The small one in the 14th Figure was much of the same Make, the Shell that covered it was black like the other, its End was also terminated by a Diaphragm, as is visible in the 15th Figure, where the transverse Section is also describ'd; but the Substance that fill'd it was quite differing, being a kind of Pyrites or Coperas-stone. The small one of the 16th Figure was of a Shape participating of the 1st and 3d, the transverse Section of it shewing it to be thinner than the 1st, but thicker than the 3d, was terminated by a Diaphragm very finely leav'd, and with viewing it very intensely, I could perceive the Sutures very finely wrought, much like those of the 5th Figure: It was fill'd with a black, stony Substance, and on the other Side of it (being a little broken) several of the Cavities between the Diaphragms appear'd empty. The little Part of one describ'd in the 18th Figure, was compounded as it were of the 8th and 14th, as may be seen by the transverse Section of it. Fig. 19. This, as the rest, had visible Diaphragms also, 'twas of a Substance like rusty Iron: These preceding were all of them of a Figure that taper'd very much, so as the Spiral from a very large Circumference, was presently contracted into a little one; but the following were of a Figure more protracted, and made many more Revolutions before they ended. Of this kind the 20th was the plainest, resembling that of the first of the other kind; 'twas ribb'd not much unlike it, and the transverse Section was much the same with that of the 2d Figure, as is visible in the 21st Figure.

The 22d was somewhat like the 12th, but of a smaller Spiral; it was terminated with a Diaphragm, and had a small Spine or Quill which was laid round the Back of it, as may be seen by the 23d Figure; the Shell of it was yet sticking on it, and it look'd very like burnisht Brass; it seem'd to be a very hard Stone. The 24th somewhat resembled the 14th, the Surface of it may be perceiv'd by the 24th, and the transverse Section by the 25th Figure; 'twas a Pyrites, and one part of it was dissolv'd into Salt by the Air: I had two or three others of the same shape, one of a kind of grey Marble, another of a Flint, a third of an iron Stone, which I have describ'd in the 26th Figure, the Stone incompassing it, and the filling of the Shell it self being both of the same Substance: One of these was bruised in the hardning, so that the Cracks of the Shell were very visible; the like Accident was common to many of the rest, and the Shell encompassing was of a distinct Substance from the rest, and was easie to be pick'd off. But the prettiest of all the rest was the 27th, where the several Coats of the Shell and Diaphragms were very distinct, tho' they seem'd to be all petrify'd and turn'd to another Substance. It had been very much broken before the hardning, and all the Cracks of the Shell were very distinct; and which seem'd a little strange, some Parts of it were thrust outward, as if it had been fill'd with Water; and, by Congelation, the Ice had swell'd and broken out the sides of it, which probably might be the Cause; for all between the Diaphragms it was fill'd with a transparent Spar or Caulk, such as is usually dug out of Lead Mines, a Substance between Crystal and Talk; the Original of which Substance seems to me not unlikely to be congeal'd petrifying Water; the Voluta of it was curiously ribb'd or moulded, and the Foliage or Edges of the Diaphragms were very Ornamental. It had a Spine or Quill went round the back of it, as several of the former; the transverse Section you have in the 28th Figure.

The

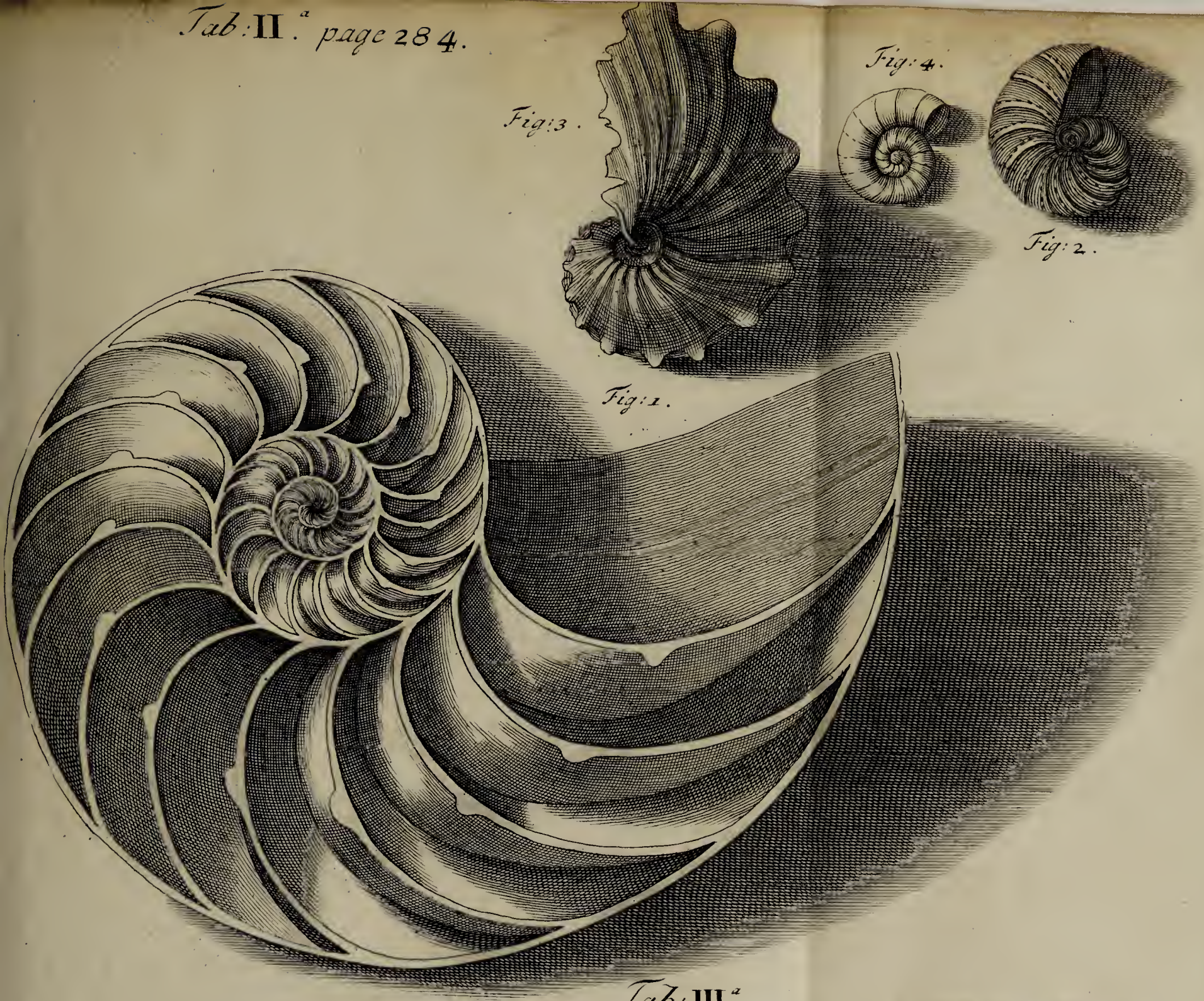
The Surface of the 29th was of a peculiar kind of carving, as is visible by the Figure; it was of a reddish Flint, the outside very smooth and polish'd, the side not visible was not so perfect, being broken in several places, and discovering the Diaphragms, and that some of the interjacent Spaces were empty. The greater End of this looking very irregular, I broke with a smart stroke of a Hammer a little piece off from it, and discover'd two small Snakes-stones within it, which probably had been tumbled into the Mouth of it before it was concreted; for they were of the very same Substance, but of a differing Figure from any I have yet describ'd, being ribb'd like the 24th, but only they were bigger and farther distant, and they went quite round the back. This last, and another like the 24th were taken up near *Keinsham*, about 4 or 5 Miles from *Bristol*, and sent by Dr. *Beal*, whence also I suppose several of the other may have come.

Had they not been much too large, I would have describ'd also one or two of those *Cornua Ammonis*, presented to the Repository by the Right Honourable *Henry Howard* of *Norfolk*, which are in Diameter about 2 ½ Foot, and the concave Impression of one of a greater Magnitude, which I found in a Piece of *Portland*-stone. These large Stones are between 300 and 400 Weight, and of a Stone in all Particulars much like *Portland*-stone, whence I suppose they were at first fetch'd: They are all shap'd much like that of the 20th Figure; but the coiled Cone is not altogether so round, nor so slender, or of so acute an Angle, but the Undulations of the Surfaces are alike, and so are also the Diaphragms. I have been also told by Persons of very good Credit, that they have seen in *Darbyshire* and *Yorkshire* Snail-stones of a much more prodigious bigness, 3 or 4 times as big as these; which I have not had an Opportunity to send to enquire more curiously into, though I have much desired; and so much the rather, because it seems much more to excel in bigness all other Shell-fishes we know, than the Giants (Stories tells us of) did exceed the ordinary Size of Men now living.

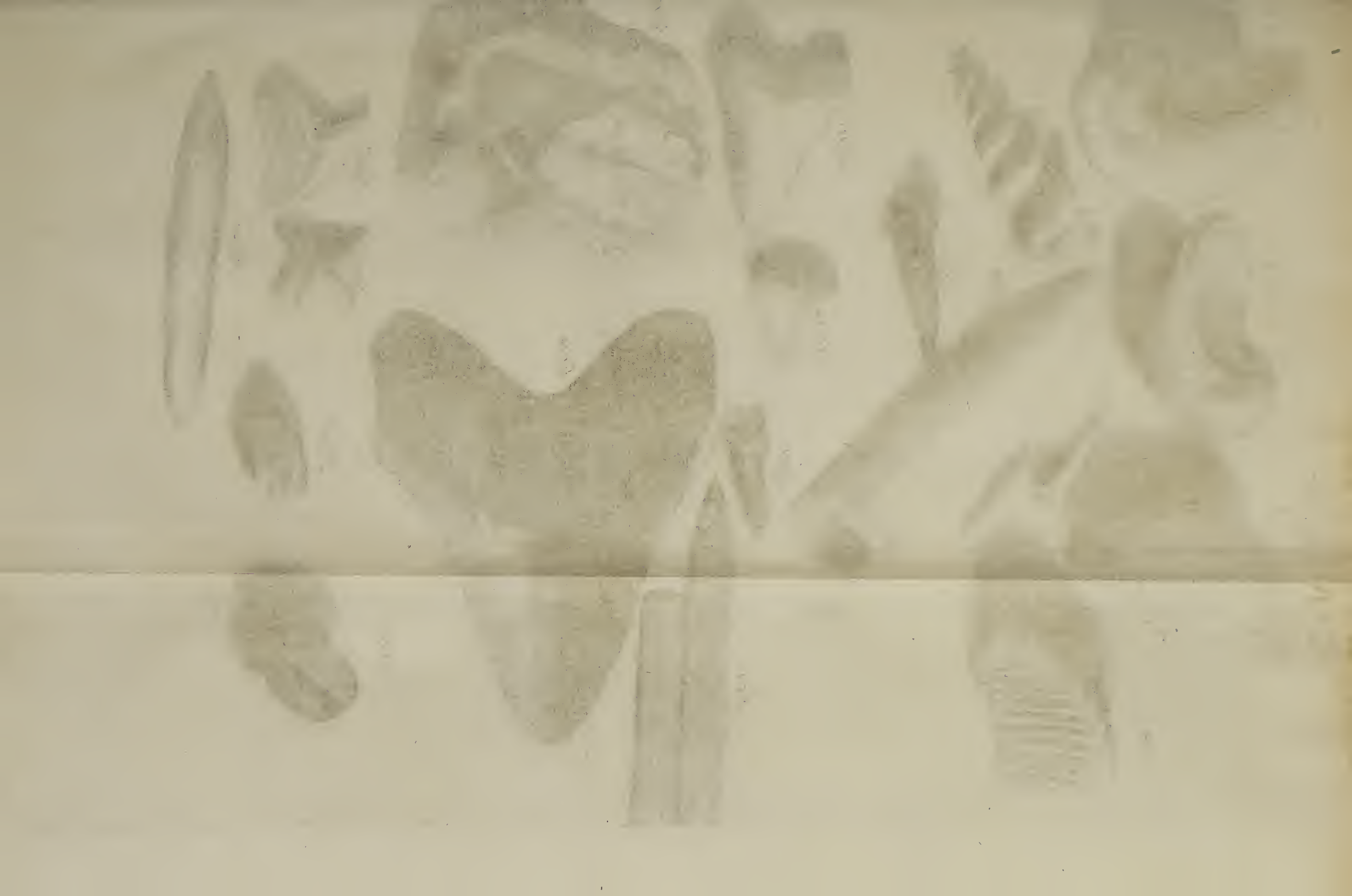
I have, to parallel these Snake-stones added in Table II. a Description of three several sorts of Nautil-shells, because I had no greater variety by me, though I have seen many other kinds. The 1st Figure represents a large Nautilus-shell cut *per axin*, and manifests the manner how the Diaphragms are placed in that kind of Shell in the concave Part thereof; and the 2d Figure shews how they are placed up the convex side; this being a small Piece of the middle of a Nautilus-shell, and the wreathed Lines shew where the Diaphragms join'd upon the back thereof. The 3d Figure represents a *Japan* Nautilus-shell, crenated on the sides, and knobbed on the back, much in the manner as several of the Snakes-stones are. The 4th Figure represents a small Piece of a peculiar kind of Nautilus, whose conical Body is divided by small Diaphragms under every of the black circuling Lines, and is coil'd so as its roundness is kept, and the Parts do not touch one another. The Name of it I know not, being no where describ'd by any Author.

In Table III. I have described some sorts of Helmet-stones, of which I have a very great Variety, and it would have been tedious to have added them all in this Place. I have likewise described three sorts of Button-stones, all, and every of which seem to have been nothing else but the filling up of several sorts of Echini-shells, of which the European Coasts afford a great Variety. The 1st, 2d, and 3d Figures, represent three several sorts of Button-stones, all of them of very hard Flints, two of them, namely the two less, join'd to, or shap'd as 'twere out of irregular Pieces of Flint of the same Substance. They have all of them this in common with all the other sorts of Helmet-stones, that they have two Parts, which seem to have been the fillings up of two Holes or Vents in the Shell, and they are divided into five Parts, though every of them of distinct Shapes, as may be seen by the Figures. That of the 1st Figure also hath this Property, in common with the finer sort of Helmet-stones, that it exhibits the Sutures or Junctures of the Shell, as are more plainly to be seen in the 4th, 5th, and 6th Figures. The 4th Figure represents a Helmet-stone, look'd down upon almost directly,

Tab: II.a page 284.



Tab: III.a



Tab: IV. page 285.

rectly exhibiting the Impressions of the several Holes, Sutures, and Cracks that appear upon the top of one of these Stones. The 5th and 6th Figures represent another Helmet-stone of the same kind with the former, but less look'd upon against the bottom and side, exhibiting the Impressions of the several Holes, Sutures, and Cracks, that were in the imprinting Shell from which these Stones receiv'd their Shape: These were both of a kind of grey Flint. The 7th Figure represents the bottom of another sort of Helmet-stone, where the Vents *a* and *b* are placed in another manner, than they were in the 1st, 2d, 3d, or 5th Figures. The 8th and 9th Figures represent the bottom and top of another sort of Helmet-stone, which seems to be the filling up of a kind of *Echini*-shell, very like to those found in *Devonshire* and *Cornwal*, one of which I have delineated in the 10th Figure: This last kind was of Chalk. I have several other sorts, which I have not now time to delineate, some of transparent Pebbles, some of Marble, some of a Stone as hard as *Portland*, some of black, red, grey, and other Flints, some of Coperas-stone, some of other kinds of Stone, none of Spar. I would to this have added the Description of a great Variety of *Echini*-shells, divers of which I have by me in the Repository of the Royal Society, and others that I have met with elsewhere, but that I shall do it elsewhere: They are indeed almost infinite, but all concur in these Properties which all Helmet-stones likewise have. First, that they are distinguish'd into five Parts, by Sutures, Ribs, and Furrows. Secondly, that they have two Vent-holes: They have divers of them also little Edges, being the Impressions of the Sutures, and divers little rows of Pins, being the Impressions of the small Holes; and any one that will diligently and impartially examine both the Stones and the Shells, and compare the one with the other, will, I can assure him, find greater reason to perswade him of the Truth of my Position, than any I have yet urged, or can well produce in Words; no Peswasions being more prevalent than those which these dumb Witnesses do insinuate.

TABLE IV.

THE Figures of this and the next Table were left undescribed by Dr. Hooke, *which Defect I have endeavoured to supply in some measure. Fig 1st and 2d represent a sort of Shell, of which I think we have no Species now described; they are very thick and heavy: Of this sort I found one upon the Sand, on the side of the* Severn *about* 8 *or* 10 *Miles from* Gloucester; *it was a perfect Stone. Fig. the 3d, another unusual shaped Stone exceeding thick and heavy. I know not what the 4th is, it shews something like the Spine of some Fish. Of the 5th Figure I have seen several, and is well represented; they call them in that Country* Screw-stones. **The rest of the Figures in this Table shew several sorts of Sharks-teeth, except the 18th and 19th, which seem to be the Shells of some Fish. The 10th Figure shews the Make of the inside of one of those long Teeth, if they are so, of which I think not many now doubt; in this the manner of the Fibres radiating from the Center, is very conspicuous.* † *At the Basis of the 8th Figure, is observable the very great Cavity, as likewise the largeness of it. The 14th Figure represents one of thi largest* Glossopetræ *that has been seen. Upon the 16th and 17th Figure Dr.* Hooke *makes this Remark, that there are* 220 *of them in the Fishes Mouth. What the 15th is I know not, except it be a petrify'd Grinder bedded in Stone.*

* 'Tis figured by Dr. *Plott*, in his Natural History of *Oxfordshire*, *Tab.* 4. *Fig.* 1.

† 'Tis true these have by former Writers been thought *Lapides sui generis*, and call'd *Belemnites*. I shall wave the Dispute.

TABLE. V.

FIGURE the 1st, the petrified Grinder of some large Animal, possibly of a Whale or Elephant. Dr. Grew, *in his* Museum, *says of a Sea-Animal.*

Fig. 2. *a petrify'd Crab, very much resembling the Fish it self.*

Figure the 3d, 4th, 5th, 6th, 7th, 8th, and 9th, I take to be Pieces of petrify'd Wood, tho' I know they have been otherwise esteem'd by some Writers. Whether the 14th may not be the same, I will not determine. The 10th, 11th, 12th, and 13th, I take to be some sorts of petrify'd Fruits, or possibly some of them Seed-vessels. The 15th and 16th Figures are the Astroites or Star-stones, of which one is given

separate in the 16th. These in our Author's Opinion were Pieces broken off from the numerous Legs of that sort of Star-fish, of which one was many Years since sent from New England, *if I mistake not, and is now in the Society's Repository: It is described in the Philosophical Transactions, publish'd by Mr.* Oldenburg *by the Name of* Piscis Echino-stellaris Visci formis. *The 17th Figure I take for a sort of* Fungus *petrify'd.*

Philos. Trans. N. 50. p. 1153.

It is a great Misfortune that the Descriptions of these two Tables are wanting amongst the Papers, if they were ever drawn up, which I somewhat question; for the Figures were not number'd: For had he done it himself, he would have made several very considerable Remarks; which if I could, is not so proper for me to attempt; nor do I know any thing of the History concerning the Places where they were found, or the like: However I judged it not convenient they should be lost; and therefore ordered them to be graved, and have ventured this imperfect Description. What follows next, is the Abstract of a Letter I sent him from Bristol, 1687.

R. W.

Bristol, Aug. 17. 1687.

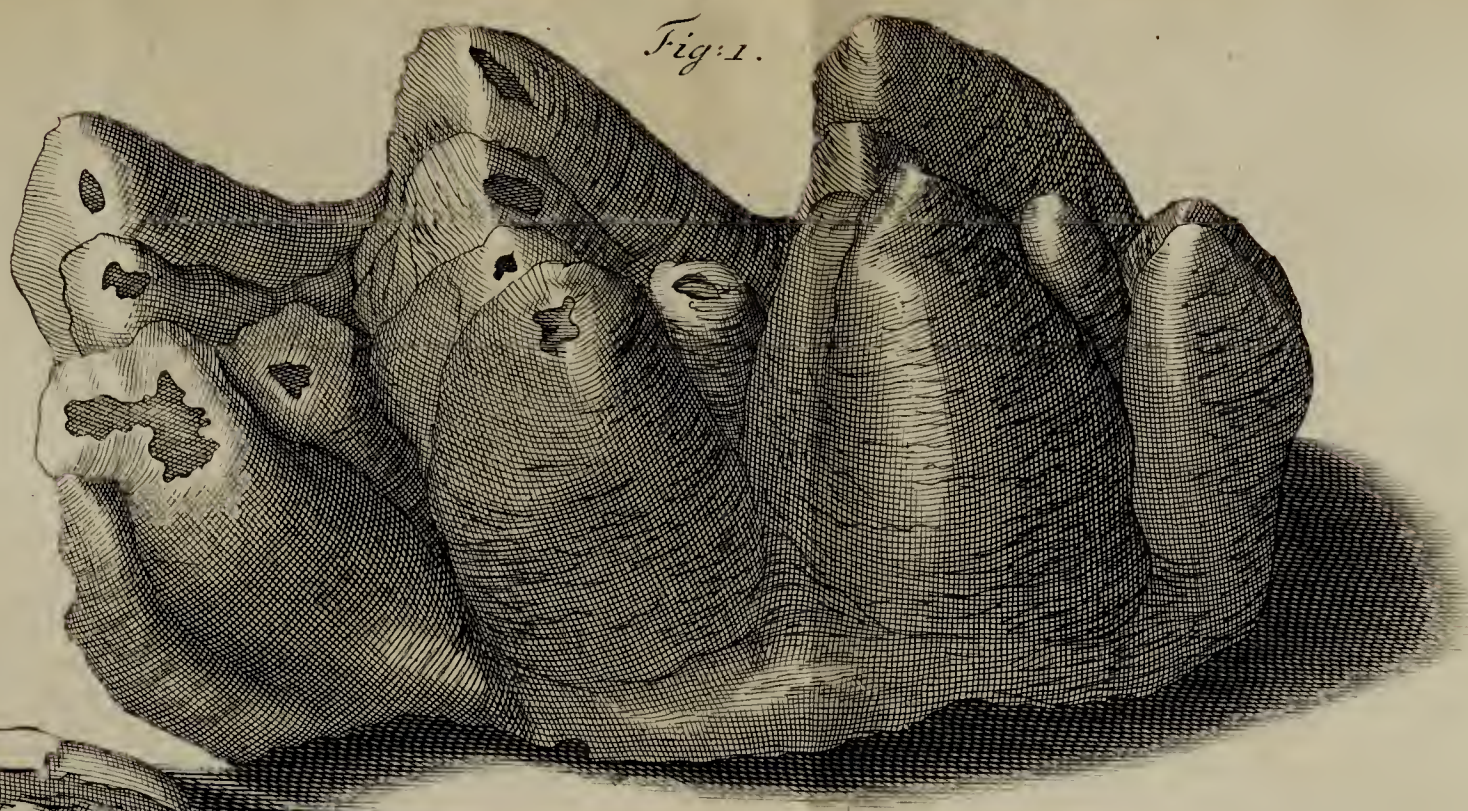
SIR,

IN answer to some of your Enquiries, as to the *Cornua Ammonis*, and other Shell-like Stones found about *Keinsham*, and other Places, I shall give you this short Information of my Discoveries, and present you with the Draughts of some I happen'd to meet with there, and in other Places not very far distant, that is, in Part of *Gloucester* and *Somersetshire*.

The *Cornua Ammonis*, near *Keinsham*, lie most of them upon a little Hill, or rising Ground, above *Keinsham*-Bridge; the Place, as I take it, is about 18 Foot above the River: The River there runs half round the Foot of the Hill, where they lye very thick almost to touch each other, and are all of the large sort bedded in an hard Rock or Stone; some also I found near a Mile from thence in the Stone-walls of their Fields, and on the way in the Lanes; and at *Stowey*, four or five Miles from *Keinsham*, I saw some Snake-stones, Oyster, and Cockle-shells petrified and bedded in hard Stone, where is also a petrifying Spring incrustating the Moss and Grass, and all the wooden Troughs, by which it is conveyed with a stony Substance. Where they are not found fastned to a Rock, I found them encompassed in a pretty large irregular Mass of Stone, not sandy, but rather like a whitish Clay harden'd, and these stony Masses bedded in a loamy kind of Earth; in which soft Earth are also found Star-stones, and a sort of petrified Cockle-shells, such as Fig. 7. Tab. VI. I found none of the Snake-stones to have above 6 Turns, except one Mr. *Beaumont* shewed me of seven, and another amongst Mr. *Cole*'s Rareties. But that which I esteemed the greatest Curiosity, was a large Stone of the true Shape and Figure of the common *Nautilus*, or Mother of Pearl-shell, which tho' but a part of the whole Shell, weighs about 30 pound: This I found in one of the dry Walls, near *Keinsham*, and not far from it another Piece of the same; these are figured in the VIIth Table, Fig. 1, 2, 3, 4; and in these not only the Diaphragms are very visible, but the Holes also in the middle of them, by which the Gut or String passes from one to another, in all respects answering to that of the *Nautilus*-shell; which, I think, will evince this at least to be a petrify'd Shell, tho' much larger than any of that kind that have been yet mention'd. Going down from *Mendip*-hills to *Okey*-hole, I found a small Muscle-shell petrify'd, on this the Shell was yet discoverable in some Places; this is figured, Tab. VI. Fig. 1.

On the Face of the Rocks that are on the sides of the *Avon*, not far from St. *Vincent*'s Rock, I found several wood-like Pieces of Stone standing out a little from the Rock it self; some of which I have broke off, and have represented them in the Figures, Tab. VII. Fig. 5, 6, 7, and 8, and some such like Bits of Wood in the Earth between the Layers of Stone unpetrify'd. But I shall at present detain you no longer, but for a more exact Information refer to the Figures themselves; which I can assure you are truly design'd, and are all Stones or Petrifactions, except the 6th Figure.

Tab.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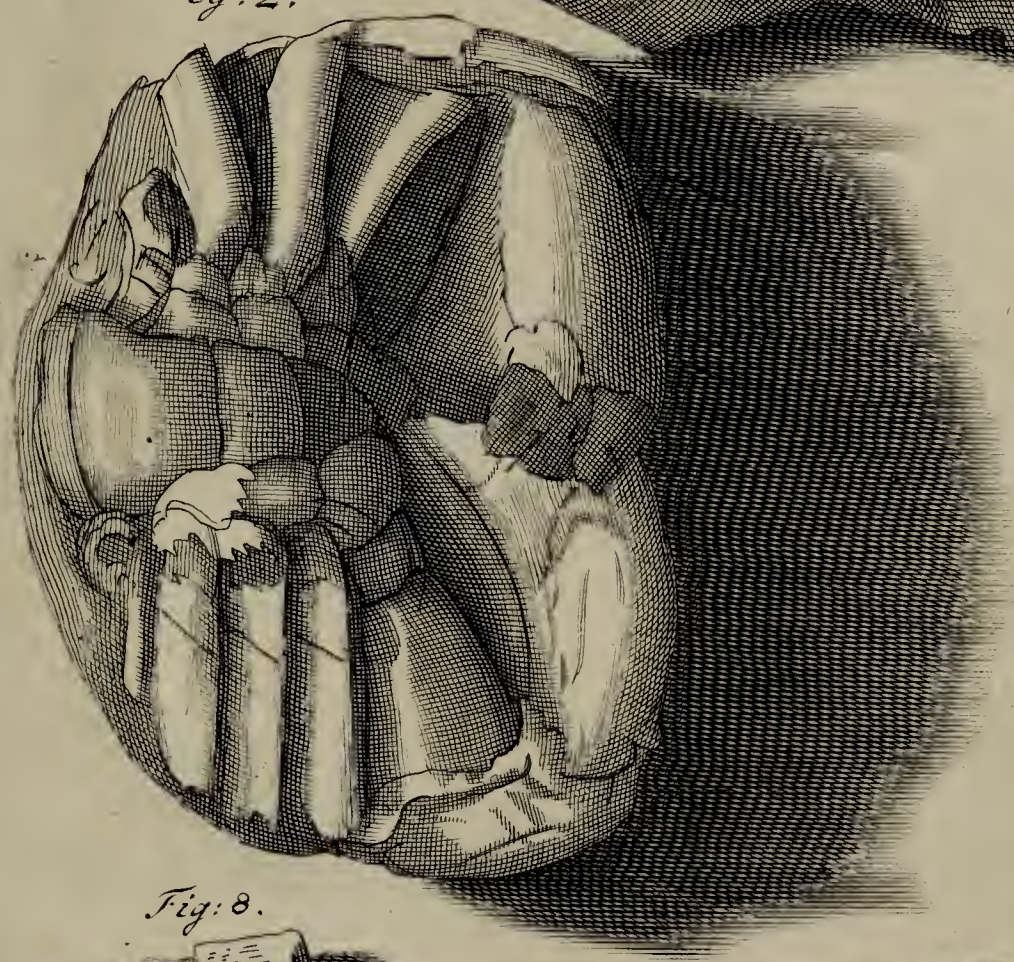
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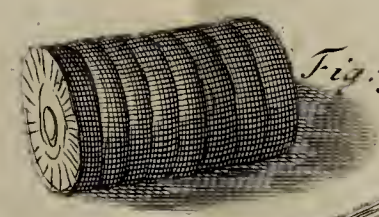
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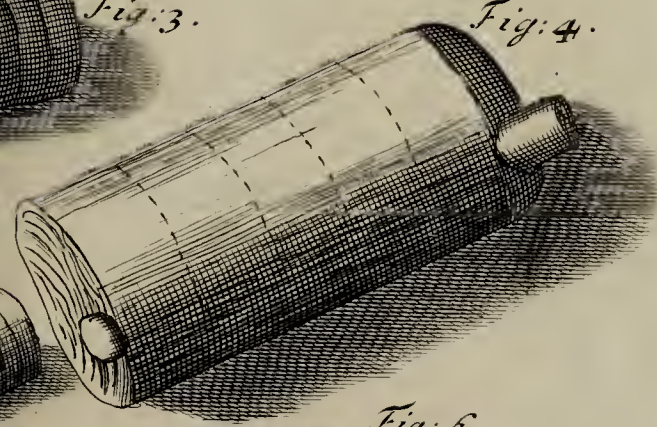
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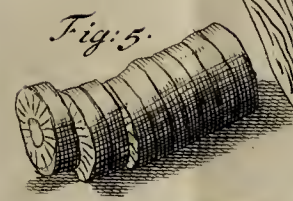
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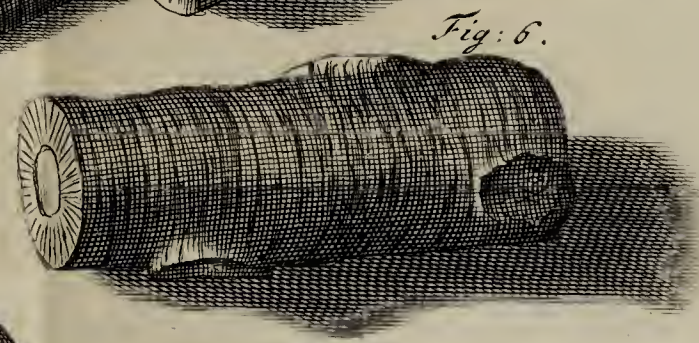
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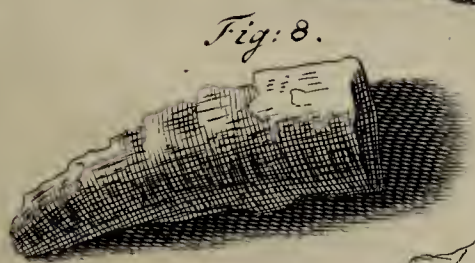
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Fig: 12.

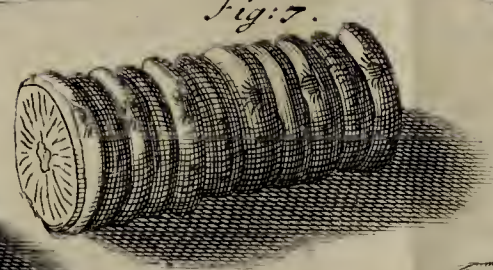
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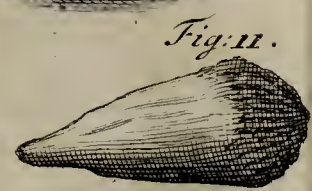
Fig: 10.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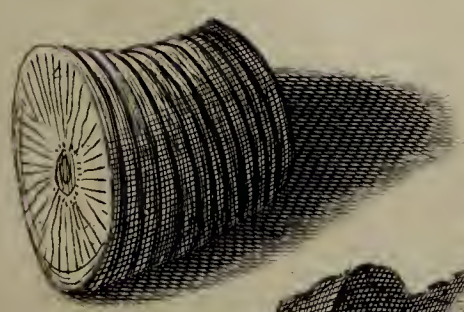
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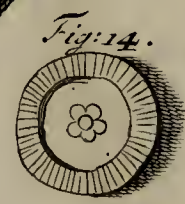
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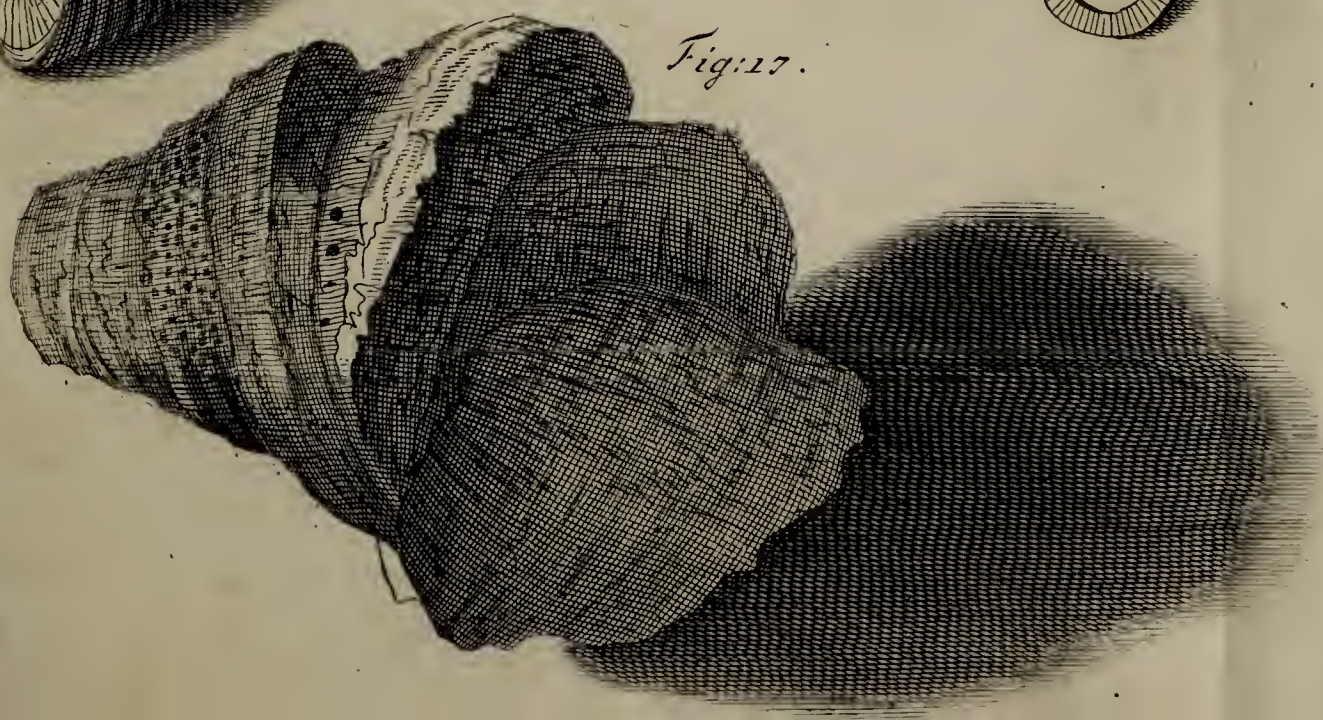
Fig: 16.


Fig: 15.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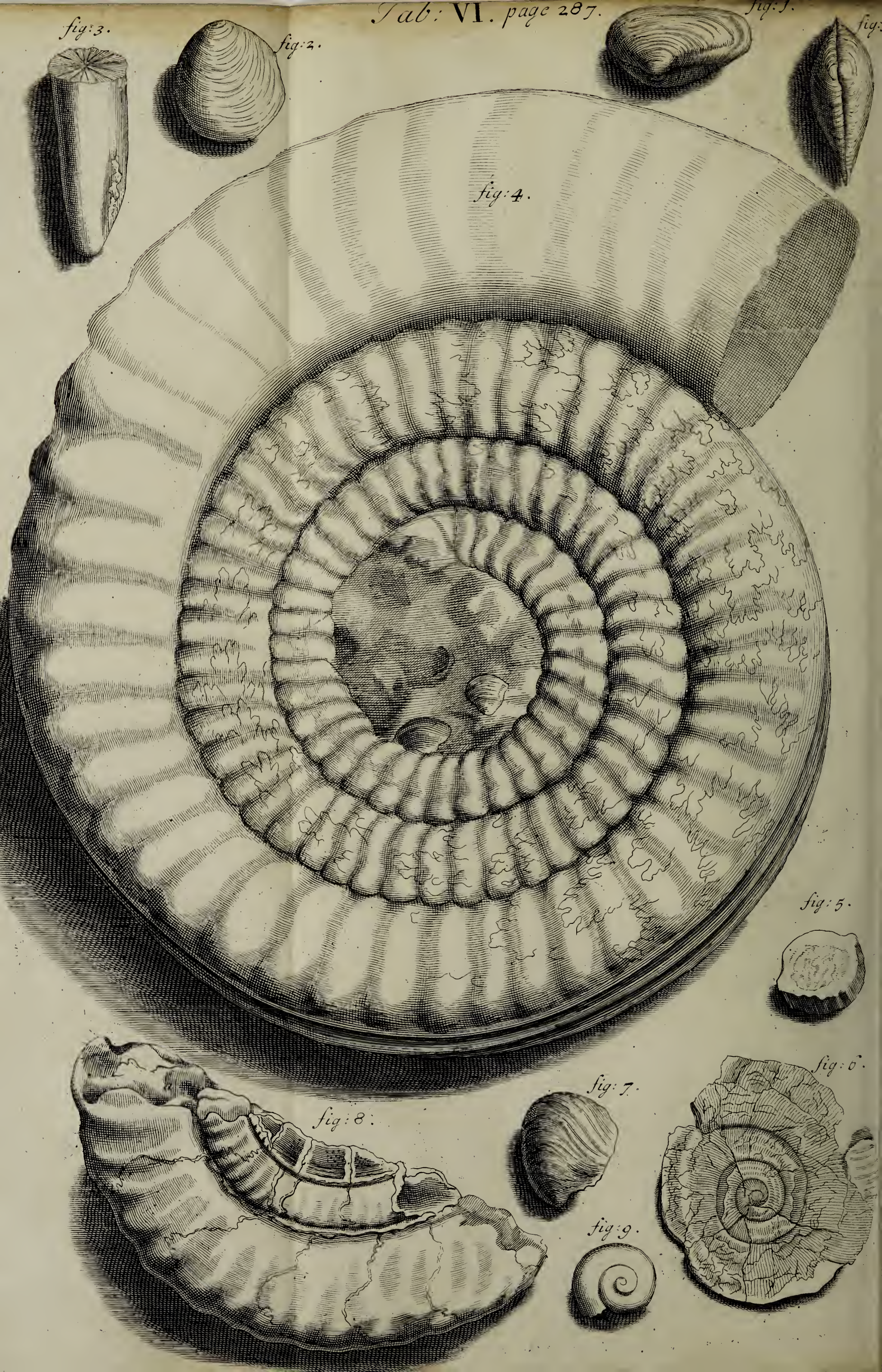
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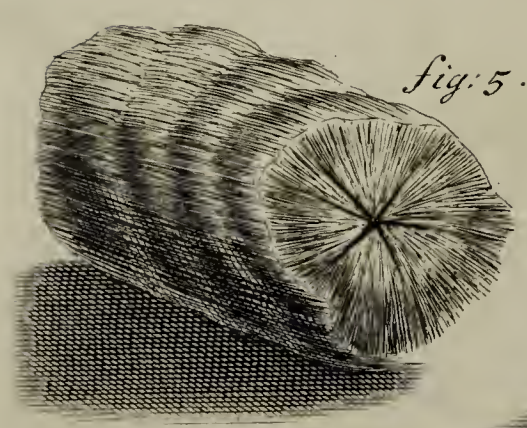
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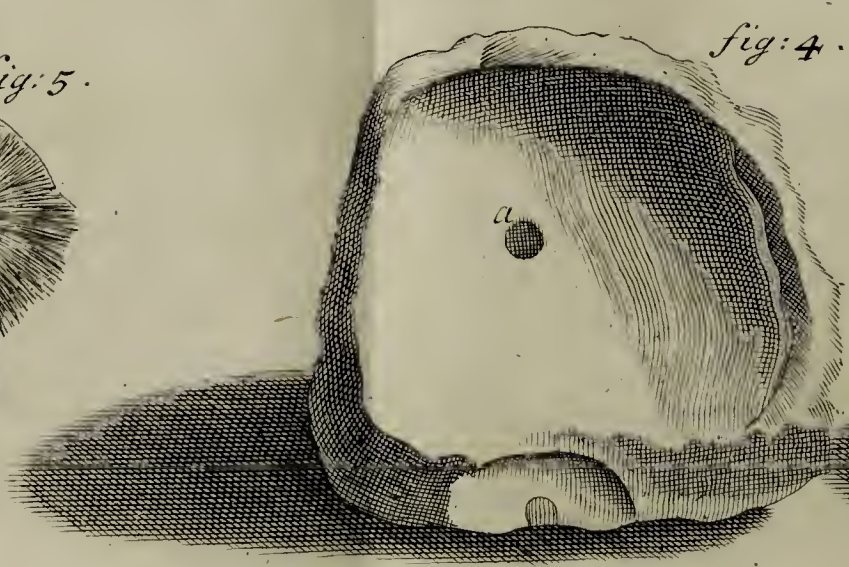
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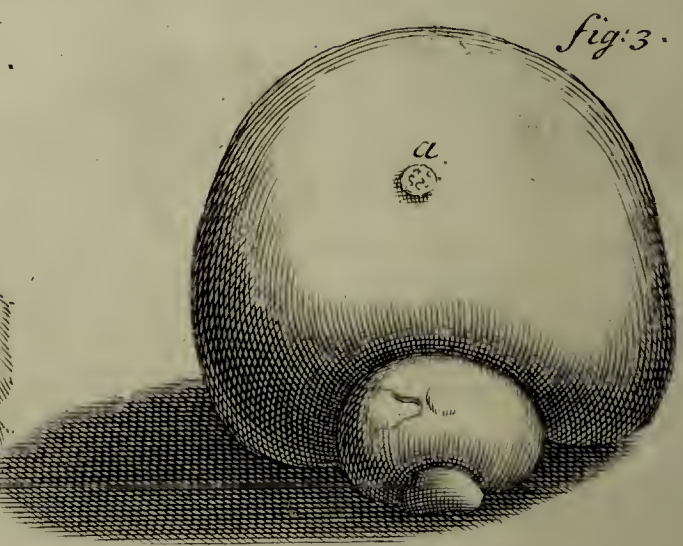
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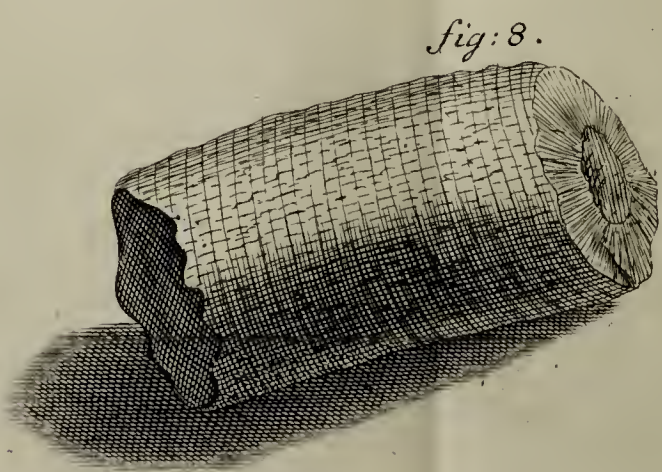
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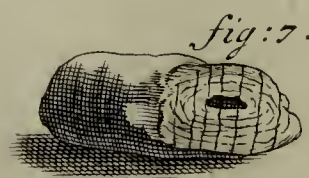
fig: 7.


fig: 6.

Tab. VI. Fig. 1. represents two Views of a sort of Muscle-shell found near *Okey*-hole.

Fig. 2. a sort of Cockle, on this likewise part of the Shell was visible.

Fig. 3. a Piece of a *Belemnites*, these are of the true bigness.

Fig. 4. a large *Cornu-Ammonis*, about 18 Inches Diameter; there are much larger to above 2 Foot, but this was one of the most perfect and neat I could find; on this the curious Foliage (as I may call it) of the Diaphragms was very visible, as is represented in the Figure, and near the Center several small Shells petrify'd: This I had from *Keinsham*.

Fig. 5. I know not what to make of, except it be one joint of the Spine of the Back of some Fish; something like it I have seen in the Backs of Salmons.

Fig. 6. a sort of *Nautilus*-shell not petrify'd, being still visibly a Shell broken, squeezed and flatted to the thickness of an Half-crown; the several Fragments were each roundish, and stuck together with a kind of blewish Clay. This was given me by Mr. *Cole*, who told me there had been several of them found amongst the Rocks and Stones in Quarries.

Fig. 7. another sort of Muscle or Cockle; these are frequently found about *Bristol*, particularly on the top of St. *Michael*'s Hill on the Road, and near the Gallows bedded in the Earth, not Stone, but are themselves an hard Stone, and very thick and strong.

Fig. 8. a Piece of a broken *Cornu-Ammonis*, in which several of the Diaphragms are very visible, the hollows not being fill'd up, but shot on the sides with a sort of flinty, hard, and transparent Spar.

Fig. 9. a small *Cornu-Ammonis* of but three Turns, yet seems perfect and unbroken; I know not whether it has any Diaphragms.

TABLE VII.

FIG. 1. shews the large Stone of the Common Nautilus-shape, in which *d d d d* shews the Diaphragms to be seen on the outside of the Stone; as far as *f* is the larger Piece, which weigh'd near 30 Pound; from *f* to *g* is a lesser Piece, in which also the Diaphragms are visible on the outside *d d d*, and likewise on the inside, where the Piece was broken cross, some of the Diaphragms appear; as at *a a a*, *e e*, shews part of the Shell still sticking to the outside: *i i i* is a small Piece of the Center of the Stone, being only as much as makes 3 Diaphragms; the prick'd Lines *b* and *c* shew where the Stone should have been to have made it perfect: This is drawn not a quarter so large as the Stone it self.

Fig. 2. another Piece of the same sort found at another Place in *d d d*, are the Diaphragms, *e* a part of the Shell remaining: These shelly Parts are of a different Substance from the rest.

Fig. 3. a Piece of the same Stone near the Center, with the lesser part *c*; these have at *a* and *c* a protuberant part, being the hole of the Diaphragm.

Fig. 4. a Piece taken off from the former, in which at *a* and *c* are two small Cavities, answering the Protuberances *a* and *c* in the third Figure; *e* the edge of the thin Shell which covers all the part from *e* to *a*.

Fig. 5, 6, 7, 8, Pieces of Stone resembling Wood petrify'd, of which the 6th is of several small Bits sticking to the hard Stone; this I broke off from the Rock; as also the 7th, wherein the cross Lines shew the ends of the long Fibres cut aslope; this exactly resembled a small Stick cut slanting. In the middles of the 5th and 7th was a Cavity in the place of the Pith. The middle of the 8th was filled with a stony Concretion very hard, as were all these Pieces, but something different from the rest of the Stone.

Yours, R. W.

These, and the like Shapes, because many of them are curious, have so far wrought on some Men, that they have endeavoured to give us an Explication of the manner of their Formation; in doing of which they have so far rambled from the true and genuine Cause of them, that they have left the Matter much more difficult than they found it. Amongst the rest, *Gaffarel*, a

French

French Writer, seems not the least mistaken, who has transferr'd them over to the Confirmation, as he thinks, of his Astrological and Magical Fancy; and thinks that as they were produced from some extraordinary Celestial Influence, and that the Aspects and Positions of the fix'd Stars and Planets conduc'd to their Generation, so that they also have in them a secret Vertue whereby they do at a distance work Miracles on things of the like Shape. But these, as fantastical and groundless, I shall not spend time on at present to refute, nor on the Conjectures and Hypotheses of divers others; which though perhaps somewhat more tolerable than that I last recited, yet most of them have recourse to some vegetative or plastick Vertue inherent in the Parts of the Earth where they were made, or in the very parcels of which they consist, which, to me, seems not at all consonant to the other workings of Nature; for those more curiously carved and beautiful Forms are usually bestow'd on some vegetable or animal Body. But my Business at present shall not be so much to confute others Conjectures, as to make probable some of my own; which tho' at the first hearing they may seem somewhat paradoxical, yet if the Reasons that have induced me thereunto be well consider'd and weigh'd, I hope at least they may seem possible, if not more than a little probable.

Enumeration of the Phenomena.

The particular Productions of this kind that I have taken notice of my self in my own Enquiries, and which I find dispersed up and down in the Writing of others, may be reduced under some one or other of these General Heads or Propositions.

1. First, That there are found in most Countries of the Earth, and even in such where it is somewhat difficult to imagine (by reason of their vast distance from the Sea or Waters how they should come there) great quantities of Bodies resembling both in Substance and Shape the Shells of divers sorts of Shell-fishes; and many of them so exactly, that any one that knew not whence they came, would without the least scruple firmly believe them to be the Shells of such Fishes: But being found in Places so unlikely to have produced them, and not conceiving how else they should come there, they are generally believed to be real Stones form'd into these Shapes, either by some plastick Vertue inherent in those Parts of the Earth, which is extravagant enough, or else by some Celestial Influence or Aspect of the Planets operating at a distance upon the yielding Matter of the Parts of the Earth, which is much more extravagant. Of this kind are all those several sorts of Oyster-shells, Cockle-shells, Muscle-shells, Periwinkle-shells, and the like, which are found in *England*, *France*, *Spain*, *Italy*, *Germany*, *Norway*, *Russia*, *Asia* and *Africa*, and divers other Places; of which I have very good Testimonies from Authors of good Credit.

2. Secondly, That there often have been, and are still daily found in other Parts of the Earth buried below the present Surface thereof divers sorts of Bodies, besides such as I newly mention'd, resembling both in Shape, Substance, and other Proprieties, the Parts of Vegetables, having the perfect Rind or Bark, Pith, Pores, Roots, Branches, Gums, and other constituent Parts of Wood, though in another posture, lying for the most part Horizontal, and sometimes inverted, and much differing from that of the like Vegetables when growing, and wanting also, for the most part, the Leaves, smaller Roots and Branches, the Flower and Fruit, and the like smaller Parts, which are common to Trees of that kind; of which sort is the *Lignum Fossile*, which is found in divers Parts of *England*, *Scotland*, *Ireland*, and divers Parts of *Italy*, *Germany*, the *Low Countries*, and indeed almost in every Country of the World.

3. Thirdly, That there are often found in divers other Parts of the Earth, Bodies resembling the whole Bodies of Fishes, and other Animals and Vegetables, or the Parts of them, which are of a much less permanent Nature than the Shells abovementioned, such as Fruits, Leaves, Barks, Woods, Roots, Mushrooms, Bones, Hoofs, Claws, Horns, Teeth, *&c.* but in all other Proprieties

prieties of their Substance, save their Shape, are perfect Stones, Clays, or Earths, and seem to have nothing at all of Figure in the inward Parts of them. Of this kind are those, commonly call'd Thunder-bolts, Helmet-stones, Serpentine-stones, or Snake-stones, Rams-horns, Brain-stones, Star-stones, Screw-stones, Wheel-stones, and the like.

Fourthly, That the Parts of the Earth in which these kinds have been found, are some of them some hundred of Miles distant from any Sea, as in several of the Hills of *Hungary*, the Mountain *Taurus*, the *Alpes*, *&c.* 4.

Fifthly, That divers of those Parts are many Scores, nay, some many Hundreds of Fathoms above the Level of the Surface of the next adjoining Sea, there having been found of them on some of the most Inland, and on some of the highest Mountains in the World. 5.

Sixthly, That divers other Parts where these Substances have been found, are many Fathoms below the Level both of the Surface of the next adjoining Sea, and of the Surface of the Earth itself, they having been found buried in the bottoms of some of the deepest Mines and Wells, and inclosed in some of the hardest Rocks and toughest Metals. Of this we have continual Instances in the deapest Lead and Tin-mines, and a particular Instance in the Well dug in *Amsterdam*, where at the Depth of 99 Foot was found a Layer of Sea-shells mixed with Sand of 4 Foot thickness, after the Diggers had past through 7 Foot of Garden-mould, 9 Foot more of black Peat, 9 Foot more of soft Clay, 8 of Sand, 4 of Earth, 10 of Potters-clay, 4 more of Earth, 10 Foot more of Sand, upon which the Stakes or Piles of the *Amsterdam* Houses rest; then 2 Foot more of Potters-clay, and 4 of white Gravel, 5 of dry Earth, 1 of mix'd, 14 of Sand, 3 of a Sandy Clay, and 5 more of Potters-clay mix'd with Sand. Now below this Layer of Shells immediately joining to it, was a Bed of Potters-clay of no less than 102 Foot thick; but of this more hereafter. 6.

Seventhly, That there are often found in the midst of the Bodies of very hard and close Stone, such as Marbles, Flints, *Portland*, and Purbeck-stone, *&c.* which lye upon, or very near to the Surface of the Earth, great quantities of these kind of figured Bodies or Shells, and that there are many of such Stones which seem to be made of nothing else. 7.

These Phænomena, as they have hitherto much puzled all Natural Historians and Philosophers to give an Account of them, so in truth are they in themselves so really wonderful, that 'tis not easie without making multitudes of Observations, and comparing them very diligently with the Histories and Experiments that have been already made, to fix upon a plausible Solution of them. For as on the one side, it seems very difficult to imagine that Nature formed all these curious Bodies for no other End, than only to play the Mimick in the Mineral Kingdom, and only to imitate what she had done for some more noble End, and in a greater Perfection in the Vegetable and Animal Kingdoms; and the strictest Survey that I have made both of the Bodies themselves, and of the Circumstances obvious enough about them, do not in the least hint any thing else; they being promiscuously found of any kind of Substance, and having not the least appearance of any internal or substantial Form, but only of an external or figured Superficies. As, I say, 'tis something harsh, to imagine that these thus qualified Bodies should, by an immediate plastick Vertue, be thus shaped by Nature contrary to her general Method of acting in all other Bodies; so on the other side, it may seem at first hearing somewhat difficult to conceive how all those Bodies, if they either be the real Shells or Bodies of Fish, or other Animals or Vegetables, which they represent, or an Impression left on those Substances from such Bodies, should be, in such great quantities, transported into Places so unlikely to have received them from any help of Man, or from any other obvious Means. *How the Difficulty may be solved.*

The former of these ways of solving these Phænomena, I confess I cannot for the Reasons I now mention'd, by any means assent unto; but the latter, tho' it has some Difficulties also, seems to me not only possible, but probable.

Object. 1. The greatest Objections that can be made against it, are, First, by what means those Shells, Woods, and other such like Substances (if they really are the Bodies they represent) should be transported to, and be buried in the Places where they are found? And,

2. Secondly, Why many of them should be of Substances wholly differing from those of the Bodies they represent; there being some of them which represent Shells of almost all kinds of Substances, Clay, Chalk, Marble, soft Stone, harder Stone, Marble, Flint, Marchasite, Ore, and the like.

In answer to both which, and some other of less Importance, which I shall afterwards mention, give me leave to propound these following Propositions, which I shall endeavour to make probable. Of these in their Order.

1. *Answered by these Propositions.* My first Proposition then is, That all, or the greatest part of these curiously figured Bodies found up and down in divers Parts of the World, are either those Animal or Vegetable Substances they represent converted into Stone, by having their Pores fill'd up with some petrifying liquid Substance, whereby their Parts are, as it were, lock'd up and cemented together in their Natural Position and Contexture; or else they are the lasting Impressions made on them at first, whilst a yielding Substance by the immediate Application of such Animal or Vegetable Body as was so shaped, and that there was nothing else concurring to their Production, save only the yielding of the Matter to receive the Impression, such as heated Wax affords to the Seal; or else a subsiding or hardning of the Matter, after by some kind of Fluidity it had perfectly fill'd or inclosed the figuring Vegetable or Animal Substance, after the manner as a Statue is made of Plaister of *Paris*, or Alabaster-dust beaten, and boil'd, mixed with Water and poured into a Mould.

2. Secondly, Next that there seems to have been some extraordinary Cause, which did concur to the promoting of this Coagulation or Petrification; and that every kind of Matter is not of it self apt to coagulate into a strong Substance, so hard as we find most of those Bodies to consist of.

3. Thirdly, That the concurrent Causes assisting towards the turning of these Substances into Stone, seem to have been one of these, either some kind of fiery Exhalation arising from subterraneous Eruptions or Earthquakes; or secondly, a Saline Substance, whither working by Dissolution and Congelation, or Crystallization, or else by Precipitation and Coagulation; or thirdly, some glutinous or bituminous Matter, which upon growing dry or setling grows hard, and unites sandy Bodies together into a pretty hard Stone; or fourthly, a very long continuation of these Bodies under a great degree of Cold and Compression.

4. Fourthly, That Waters themselves may in tract of time be perfectly transmuted into Stone, and remain a Body of that Constitution without being reducible by any Art yet commonly known.

5. Fifthly, That divers other fluid Substances have after a long continuance at rest, have settled and congealed into much more hard and permanent Substances.

6. Sixthly. That a great part of the Surface of the Earth hath been since the Creation transformed and made of another Nature; namely, many Parts which have been Sea are now Land, and divers other Parts are now Sea which were once a firm Land; Mountains have been turned into Plains, and Plains into Mountains, and the like.

Seventhly,

Seventhly, That divers of these kind of Transformations have been effected in these Islands of *Great Britain*; and that 'tis not improbable, but that many very Inland Parts of this Island, if not all, may have been heretofore all cover'd with the Sea, and have had Fishes swimming over it. 7.

Eighthly, That most of those Inland Places, where these kinds of Stones are, or have been found, have been heretofore under the Water; and that either by the departing of the Waters to another part or side of the Earth, by the alteration of the Center of Gravity of the whole Bulk, which is not impossible; or rather by the Eruption of some kind of subterraneous Fires, or Earthquakes, whereby great quantities of Earth have then been rais'd above the former Level of those Parts, the Waters have been forc'd away from the Parts they formerly cover'd, and many of those Surfaces are now raised above the Level of the Water's Surface many scores of Fathoms. 8.

Ninthly, It seems not improbable, that the tops of the highest and most considerable Mountains in the World have been under Water, and that they themselves most probably seem to have been the Effects of some very great Earthquake, such as the *Alpes* and Appennine Mountains, *Caucasus*, the Pike of *Tenariff*, the Pike in the *Terceras*, and the like. 9.

Tenthly, That it seems not improbable, but that the greatest part of the Inequality of the Earth's Surface may have proceeded from the Subversion and tumbling thereof by some preceding Earthquakes. 10.

Eleventhly, That there have been many other Species of Creatures in former Ages, of which we can find none at present; and that 'tis not unlikely also but that there may be divers new kinds now, which have not been from the beginning. 11.

There are some other Conjectures of mine yet unmention'd, which are more strange than these; which I shall defer the mentioning of till some other time; because tho' I have divers Observations concurring, yet having not been able to meet with such as may answer some considerable Objections that they are liable to, I will rather at present endeavour to make probable those already mentioned, by setting down some of those Observations (for it would be tedious to insert all) I have collected, both out of Authors, and from my own Experience.

The First was, That these figured Bodies dispersed over the World, are either the Beings themselves pretrify'd, or the Impressions made by those Beings. To confirm which, I have diligently examin'd many hundreds of these figured Bodies, and have not found the least probability of a plastick Faculty. For first, I have found the same kind of Impression upon Substances of an exceeding differing Nature, whereas Nature in other of her Works does adapt the same kind of Substance to the same Shape; the Flesh of a Horse is differing from that of a Hog, or Sheep, or from the Wood of a Tree, or the like; so the Wood of Box, for Instance, is differing from the Wood of all other Vegetables; and if the outward Figure of the Plant or Animal differ, to be sure their Flesh also differs: And under the same Shape you always meet with Substances of the same kind; whereas here I have observed Stones bearing the same Figure, or rather Impression, to be of hugely differing Natures, some of Clay, some of Chalk, some of Spar, some of Marble, some of a kind of Free-stone, some like Crystals or Diamonds, some like Flints, others a kind of Marchasite, others a kind of Ore. Nay, in the same figur'd Substance I have found divers sorts of very differing Bodies or kinds of Stone, so that one has been made up partly of Stone, partly of Clay, and partly of Marchasite, and partly of Spar, according as the Matter chanced to be jumbled together, and to fill up the Mould of the Shell. *The first Proposition confirmed.*

Another Circumstance, which makes this Conjecture the more probable, is, that the outward Surface only of the Body is form'd, and that the inward

Part

Part has nothing of Shape that can reasonably be referr'd to it; whereas we see that in all other Bodies that Nature gives a Shape to, she figures also the internal Parts or the very Substance of it, with an appropriate Shape. Thus in all kinds of Minerals, as Spars, Crystals, and divers of the precious Stones, Ores, and the like, the inward Parts of them are always correspondent to the outward Shape; as in Spar, if the outward Part be shap'd into a Rhomboidical parallepiped, the inward Part of it is shap'd in the same manner, and may be cleft out into a multitude of Bodies of the like Form and Substance.

Another Circumstance is, that I have in many found the perfect Shell inclosed making a concave Impression on the Body that inclosed it, and a convex on the Body that it did inclose; which I have sometimes been able to take out intire, and found it to be both by its Substance and Shape, and reflective shining, and the like Circumstances, a real Shell of a Cockle, Periwinkle, Muscle, or the like.

And farther, I have found in the same place divers of the same kinds of Shells, not fill'd with a Matter that was capable of taking the Impression, but with a kind of sandy Substance; which lying loose within it could be easily shook out, leaving the inclosing Shell perfectly intire and empty; others I have seen which have been of black Flint, wherein the Impression has been made only of a broken Shell, which stuck also into it; the other Part of the Surface of that Stone, which was not within the Shell, remaining only form'd like a common Flint.

And which seems to confirm this Conjecture much more than any of the former Arguments, I had this last Summer an Opportunity to observe upon the South-part of *England*, in a Clift whose Bottom the Sea wash'd, that at a good heighth in the Clift above the Surface of the Water, there was a Layer, as I may call it, or Vein of Shells, which was extended in length for some Miles: Out of which Layer I digg'd out, and examin'd many hundreds, and found them to be perfect Shells of Cockles, Periwinkles, Muscles, and divers other sorts of small Shell-Fishes; some of which were fill'd with the Sand with which they were mix'd; others remain'd empty, and perfectly intire: From the Sea-waters washing the under part of this Clift, great quantities of it do every Year tumble or founder down, and fall into the Salt-water, which are wash'd also by several Mineral-waters issuing out at the bottom of those Clifts. Of these founder'd Parts I examined very many Parcels, and found some of them made into a kind of harden'd Mortar, or very soft Stone, which I could easily with my Foot, and even almost with my Finger, crush in Pieces; others that had lain a longer time exposed to the Vicissitudes of the rising and falling Tides, I found grown into pretty hard Stones; others that had been yet longer, I found converted into very hard Stone, not much yielding to the hardness of Flints. Out of divers of these, I was able to break and beat out divers intire and perfect Shells, fill'd with a Substance which was converted into a very hard Stone, retaining exactly the Shape of the inclosing Shell. And in the part of the Stone which had encompass'd the Shell, there was left remaining the perfect Impression and Form of the Shell; the Shell it self remaining as yet of its natural white Substance, though much decay'd or rotted by time: But the Body inclosing and included by the Shell, I found exactly stamp'd like those Bodies, whose Figures Authors generally affirm to be the Product of a Plastick or Vegetative Faculty working in Stones.

Another Argument, that these petrify'd Substances are nothing but the Effects of those Shells being fill'd with some petrifying Substance, is this, That among those which are call'd *Cornu-Ammonis*, or Serpentine-stones, (found about *Keinsham*, and in several other Parts of *England*, and in other Countries, as at the *Balnea Bollensia*) which are indeed nothing else but the moulding off from a kind of Shell which is much shap'd like a *Nautilus*-shell, the whole Cavity being separated with divers small Valves or Partitions, much after the same manner as those Shells of the *Nautilus* are commonly observed to be. Among these Stones, I say, I have, upon breaking, found some of the Cavities between those Partitions remain almost quite empty; others

others I have found lined only with a kind of Tartareous, or rather Crystalline Substance, which has stuck to the sides, and been figured like Tartar, but of a clear and transparent Substance like Crystal; whereas others of the Cavities of the same Stone I have found filled with divers kinds of Substances very differing: Whence I imagine those Tartareous Substances to be nought else but the hardning of some saline fluid Body, which might soak in through the Substance of the Shell. Others of these I have, which are quite of a transparent Substance, and seem to be produced from the Petrifaction of the Water that had fill'd them; others I have found fill'd with a perfect Flint, both which I suppose to be the productions of Water petrify'd: And I may perhaps hereafter make it probable, that all kinds of Flints and Pebbles have no other Original.

I could urge many other Arguments to make my first Proposition probable, that all those curiously shaped Stones, which the most curious Naturalists most admire, are nothing but the Impressions made by some real Shell in a Matter that at first was yielding enough, but which is grown harder with time. To this very Head also may be referr'd all those other kinds of petrify'd Substances, as Bones, Teeth, Crabbs, Fishes, Wood, Moss, Fruit, and the like; some of all which Kinds I have examin'd, and by very many Circumstances, too long to be here inserted, judge them to be nothing else but a real petrifaction of those Substances they resemble.

The second Proposition confirmed.

My Second Proposition will not be difficult to prove, That if these be the Effects of Petrifaction or Coagulation, it must be from some extraordinary Cause. And this because we find not many Experiments of producing of them when and where we will; besides we find that most things, especially Animal and Vegetable Substances, after they have left off to vegetate, do soon decay, and by divers ways of Putrefaction and Rotting, loose their Forms and return into Dust; as we find Wood, whether exposed to the Air or Water, in a little time to waste and decay; especially such as is exposed to the alteration of both, and even in those Places where these petrify'd Substances are to be met with. The like we find of Animal Substances; and we have but some few Experiments of preserving those Bodies, to make them as permanent as Stone, and fewer of making them into a Substance of the like Nature.

The third Proposition confirmed.

The Third thing therefore, which I shall endeavour to shew, is, That the concurring Causes to these Petrifactions seem to be either some kind of petrifying Water, or else some saline or sulphureous Mixture, with the concurrence of Heat, from some subterraneous Fire or Earthquake; or else a very long Continuation of those Bodies under a great degree of Cold and Compression, and Rest. That petrifying Waters may be able to convert both Animal and Vegetable Substances into Stone, I could, besides several Trials of my own, bring multitudes of Relations out of Natural Historians: But these are so common almost in all Countries, and so commonly taken notice of by the Curious, that I need not instance. *Cambden* and *Speed* will tell you of abundance here in *England*, as the *Peak* in *Derbyshire*, and in several other subterraneous Caverns in *England*. The Water it self does, by degrees, produce several conical pendulous Bodies of Stone, shap'd and hanging like Icicles from the Roof of the Vault; and dropping on the bottom, it raises up also conical Spires, which, by degrees, endeavour to meet the former pendulous *Stiriæ*. And indeed I have generally observ'd it, that wherever there is a Vault made with Lime under Ground, into which the Rain-Water soaking through, a pretty thickness of Ground, does at last penetrate through the Arch; I have in several places, I say, observ'd that that Water does incrustate the Roof with Stone, and in many places of it generate small pendulous Icicles. This Water I have found in a little time to incrustate Sticks, or the like Vegetable Substances with Stone, and in some places to penetrate into the Pores of the Wood, filling them up with small Cylinders of Stone. This I have observ'd also in divres of the Arches of St. *Paul*'s Church, which have been uncover'd and have lain open to the Rain, though there be

no Earth for it to soak through. And tho' I have never yet been able to petrify a Stick throughout, yet I have now by me several pieces that retain so perfectly all the Figure of Wood, and are yet so perfectly in all other propreties Stone, that I find not the least Reason of doubt to believe that those pieces have been actual Wood, having still the Bark, the Clefts, the Knots, the Grain, the Pores, and even those too which, for their smalness, I have elsewhere call'd Microscopical; tho' I confess some of these more perfect pieces seem to have been petrify'd from some more subtile and insinuating petrifying Water, than those I newly mention'd; and 'tis not improbable but that some Subterraneaous Steams and Heat may have contributad somewhat towards this Effect. But first I shall endeavour to make it probable, that these petrify'd Bodies may have been placed in those Parts where they are found, by some kind of Transformation wrought on the Surface of the Earth, by some Earth-quake: And to this end, I shall by and by mention some strange alterations that have been made by Earthquakes, after I have first made probable my fourth Conjecture.

The fourth Proposition confirmed.

The Fourth Proposition therefore to be explain'd and made probable is, That Waters themselves of divers Kinds, are, and may have been transmuted perfectly into a stony Substance, of a very permanent Constitution, being scarcely reducible again into Water by any Art yet commonly known. And that divers other Liquid or Fluid Substances have in tract of time settled and congealed into much more hard, fixt, solid and permanent Forms than they were of at first.

The probability of which Proposition may appear from these Particulars.

I. That almost in all Streams and running Waters there is to be found great quantity of Sand at the bottom, many of which Sands both by their Figure in the Microscope, and transparently, seem to have been generated out of the Water.

1st. *Arg.*

First, I say, That their transparency which they discover in the Microscope is an Argument, because I believe there is no transparent Body in the World that has not been reduc'd to that Constitution by being some ways or other made fluid, nor can I indeed imagine how there should be any. All Bodies, made transparent by Art, must be reduc'd into that Form first; and therefore 'tis not unlikely but that Nature may take the same Course; but this as only probable I shall not insist on. Next, I say, that the Figures of diverse of them in the Microscope discover the same things; for I have seen multitudes of them curiously wrought and figured like Crystal or Diamonds, and I cannot imagine by what other Instrument Nature should thus cut them, save by Crystalizing them out of a Liquid or Fluid Body, and that way we find her to work in the formation of all those curious regular Figures of Salts, and the Vitriols (as I may call them) of Metals and divers other Bodies, of which Chymistry affords many Instances. Sea-Salt and Salgem chrystylizeth into Cubes or four-sided Parrallelipipeds; Niter into triangular and hexangular Prisms. Alume into Octoedrons, Vitriols into various kinds of Figures, according to the various kinds of Metals dissolved, and the various *Menstrua* dissolving them; Tartars also, and Candyings of Vegetables are figured into their various regular Shapes from the same Method and Principle. And in truth, in the formation of any Body out of this mineral Kingdom, whose Origine we are able to examine, we may find that Nature first reduces the Bodies to be wrought on into a liquid or soft Substance, and afterwards forms and shapes it into this or that Figure. But this Argument drawn from the Sand, found in all running Streams, I shall not insist on, because some imagine it to be only washt off from the Land and Shores the River passes over, and perpaps much of it may: But yet that Sand may be made of clear Water, this second Argument will manifest, and that is this:

That

That 'tis a usual Experiment in the making of Salt in the Salterns, by the boyling up, or evaporating away the fresher part of the Sea-water, to collect great quantities of Sand at each corner of the Boyler; which, after it has been well washt with fresh Water, is, in all particulars, a perfect Sand; and yet the Water is so order'd before it is put into the Boyler, that nothing of Sand or Dregs can enter with it, the Brine being first suffer'd to stand a good while and settle in a very large Fat, so that all the Sand and Dregs may sink to the bottom; after which, the clearer Water at the top is drawn off, and suffer'd to run into the Boyler. 'Tis not impossible, perhaps, but that Substance which made this Sand, might be dissolved in Water, and afterwards by evaparation coagulated; which, if so, makes not at all against, but rather argues strongly for my fourth Proposition. 2d. *Arg.*

But that the other Solution is something more probable, namely, That 'tis made out of the very Substance of the Water itself, this third Argument will make probable; and that is, that any Water of what kind soever, tho' never so clear and insipid, may, by frequent Distillations, be all of it perfectly transmitted into a white insipid Calx not again dissolvable in Water, and in nothing differing from the Substance of Stone; this I have been assured by an eminent Physician, who has divers times made tryal of it with the same success. If therefore the whole Body of any Water may, by so easy an Operation in so very short a time, be transmuted into a stony Substance, what may not Nature do that can take her own time, and knows best how to make use of her own Principles? 3d. *Arg.*

But 4*thy*. we have many Instances by which we are assured that Nature realy does change Water into Stone, both by forming in a little time considerable Stones out of the distilling Drops of Water soaking through the Roofs of Caves and subterraneous Vaults, of which we have very many Instances here in *England*; as to name one for all at the Peak in *Derbyshire*, the pendulous Cones of this petrify'd Substance directly point at, and oftentimes meet and rest on the rising Spires, generated by the drops of Water trickling through the Roof, as I mention'd before 4th. *Arg.*

And 5*thy*. there are divers other Waters which we need not seek after in Caves that have a petrifying vertue, and incrustate all the Chanel they pass through, and the Substances soak'd in them with Stone; these are so common almost in all places, that I need not instance in any; only I cannot pass by one, which is taken notice of by *Kircher* in his *Mundus Subterraneus*, being Observations made by himself, and it has in it two Circumstances very considerable; the first is, That Vegetables should grow so plentifully in a very hot Water. The second, that only such Herbs as grew in it, and not such as were Steeped in it, will perfectly, after drying, be turned into Stone, of which I shall afterwards have occasion to make more use. I shall give the History in his own Words, as they are set down in the 7th Paragraph of the 2d Sect. of the 5th Book of his *Mundus Subterraneus*, *Hæc* (says he) *experientia didici in Itinere meo Hetrusco, in quo prope Roncolanum senensis territorii Oppidum* (a Town near *Siena* in *Tuscany*) *duos fontes calidos observavi, quorum aqua per Canales ad molares Rotas vertendas ducebatur. In hisce canalibus cyperus, junci, ranunculus similesq; herbæ tanta adolescebant fæcunditate, ut quotannis eas, ne aquæ motum interturbarent, extirpare oporteret. Extirpatas vero projectasq; in vicinum locum herbas omnes in Lapidem conversas non sine admiratione spectavi. Cujus rei causam cum a molitoribus quærerem. Responderunt aquas istiusmodi hujus virtutis esse, ut quæcunq; inter canales, aut ipsa aqua excreverint herbæ mox ac extirpatæ fuerint, Lapidescant; quæcunq; vero extra aquam in campis patentibus excreverint herbæ, istas extirpatas nunquam Lapidescere.* I pass by his Reasons and Explications, because I think them very little to the Purpose: But the Observations themselves are very considerable, and serve for the explaining of severeal Phenomena I have observ'd in petrify'd Bodies, as I shall indeavour hereafter to shew, as in Corals, both Red, White, and the several Rarities of them, in Coral- 5th. *Arg.*

lines

lines also, and petrify'd Mushromes, of each of which I have examined a very great variety. But this only by the by.

6th *Arg.* *6thly.* Therefore 'tis observable, that these petrifying Waters are for the most part very clear and limpid; so that to the Sight 'tis not distinguishable from other Water: But only by the Effects, and therefore by the newly mention'd Observations of *Kircher*, we find that Vegetables, that upon drying turn'd into Stone; whilst green and growing flourished and spread faster than others; so that the petrifying Substance past through the finest and closest Pores of the living Vegetables, and therefore must certainly be very intimately mixt with the Water that could not be separated by so fine and curious Strainers.

7th. *Arg.* But *7thly.* To confirm this Proposition yet further, there are found in several parts of the Earth, such Waters will be intirely converted into Stone. Of this kind there are several Histories in the newly-mention'd Book, which I pass over, and shall only take notice of one for all, and that is in an Account sent to the *Roman* Coledge of Jesuits from the Masters, Surveyors and Clerks of the *Hungarian* Mines, in Answer to some Queries propounded to them. Page 183. of *Kircher*'s *Mundus Subterraneus*, to the Query concerning the Properties and Metallick Experiments about Meneral Waters, they answer, That *Datur in fodinis aquæ genus quod in Figuram saccaro haud absimilem degenerat*, viz. *in Lapillos albas.*

And again, Page 185. of the same, from another Prefect of the Emperial Mines in *Hungary* in answer to the same Query, we have this Account. *Reperitur quoq; aqua quædam alba quæ in Lapidem durum abit. Si vero hæc aqua ante suam coagulationem mineram cupream transiverit, tunc generatur ex ea lapis qui Malochites vocatur, quando vero aqua illa perfluit cupream mineram continentem argentum fiet ex ea pulcher lapis ceruleus similis Turcoidi. Hæc aqua autem nullibi frequentius reperitur quam in mineris Lapidibus siliceis copiosis, & cuprum cum argento continentibus.* Whence I am apt to think, and I have many Observations and Arguments to confirm my Conjecture,

8th. *Arg.* That *8thly*, All kinds of *Talk* and *Spar*, most *Ores* and *Marchasites*: *Alumen Plumeum*, & *Asbestus*; *Fluores*, *Crystalls*, Cornish-*Diamonds*, *Amethysts* and divers other figured Mineral Bodies, may be generated from their Crystalization, or Coagulation, out of some Mineral Waters.

9th. *Arg.* And to make it yet more probable, I could in the 9th place add divers Experiments, by which several of these Concretes may be in a short time made artificially by several Chymical Operations, which would very much illustrate the former Doctrin. But I hope what I have mention'd may suffice to make the fourth Proposition probable, that Waters of divers kinds may be turned in time to Stone, without being reducible again to Water by any Art yet commonly known, which being granted, my

The fifth Proposition proved. Fifth Proposition will follow of consequence, *viz.* That divers other fluid Substances, have, after long continuance of rest, settled and congealed into much more hard and permanent Substances: For if Water it self may be so changed and metamorphosed, which seems the fartheſt removed from the nature of a solid Body, certainly those which are nearer to that Nature, and are mixt with such Waters, will more easily be coagulated: I shall not therefore any farther insist on the Proof of this, than only to mention two Particulars, and that because we have almost every where so many Instances and Experiments; and the first is that of *Pliny* in the 13th Chap. of the 35th Book of his Natural History, in all which Chapter he gives us divers Instances of several kinds of Earth, which, by the Sea-water and Air, converted into into solid and hard Stones; his Words are these: *Verum & ipsius Terræ sunt alia segmenta. Quis enim satis miretur pessimam ejus partem ideoq; pulverem appellatam in puteolanis collibus oppone maris fluctibus, mersamq; protinus fieri lapidem unum inexpugnabilem undis, & fortiorem quotidie, utiq; si cumano misceatur Cæmento.*

Eadem

Eadem est Terræ Natura & in Cizicena Regione, sed ibi non pulvis verum ipsa Terra, qualibet magnitudine excisa & demersa in mare, lapidea extrahitur: hoc idem circa Cassandriam produnt fieri: Et in fonte Gnidio dulci intra octo menses Terram lapidescere. Ab Oropo quidem Aulidem usque quicquid Terræ attingitur mari, mutatur in Saxa, &c. to the end of the Chapter he goes on to relate divers Places where Earths, *&c.* are turned into Stones. Also in the 10th Chapter of the of the 31st Book, speaking of the Nature and Kinds of Niter, he tells about the middle of the Chapter. *Nitrariæ egregiæ Ægyptiis nam circa Naucratim & Memphim tantum solebant esse, circa Memphim deteriores; nam & lapidescit ibi in acervis, multiq; sunt Tumuli ea de causa Saxei, fiuntq; ex his vasa, &c.*

The Second is an Observation of my own, which I have often taken notice of, and lately examined very diligently, which will much confirm these Histories of *Pliny*, and this my present Hypothesis; and that is a Part of the Observation I have already mentioned, which I made upon the Western Shore of the Isle of *Wight*. I observed a Cliff of a pretty height, which, by the constant washing of the Water at the bottom of it, is continually, especially after Frosts and great Rains, foundering and tumbling down into the Sea underneath it. Along the Shore underneath this Cliff, are a great number of Rocks and large Stones confusedly placed, some covered, others quite out of the Water; all which Rocks I found to be compounded of Sand and Clay, and Shells, and such kind of Stones, as the Shore was covered with. Examining the Hardness of some that lay as far into the Water as the Low-Water-mark, I found them to be altogether as hard, if not much harder than *Portland* or *Purbeck*-stone: Others of them that lay not so far into the Sea, I found much softer, as having in probability not been so long exposed to the Vicissitudes of the Tides: Others of them I found so very soft, that I could easily with my Foot crush them, and make Impressions into them, and could thrust a Walking-stick I had in my Hand a great depth into them: Others that had been but newly foundered down, were yet more soft, as having been scarce wash'd by the Salt Water. All these were perfectly of the same Substance with the Cliff, from whence they had manifestly tumbled, and consisted of Layers of Shells, Sand, Clay, Gravel, Earth, *&c.* and from all the Circumstances I could examine, I do judge them to have been the Parts of the Neighbouring Cliff foundered down, and rowl'd and wash'd by degrees into the Sea; and, by the petrifying Power of the Salt Water, converted into perfect hard compacted Stones. I have likewise since observed the like *Phænomena* on other Shores. And I doubt not but any inquisitive Naturalist may find infinite of the like Instances all along the Coast of *England*, and other Countries where there are such kind of foundering Cliffs. I shall not now mention the great Quantities of toothed Spar, which I observed to be crystallized upon the sides of these Rocks, which seem'd to have been nothing else but the meer crystallizing or shooting of some kind of Water, which was press'd or arose out of these coagulating Stones; For the History of these kinds of figured Stones belong more properly to another Discourse; namely, of the Natural Geometrical Figures, observable in Oares, Minerals, Spars, Talk, *&c.* of which elsewhere.

One Instance more I cannot omit, as being the most observable of any I have yet heard of; and that is, (Dr. *Castle*'s Relation) of a certain Place at *Alpsly* in *Bedfordshire*, where there is a corner of a certain Field, that doth perfectly turn Wood and divers other Substances in a very short time into Stone as hard as a Flint or Agat. A Piece of this kind I saw, affirm'd to have been there buried, which the Person that buried it had shot small Shots of Lead into; the whole Substance of the Wood, Bark and Pith, together with the Leaden Shot it self, was perfectly turn'd to a Stone as hard as any Agat, and yet retain'd its perfect Shape and Form; and the Lead remain'd round, and in its place, but much harder than any Iron. Of this I am promised a Sample, but have not yet receiv'd it.

But to spend no more time on the proof of that of which we have almost every where Instances, divers of which I have already mention'd, I shall proceed to the 6th Proposition; which is, That a great Part of the Surface of the *The 6th Proposition confirm'd.*

Earth hath been since the Creation transform'd, and made of another Nature: that is, many Parts which have been Sea are now Land, and others that have been Land are now Sea; many of the Mountains have been Vales, and the Vales Mountains, *&c.*

For the proving of which Proposition, I shall not need to produce any other Arguments, besides the repeating what I find set down by divers Natural Historians, concerning the prodigious Effects that have been produced by Earthquakes on the superficial Parts of the Earth; because they seem to me to have been the chief Efficients which have transported these petrify'd Bodies, Shells, Woods, Animal Substances, *&c.* and left them in some Parts of the Earth, as are no other ways likely to have been the Places wherein such Substances should be produced; they being usually either raised a great way above the level Surface of the Earth, on the Tops of high Hills, or else buried a great way beneath that Surface in the lower Valleys: For who can imagine that Oysters, Muscles, and Periwinkles, and the like Shell-fish, should ever have had their Habitation on the Tops of the Mountain *Caucasus?* Which is by divers of our Geographers accounted as high in its perpendicular Altitude, as any Mountain in the yet known World; and yet *Olearius* affords us a very considerable History to this purpose of his own Observation, which I shall hereafter have occasion to relate, and examine more particularly. Or to come a little nearer home, who could imagine that Oysters, *Echini*, and some other Shell-fish, should heretofore have lived at the tops of the *Alps*, *Appennine*, and *Pyrenian* Mountains, all which abound with great store of several sorts of Shells; nay, yet nearer at the tops of some of the highest in *Cornwal* and *Devonshire*, where I have been informed by Persons whose Testimony I cannot in the least suspect, that they have taken up divers, and seen great Quantities of them? And to come yet nearer, who can imagine Oysters to have lived on the Tops of some Hills near *Banstead-Downs* in *Surry?* Where there have been time out of Mind, and are still to this day found divers Shells of Oysters, both on the uppermost Surface, and buried likewise under the Surface of the Earth, as I was lately informed by several very worthy Persons living near those Places, and as I my self had the Opportunity to observe and collect.

The Effects of Earthquakes. To proceed then to the Effects of Earthquakes, we find in Histories Four Sorts or *Genus's* to have been performed by them.

First sort or Genus of Effects. The first is the raising of the superficial Parts of the Earth above their former Level: and under this Head there are Four Species. The 1st is the raising of a considerable Part of a Country, which before lay level with the Sea, and making it lye many Feet, nay, sometimes many Fathoms above its former height. A 2d is the raising of a considerable part of the bottom of the Sea, and making it lye above the Surface of the Water, by which means divers Islands have been generated and produced. A 3d Species is the raising of very considerable Mountains out of a plain and level Country. And a 4th Species is the raising of the Parts of the Earth by the throwing on of a great Access of new Earth, and for burying the former Surface under a covering of new Earth many Fathoms thick.

Second Sort or Genus of Effects. A second sort of Effects perform'd by Earthquakes, is the depression or sinking of the Parts of the Earth's Surface below the former Level. Under this Head are also comprized Four distinct Species, which are directly contrary to the four last named.

The *First*, is a sinking of some Part of the Surface of the Earth, lying a good way within the Land, and converting it into a Lake of an almost unmeasurable depth.

The *Second*, is the sinking of a considerable Part of the plain Land, near the Sea, below its former Level, and so suffering the Sea to come in and overflow it, being laid lower than the Surface of the next adjoining Sea.

A *Third*, is the sinking of the Parts of the bottom of the Sea much lower, and creating therein vast *Vorages* and *Abysses*.

A *Fourth*, is the making bare, or uncovering of divers Parts of the Earth, which were before a good way below the Surface; and this either by suddenly throwing away these upper Parts by some subterraneous Motion, or else by washing them away by some kind of Eruption of Waters from unusual Places, vomited out by some Earthquake.

A Third sort of Effects produced by Earthquakes, are the Subversions, Conversions, and Transpositions of the Parts of the Earth. *Third Sort or* Genus *of Effects.*

A Fourth sort of *Effects*, are *Liquefaction. Baking, Calcining, Petrifaction, Transformation, Sublimation, Distillation*, &c. *Fourth Sort or* Genus *of Effects.*

The First therefore of the Effects of Earthquakes, which I but now named, was, that divers Parts of the Surface of the Earth which lay before, either below or level with the Sea, have been raised a good height above that Level by Earthquakes. Of this *Pliny* gives us several Instances in the 85th Chapter of the 2d Book of his Natural History, *Eadem nascentium Causa terrarum est, cum idem ille Spiritus attollendo potens solo non valuit erumpere. Nascuntur enim nec fluminum tantum invectu sicut Echinades Insulæ ab Acheloo amne congestæ; majorq; pars Ægypti a Nilo, in quam a Pharo insula noctis & Diei cursum fuisse Homero credimus: Sed & Recessu Maris sicut eidem de circeiis. Quod accidisse et in Ambraciæ portu decem Millium passuum intervallo, & Athenienſium quinq; Millium ad Piræum memoratur: Et Ephesi ubi quondam ædem Dianæ alluebat. Herotodo quidem si credimus, mare fuit supra Memphin usq; ad Æthiopum montes. Itemq; a planis Arabiæ. Mare et circa Ilium et tota Teuthrania quaq; campos intulerit.* *The First Species of Effects under the first* Genus *or Sort.*

Meander, and *Sandys* also, in his Travels thro' *Italy*, and the Parts of the *Levant*, gives this Instance, *pag.* 277. speaking of the new Mountain, which was produced in the Kingdom of *Naples*, in the Year 1538. *The Lake* Lucrinus, says he, *extended formerly to* Avernus, *and so unto* Gaurus, *two other Lakes; but is how no other than a little sedgy Plash, choaked up by the horrible and astonishing Eruption of the new Mountain, whereof, as oft as I think, I am apt to credit whatsoever is wonderful. For who in* Italy, says he, *knows not, or who elsewhere will believe, that a Mountain should arise partly out of a Lake, and partly out of the Sea in one Day and a Night, to such a height, as to contend in Altitude with the high Mountains adjoining.*

In the Year of our Lord 1538 *on the* 29*th of* September, *when for certain Days foregoing, the Country thereabouts was so vext with perpetual Earthquakes, as no one House was left so intire, as not to expect immediate Ruine, after that the Sea had retired* 200 *Paces from the Shore, leaving abundance of Fish with Springs of Fresh Water rising at the bottom, this Mountain visibly ascended about the second Hour of the Night*, and so forwards. And again, *pag.* 281, speaking of the same Place, he says, *The Sea was accustomed, when urged with Storms, to flow in thro' the Lake*, Lucrinus *driving Fishes in with it; but now not only that Passage, but a Part of* Avernus *it self is choaked by the Mountain.* In which Histories I take notice only of these two Particulars at present. First, That that Part of the Land which lyes between *Lucrinus* and the Sea, that was oft-times before overflowed by the Sea, since this Earthquake, has been so far raised, as that now such Effects are no longer to be found. To confirm the rising of which the more, the other Circumstance of the Sea's departing from the Shore 200 Paces does much contribute. But not to insist on this, Mr. *Childry* in his *Britannia Baconica*, a Book very useful in its kind, being a Collection of All the Natural History of the Islands of *Great Britain*, to be met with in *Cambden*, or *Speed*, and some other Historians, together with such of his own as he had opportunity to observe, relates to us many considerable Passages to this purpose. In his History of *Norfolk*, he saith, That near St. *Benet*'s in the *Holm*, are perfect Cockles and Periwinkles sometimes digg'd up out of the Earth, which makes some think it was formerly overflow'd by the Sea. The Fenny Grounds also of *Lincolnshire* and *Cheshire*, seem to have proceeded from the rising of the Ground; and those in *Anglesy*, where lopp'd Trees are now dug up with the perfect Strokes of the Ax remaining on them, seem to have been

been first sunk under Water, then overturn'd and buried in their own Earth, and afterwards the whole Earth seems to have been raised again to its former height. Of the raising of the Surface of the Earth, by the overflowings and stopping of Rivers and Waters, I shall afterwards speak.

Linschoten gives us a Relation of the like Effects of an Earthquake that hapned in the *Terceras*. The Relation, as I find it epitomiz'd by *Purchas* in the 1677 Page of the 4th Part of his *Pilgrims*, is this: ,In *July*, *Anno* 1591. 'there happen'd an Earthquake in the Island of St. *Michael*, which lyeth from 'Tercera South-East about 28 Miles, an Island 20 Miles long, and full of 'Towns, which continued from *July* 26. to *Aug.* 12. in which time none durst 'stay within his House, but fled into the Fields, fasting and praying with 'great Sorrow, for that many of their Houses fell down, and a Town, called '*Villa Franca*, was almost razed to the Ground, all the Cloysters and Houses 'shaken to the Earth, and therein People slain. *The Land in some Places rose* '*up*, and the Clifts removed from one Place to another, and some Hills were 'defaced and made even with the Ground. The Earthquake was so strong, 'that the Ships that lay in the Road, and in the Sea, shaked as if the World 'would have turn'd round. There sprang also a Fountain out of the Earth, 'from whence for the space of four Days there flow'd a most clear Water, and 'after that it ceased. At the same time they heard such Thunder and Noise 'under the Earth, as if all the Devils had been assembled together at that 'Place, wherewith many dy'd for fear. The Island of *Tercera* shook four times 'together, so that it seem'd to turn about; but there happen'd no other Mis-'fortune unto it. Earthquakes are common in those Islands: For about 20 'Years past there happen'd another Earthquake, when a high Hill that lyeth 'by the same Town *Villa Franca* fell half down, and covered all the Town with 'Earth, and killed many Men. I have transcribed here once for all the whole Relation, because there are many other considerable Circumstances in it besides the rising of the Earth, which I shall have occasion to refer to, under others of the Heads or Propositions to be proved, and therefore shall not need repetition. Two other Relations I find collected by *Purchas*, confirming this and several of the other Propositions: The one is that of *Dithmar Blefken*'s, in his History of *Island*, Page 648 of the 3d Part of his *Pilgrims*. 'On the 29th 'of *November* about Midnight, in the Sea, there appear'd a Flame near *Hecla*, 'which gave Light to the whole Island: An hour after the whole Island trem-'bled, as it would have been moved out of the Place: After the Earthquake 'follow'd a horrible Crack, that if all warlike Ordnance had been discharg'd 'it had been nothing to this Terror. It was known afterwards that *the Sea* '*went back two Leagues in that Place, and remain'd dry.*

A Second History *Purchas* has collected out of the History of *Joseph Acosta* of the *West Indies*, Page 940 of the 3d Part: omitting for the present divers other Circumstances he takes notice of, I shall only mention that of the receding of the Sea. 'Upon the Coast of *Chile*, (says he) I remember not well 'in what Year, there was so terrible an Earthquake, as it overturn'd whole 'Mountains, and thereby stopt the Course of Rivers, which it converted into 'Lakes: It beat down Towns, and slew a great number of People, causing the 'Sea to leave her Place some Leagues, so as the Ships remain'd on dry Ground 'far from the ordinary Road, *&c.* An Example somewhat like this happen'd lately in the *East-Indies*, as I was inform'd by a Letter sent thence to Mr. *D.* on *London-Bridge*. The thing in short was this: At a Place, about 7 Days Journey from *Ducca*, the Earth trembled about 32 Days; and the Sequel was, that it raised the bottom of a Lake, so as to drive out all the Water and Fish upon the Land, so that a Place which was formerly a Lake is now dry Ground. This was written from *Ballasore*, *Jan.* 6. 1665. The Words of the Letter I shall give afterwards.

The Second Species under the first Head or Genus of the Effects of Earthquakes.

The second Species of Effects of Earthquakes, is the raising of a considerable Part of the bottom of the Sea, and making it lye above the Surface of the Water, by which means divers Islands have been generated. Of this *Pliny*, in the 86th and 87th Chap. of the 2d Book of his Nat. Hist. gives us several Instances. *Nascuntur*, says he, *& alio modo Terræ*, (having in the preceding

ding Chapter spoken of the Shore's rising above the Water, or the Water's deceding from the Shore, *ac repente in alto mari emergunt, veluti paria secum faciente Natura, quæque hauserit hiatus alio loco reddente. Claræ jam pridem Insulæ Delos & Rhodos memoria produntur enatæ. Postea minores, ultra Melon Anaphe*, (of which *Strabo* makes mention in his Tenth Book.) *Inter Lemnum & Hellespontum Nea. Inter Lebedum & Teon, Alone: inter Cycladas, Olympiadis* CXXXV *ann.* 4*to Thera & Therasia. Inter easdem post ann.* CXXX *Hiera: & ab ea duobus Stadiis post ann.* CX *in Nostro ævo Thia.* Two of which Histories are also confirm'd by *Seneca*, in the Sixth Book of his Natural Questions and twenty first Chapter, where explicating the effects of Earthquakes by the commixture of Fire and Water, he says, *Theren & Therasiam & hanc nostræ ætatis insulam, spectantibus nobis in Ægeo mari enatam quis Dubitat quin in lucem Spiritus vexerit. Sandis* speaking of the *Jolian* Islands, saith, 'Of those 'there were only Seven, now there are Eleven in Number, which heretofore 'all flamed, now only *Vulcano* and *Strombylo*, two of that Number do burn. *Vulcano* is said to have first appear'd above Water about the time that *Scipio Africanus* died. But we have much later Instances to confirm this our Assertion: for about twenty eight Years since, an Island was made among the *Azores* by an Eruption of Fire; of which divers have related the Story. But *Kircher* in his *Mundus Subterraneus*, from the Relation of the Jesuits, has added the most particular one. Having spoken of the exceeding height of the Pike of *Teneriff* in the *Canaries*, and of the Eruptions of Fire in it, and the hot Springs found about it, he adds, that in the Azores also there are found places having almost the same Proprieties. The *Pico de Fayal de Santo Gregorio*, being almost of equal hight, and St. *Michael*'s Island having heretofore had several Vulcans, and having been troubled with many Earthquakes, and very notably about thirty eight Years since, wherein all the Island was so terribly shaken, that the utter Ruin and Submersion of the whole was feared. The History of which, in short, is this; That '*June* 26. '1638. the whole Island began to be shaken with Earthquakes for eight days, 'so that the Inhabitants left Cities, Castles and Houses, and dwelt in the 'Fields, but especially those of a Place call'd *Vargen*, where the Motion was 'more violent. After which Earthquake, this Prodigy followed; At a place of 'the Sea, where Fisher-men us'd to fish in Summer, because of the great 'abundance of Fish there caught, call'd *La Femera*, about 6 Miles from *Pico* '*Delle Carmerine*, upon the first *Sunday* in *July*, a subterraneous Fire, notwith-'standing the weight and depth of the Sea in that Place, which was 120 Foot, 'as the Fishermen had often before that found by sounding, and the multi-'tude of Waters which one would have thought sufficient to have quenched 'the Fire: A subterraneous Fire, I say, broke out with a most unexpressible 'violence, carrying up into the Clouds with it Water, Sand, Earth, Stones, 'and other vast great bulks of Bodies; which to the sad Spectators, at a di-'stance, appear'd like Flocks of Wool or Cotton, and falling back on the Sur-'face of the Water look'd like Froth. The Space of this Eruption was about 'as big as a Space of Land, that might well be sown by two Bushels of Grain. 'By great Providence the Wind blew from the Land; otherwise the whole 'Island would, in all probability, have perished by the merciless Rage of these 'devouring Flames, such vast bulks of Stone were thrown up into the Air, 'about the height to seeming of three Pikes Lengths, that one would rather 'think them Mountains than Rocks. And which added further Horror to 'this dreadful Sight, was, that these Mountains returning again, often met 'with others ascending or being thrown up, and were thereby dasht into a '1000 Pieces; divers of which Pieces being afterwards taken up and bruised, 'easily turn'd into a black shining Sand. Out of the great multitude and va-'riety of these vast rejected Bodies, and the immense heaps of Rocks and Stones, 'after a while was form'd a new Island out of the main Ocean, which at first 'was not above 5 Furlongs over; but after a while, by daily accesses of new 'Matter, it increased after 14 Days to an Island of 5 Miles over. From this 'Eruption, so great a quantity of Fish was destroy'd and thrown upon the next 'adjoining Island, that 8 of the biggest *Indian* Galeons would not be suffici-'ent to contain them; which the Inhabitants fearing, lest the Stink of them

, might create a Plague, for 18 Miles round collected and buried in deep Pits. , The Stink of the Brimstone was plainly smelt at 24 Miles distance. Thus far he. But we have one Instance more of the Generation of an Island out of the bottom of the Sea, by an Eruption; which because it happen'd very lately, namely in 1650, and near an Island in the *Archipelago*, which *Pliny* relates to have been heretofore after the same manner produced, I shall in short relate, as it is more largely recorded by *Kircher*, in his *Mundus Subterraneus*, from the Mouth of Father *Franciscus Riccardus*, a Jesuit, who was at the same time in the adjoining Island, and was an Eye-witness of all the *Phænomena*.

'From the 24th of *September* to the 9th of *October*, 1650, the Island of *Santerinum*, formerly call'd by *Pliny Thera*, was dreadfully shaken with Earthquakes, so that the Inhabitants expected nothing but utter ruine; and were yet more amazed by a horrid Eruption of Fire out of the bottom of the Sea; about 4 Miles to the Eastward of the Island: Before which the Water of the Place was rais'd above 30 Cubits perpendicularly, (I suppose he means as to appearance from the Island, otherwise 'tis but very little) which Wave spreading it self round every way, overturn'd every thing it met, destroying Ships and Galleys in the Harbour of *Candie*, which was fourscore Miles distant. The Eruption fill'd the Air with Ashes and horrible sulphureous Stinks, and dreadful Lightnings and Thunders succeeded. All things in the Island were covered with a yellow sulphureous Crust, and the People almost blinded as well as choak'd. Multitudes of Pumice, and other Stones were thrown up, and carried as far as *Constantinople*, and to Places at a very great distance. The Force of this Eruption was greatest the two first Months, when all the Neighbouring Sea seem'd to boil, and the *Vulcan* continually vomited up Fire-balls. Upon the turning of the Wind, great Mischief was done in the Island of *Santerinum*, many Beasts and Birds were kill'd: And on the 29th of *October*, and 4th of *November*, about 50 Men were kill'd by it. The other four Months it lasted, tho' much abated of its former Fierceness, yet it still cast up Stone, and seem'd to endeavour the making of a New Island; which though it do not yet perfectly appear above Water, yet 'tis cover'd but 8 Foot by the Water; and the bubbling of the Water seems to speak another Eruption, that may in time finish Nature's Birth. And in the Year he writ this, which he says was 1656, there was an extraordinary boiling of the Sea, and an Eruption of Smoke. And though our Natural Historians have been very scarce in the World, and consequently such Histories are very few; yet there has been no Age wherein such Historians have liv'd, but has afforded them an Example of such Effects of Earthquakes. And I doubt not, but had the World been always furnisht with such Historians as had been inquisitive and knowing, we should have found not only *Thera* or *Santerinum*, and *Volcano* and *Delos*, and that in the *Azores*, and one lately in the *Canaries*, but a very great part of the Islands of the whole World to have been rais'd out of the Sea, or separated from the Land by Earthquakes: for which Opinion I shall afterwards relate several Observations both of my own and others, which seem to afford probable Arguments.

The third Species under the first Genus *of Effects.*

But to proceed to the third Kind or Species of Effects produced by Earthquakes, which is the raising very considerable Mountains out of Plains. Of this I shall add a few Instances; but none more notable, than that of the new Mountain near *Naples*, of which I said somewhat before out of *Sandys*'s Travels. In the Year 1538. *Septemb.* 29. this Mountain visibly ascended about the 2d hour of the Night, with a hideous roaring, horribly vomiting Stones, and such store of Cinders, as overwhelm'd all the Buildings thereabout, and the salubrious Baths of *Tripergula*, for so many Ages celebrated, consuming all the Vines to Ashes, and killing Birds and Beasts, and frighting away all the Inhabitants, who fled naked and defiled through the dark: And has advanced its top a Mile above the Basis: the Stones of it are so light and pory, that they will not sink when thrown in the Sea. This new Mountain, when new rais'd, had a number of Issues, at some of them smoking, and sometimes flaming;

ming; at others disgorging Rivulets of hot Water, keeping within a terrible rumbling; and many perished that ventured to descend into the hollowness above. But that hollow at the top is at present an Orchard, and the Mountain throughout bereft of its Terrors. 'It is reported, saith *Childrey*, that in a 'Parish by the Sea-side, not far from *Axbridge* in *Somersetshire*, within these 50 'Years, a Parcel of Land swell'd up like a Hill; but on a sudden clave asun-'der, and fell down into the Earth, and in the place of it remains a great 'Pool. Our English Chronicles say, at *Oxenhal*, in the Bishoprick of *Durham*, on *Christmas* Day 1679, the Ground heav'd up aloft like a Tower, and continued all that day immoveable, till Evening, and then fell with a horrible noise, sinking into the Earth, and leaving three deep Pits, call'd Hell-kettles. *Varenius* tells us of a new Mountain likewise raised in *Java*, in the Year 1586, with the like Effects of those I formerly named of the new Mountain; first shaking the Earth, then heaving up and throwing up into the Air the upper Parts of the Earth, afterwards the Rock and inner Parts, then fiery Coals and Cinders, overwhelming the circumjacent Fields and Towns, and killing above 10000 Men, and burning what was not overwhelmed. I have not time to reckon up the multitude of Instances I have met with in Authors; such as *Ætna* in *Sicily*, *Vesuvius* in *Italy*, one in *Croatia*, near the City *Valonia*, the *Pike* in *Tenarif*, and the *Pike* in the *Azores*, *Hecla*, *Helga*, and another in *Island*: The Mount *Gonnapi* in one of the Islands of *Banda*, which made an horrid Eruption at the same time with that in *Java*: The Mount *Balavane* in *Sumatra*: Others in the *Molucca* Islands, in *China*, *Japan*, and the *Philippines*, and in some of the *Mauritian* Islands, and several other Parts of the *East Indies*. In the *West Indies* also we have multitudes of Examples, several in *Nicaragua*, and all along the Ledge of Mountains in *Peru* and *Chile*, and in *New Spain* and *Mexico*: In the Islands of *Papoys*, discover'd by *Le Mair*, joining to the South Continent in *Mar Del Zur*: All which are as so many shining Torches to direct us in the search after this Truth. There are many other Instances of Mountains, that have but lately as it were left to burn, and are cover'd with Wood and grown fruitful. So the new Mountain I formerly mention'd, has an Orchard growing where the Fire at first flamed. Another in the Island *Quimeda*, near the River *Plat* in *Brasill*: The Islands also of St. *Helena*, and *Ascension*, discovered by the great plenty of Cinders, and the Fashions of the Hills to have formerly contained *Vulcanoes*, and probably were at first made by some subterraneous Eruption, as indeed most of those Islands in the main Ocean; such as the *Canaries*, and the *Azores*, and the *East Indian*, and the *Cariby* Islands and divers others seem to have been. A Passage, to make this Assertion somewhat more probable, I have met with in *Linschoten*'s Description of the Island of *Tercera*, which as *Purchas* has epitomized I have here added. Pag. 1670. of the 4th Part of his Pilgrims (he saith, speaking of the Island of *Tercera*) 'The Land is very high, and as it 'seemeth hollow; for that as they pass over an Hill of Stone, the Ground 'soundeth under them as if it were a Cellar. So that it seems in divers Pla-'ces to have holes under the Earth, whereby it is much subject to Earth-'quakes, as also all the other Islands are; for there it is a common thing: 'and all those Islands, for the most part, have had Mines of Brimstone; for 'that in many Places of *Tercera* and St. *Michael*, the Smoke and Savour of 'Brimstone doth still issue out of the Ground, and the Country round about 'is all singed and burnt. Also there are Places wherein there are Wells, 'the Water whereof is so hot that it will boil an Egg, as if it were over a 'Fire. Besides which, the shape of the Hills, and several other Circumstances mention'd in *Linschoten*, do make it probable that those have been all *Vulcano's*.

But to proceed to the Fourth Species of Effects of Earthquakes under this Head; and that is, the raising of the Parts of the Earth by the throwing on a great access of new Earth: Of this I have already given many Instances in the newly mentioned Histories of Eruptions, where I mentioned the overwhelming of Fields, Towns, and Woods, and the like, by Materials thrown out by these Eruptions. I shall only add one Instance or two more to confirm this

Fourth Species under the first Genus of Effects.

this Head, and then proceed. The first is that mentioned by *Olaus Wormius*, in the 5th Chapter of the 1st Section of the 1st Book of his *Musæum*, wherein he gives an Account of an extraordinary Earthquake in *Iceland*, which fill'd the Air with Dust, Earth, and Cinders, and overwhelmed Towns, Fields, and even Ships a good way distant on the Sea; and which sent forth its Fumes with such violence and Plenty, as covered all the Decks and Sails of Ships lying on the Coast of *Norway*, some hundred Leagues distant. His Words are Page the 18th thus, *Alterum portentosæ Terræ genus, &c.* And to make this of *Wormius* the more probable, I have now by me a Paper of Dust, which was rained out of the Air upon a Ship lying at *Algier* upon the Coast of *Barbary*, upon a great Eruption of *Vesuvius* in the Year 16--- The Relation of which, as I received it together with the Paper of Dust from that eminent Virtuoso, *John Evelyn*, Esq; I shall here annex. * But which is beyond all, is the late Eruption of *Mongibell* or *Ætna*.

* *This was omitted by the Author.*

And to confirm this Proposition yet further, I cannot pass by a very remarkable Rain of Earth and Ashes, that happen'd in *Peru*, *Anno* 1600, mentioned by *Garcilasso De la Vega*, one of the Off-spring of the *Incas* of *Peru*, in his History of *America*. The Epitome of which by *Purchas*, is this, pag. 1476 of the 4th Part of his *Pilgrims*. 'I might add, says he, the great Earth-'quakes, *An.* 1600, in *Peru* at *Arequepa*, the raining of Sand, as also of 'Ashes, about 20 days from a *Vulcan* breaking forth: The Ashes falling in 'Places above a Yard thick, in some Places more than two, and where least 'above a quarter of a Yard, which buried the Corn-grounds of Maize and 'Wheat, and the Boughs of Trees were broken and fruitless, and the Cattel 'great and small dy'd for want of Pasture. For the Sand which rained covered 'the Fields 30 Leagues one way, and above 40 Leagues another way, round 'about *Arequepa*, they found their Kine dead by 500 together in several Herds, 'and whole Flocks of Sheep, and Herds of Goats and Swine buried. Hou-'ses fell with the weight of the Sand; others cost much Industry to save them; 'mighty Thunders and Lightning were heard and seen 30 Leagues about *A-'requepa*. It was so dark whilst those Showers lasted, that at mid-day they 'burned Candles to see to do business.---I could add divers other Instances to confirm this Proposition; but these may at present suffice.

But this is but one way by which divers things have been buried: there is another way which I can only at present mention, and must refer the Probation and Prosecution to some other occasion; and that is, that very many of the lower superficial Parts of the Earth, have been and continually are covered and buried by the access of Matter, tumbled and washed down by Excesses of Wind and Rain, and by the continual sweepings of Rivers and Streams of Water. Under this Head, I shall shew several Places and Countries in the World, that are nothing else but the Productions of these Causes. To this purpose, *Peter de la Valle* gives some Observations which he made in *Egypt*, in the 11th Letter dated from *Grand Caire*, *Jan.* 25. 1616. 'Of the 'former seven Mouths of *Nile* (says he) there are only four left, and of 'those but two Navigable; the rest are either fill'd, or run no more, or are 'small Streams not taken notice of, or only Torrents in the time of great 'Rains; but I could learn nothing of them, because the great Expence of 'the Ancients for cleansing the Ditches, has been intermitted for several 'hundreds of Years. He is likewise of Opinion with *Herodotus*, that the *Delta*, and all the Lower *Egypt*, where the *Greeks* navigated in his time, was in the first Ages of the World made by the Sand and Mud of *Nile*.

All which Histories and Particulars do manifestly enough evince, that there have been in very many Parts of the World considerable Mutations of the superficial Parts, since the beginning; and that therefore those Places where these figured petrify'd Bodies are found; though they now seem never so much foreign, and differing from the likely native Places of such animated Bodies, may notwithstanding heretofore have been in such another kind of condition, as was most sutable to the breeding and nourishing of them: Which I shall yet further manifest, by comparing the other Effects produced by Earthquakes; such as the sinking, and burying, and transposing, and overturning of the superficial Parts of the Earth.

Another

Another Sort of Effects, is the sinking of the superficial Parts of the Earth, and placing them below their former Position, both in respect of some Parts newly raised, and in respect of some other adjacent Parts not displaced. And this seems to be caus'd by the subsiding or sinking of those Parts into such Caverns, as by the strength of the Eruption passing below before it breaks out are made underneath: For so great is the Violence of these subterraneous Fires, that nothing almost is able to resist their Power of expanding; but spreading themselves, and rushing that way which is most easy, they carry along before them Earth, Sand, and Rocks, and Mountains, and whatever lies in their way, and raise the superficial Parts of the Earth whilst they pass underneath. And if the Parts of the Earth underneath are so loose or obnoxious to the Force of the Fire, as to be dislodged, unless the remaining Parts are very strong and constitute a very firm Stony Arch, the Earth does easily tumble into the Holes and Hollows made by the Fire. Now it cannot be imagin'd but that all those vast Congeries of Earth, which I have already mention'd to have been thrown up, and to create new Islands and new Mountains, and the like, must leave vast Caverns below them, to be fill'd either with the Parts of the Earth that hang immediately over them, or with the Sea, or other subterraneous Waters, if the Roofs of these Cavities be strong enough to sustain the Earth above them from sinking. And some such Power as these subterraneous Fires, seems to me to have been the Cause of the strange Positions and Intermixture of the Veins of Ores and Minerals in the Bowels of the Mountains, where, for the most part, they are now found; and even of bringing those Substances so near the Surface of the Earth, which, from the Consideration of very many Circumstances, seem to me to be naturally situated at a much greater Depth below within the Bowels of this Globe. And hence may be rendred a Reason of the Figures of these Minerals, and other Substances mix'd with them, and of the compounding and blending of several of those Substances together, whereby some of them are very strangely united and alter'd. But this I mention only by the Bye, and shall not insist on it, belonging more properly to another Head. To proceed then under this General Head, are comprised several Kinds of Effects, differing only according to the Parts of the Earth they have been wrought upon.

The second sort or General Head of Effects of Earthquakes.

The first is, The sinking of several Inland Parts, which were before eminent, and laying them much lower into Vales. Sometimes, the sinking of a Part of the Earth to a very great Depth, and leaving behind, instead of a firm Ground, a Lake of Salt or Sea-water. Of these we have several Instances in Natural Historians. And, to pass by many others, I shall only mention such as have lately happen'd. Of this kind Mr. *Childrey*, in his *Britannia Baconica*, has collected several Instances; two out of our English Chronicle. His Relations are these, *Pag.* 62. '*August* the 4th, 1585. after a very violent Storm of Thunder and Rain, at *Nottingham* in *Kent*, Eight miles from *London*, the Ground suddenly began to sink; and Three great Elms growing upon it, were carried so deep into the Earth, that no Part of them could any more be seen. The Hole left (saith the Story) is in Compass 80 Yards about, and a Line of 50 Fathoms plummed into it finds no Bottom. Also,

The first Species of those Effects, under the second general Head or Genus of Earthquakes.

'*Dec.* 18. 1596. a Mile and half from *Westram*, Southward (which is not many Miles from *Nottingham*) a Part of an Hedge of Ashes, 12 Perches long, were sunk 6 Foot and an half deep; the next morning 15 Foot more; the third morning 80 Foot more at least, and so daily. (And presently after, he says) Moreover, in one Part of the Plain Field, there is a great Hole made by sinking of the Earth, to the Depth of 30 Foot at least, being in Breadth in some Places 2 Perches over, and in Length 5 or 6 Perches. There are sundry other Sinkings in divers other Places, one of 60 Foot, another of 47, and another of 34 Foot; by means of which Confusion it is come to pass, that where the highest Hills were, there be the lowest Dales, and the lowest Dales are become the highest Grounds, *&c.*

And again, *Pag.* 131. he gives an Instance, upon his own Knowledge, much to the same purpose, which lately happen'd; namely, '*July* the 8th 1657. 'about

'about 3 of the Clock, in the Parish of *Bickly*, was heard a very great Noise 'like Thunder afar off; which was much wonder'd at, because the Sky was 'clear, and no Appearance of a Cloud. Shortly after (saith the Author of 'this Relation) a Neighbour came to me, and told me, I should see a very 'strange thing if I would go with him. So coming into a Field, called the '*Lay-field*, we found a very great Bank of Earth, which had many tall Oaks 'growing on it, quite sunk into the Ground Trees and all. At first we durst 'not go near it, because the Earth, for near 20 Yards about, was exceeding-'ly much rent, and seem'd ready to fall: But since that time, my self and 'some others have ventured to see the bottom, I mean to go to the Brink, so 'as to discern the visible Bottom, which is Water, and conceived to be about '30 Yards from us; under which is sunk all the Earth about it, for 16 Yards 'round at least, 3 tall Oaks, a very tall Awber, and certain other small 'Trees, and not a Sprig of them to be seen above Water. 4 or 5 Oaks 'more are expected to fall every moment, and a great Quantity of Land is 'like to fall, indeed never ceasing more or less; and when any considerable 'Clod falls, it is much like the Report of a Cannon. We can discern the 'Ground hollow above the Water a great Depth; but how far hollow or how 'deep, is not to be found out by Man. Some of the Water, (as I have been 'told) drawn out of this Pit with a Bucket, was found to be as salt as Sea-'water, *&c.*

A considerable Circumstance also to confirm this Proposition, is a Passage in that History I have mention'd out of *Linschoten*, of the Island of *Tercera*; where he says [*and some Hills were defaced, and made even with the Ground.*]

Kircher in the Preface to his *Mundus Subterraneus*, Chap. 2. tells us a very remarkable History of the sinking of a Town, and the Land about it, and the Generation of a Lake instead of it. *Contigit* (says he) *hac eadem hora res æterna ac immortali Memoria digna, subversio videlicet celeberrimi oppidi quod Sanctam Euphemiam dicunt, erat hoc in extrema Sinus ora situm sub equitum Melitensium Jurisdictione. Cum itaq; ad Lopicium ex vehementi Terræ subsultatione veluti exanimes in terra prostrati tandem subsidente Naturæ paroxysmo, oculis in circum jacentia Loca conjectis, ingenti nebula, paulo ante memoratum oppidum circumdatum vidissemus; ter sane post Meridiem, hora tertia præsertim Cœlo sereno mira & insolita nobis videbatur. Dissipata vero paulatim nebula, oppidum quæsivimus sed non invenimus. Mirum Dictu, Lacu putidissimo in ejus Locum enato. Quæsivimus Homines qui de insolito rei eventu nonnihil certi nobis enarrare possent, sed formidabilis casus tantaq; stragis nuncium non reperimus, &c.---- Nos itineri insistentes Nicastrum, Amanteam, Paulam, Belviderium transeuntes nil aliud ad 200 Millia passuum nisi cadavera Urbium, castallorum, strages horrendas reperimus, Hominibus per apertos campos palantibus & præ timore veluti exarescentibus.* That is, 'At this very time happened a thing worthy never to be forgotten, *viz.* the 'Subversion of the most famous Town, call'd St. *Euphemia*: 'twas situated at 'the side of the Bay under the Jurisdiction of the Knights of *Malta*. When 'therefore we had come to *Lopiz*, almost dead from the vehement shak-'ing of the Earth, and lying prostrate on the Ground, at last the *Paroxysm* 'of Nature remitting, casting our Eyes towards the Neighbouring Places, 'we saw the forementioned Town encompassed with a great, wonderful, and 'unusual Cloud, which was seen by us three times, especially at Three-a-clock 'in the Afternoon, the Heavens being clear. This Cloud being, by degrees, 'dissipated, we look'd for the Town, but found it not, a stinking Lake (to 'our wonder) appearing in the Place of it. We sought for some Person or 'other, to give us some certain Account of this unusual Event; but could 'not find one to tell any News of this dreadful Accident and great Destru-'ction, *&c.* We prosecuting our Journey, passing by *Nicastrum*, *Amantea*, '*Paula*, and *Belvedere*, found nothing for 200 Miles, but the remaining Car-'casses of Cities and Castles, and horrid Destructions; the Men lying in 'the open Fields, and, as it were, dead and withered through Fear and 'Terror.

To this purpose, give me leave to adjoin an Extract of a Letter, sent from *Balasore* in the *East Indies*, *Jan.* 6. 1665. 'The same Star appeared in our 'Horizon, about the same time 'twas seen with you. The Effects in part

'have

'have already been felt here by unseasonable Weather, great Mortalities a-
'mongst the Natives, *English*, and others. We have had several Earth-
'quakes unusual here, which, with hideous Noises, have in several Places
'broke out and swallow'd up Houses and Towns. But about 7 Days Journey
'from *Ducca*, where were at that time 3 or 4 *Dutch*, they and the Natives
'relate, That in the Market-Place the Earth trembled about 32 Days and
'Nights, without Intermission. At the latter end, in the Market-place, the
'Ground turn'd round as Dust in a Whirlwind, and so continued several
'Days and Nights, and swallow'd up several Men who were Spectators, who
'sunk and turned round with the Earth, as in a Quagmire. At last, the
'Earth worked and cast up a great Fish bigger than hath been seen in this
'Country, which the People caught: But the Conclusion of all was, that the
'Earth sunk with 300 Houses, and all the Men, where now appears a large
'Lake some Fathoms deep. About a Mile from this Town was a Lake full
'of Fish, which in these 32 Days of the Earthquake cast up all her Fish on
'dry Land, where might have been gather'd many, which had run out of the
'Water upon dry Land, and there died: But when the other great Lake ap-
'peared, this former dried up, and is now firm Land.

To the same purpose also we have several other Instances, some later and some nearer home. 'Near *Darlington* (says *Childrey*, in his *Britannia Baconi-*
'*ca*, speaking of the Rarities of the Bishoprick of *Durham*) are three Pits,
'whose Waters are warm (hot, says *Cambden*) wonderful deep, call'd Hell-
'Kettles. These are thought to come of an Earthquake, that happen'd
'*Anno* 1179. For on *Christmas* Day, says our Chronicles, at *Oxenhall*, which
'is this Place, the Ground heaved up aloft like a Tower, and so continued
'all that Day, as it were immovable, till Evening, and then fell in with a
'very horrible Noise, and the Earth swallow'd it up, and made in the same
'Place 3 deep Pits. The same in the Section of *Brecknock*, says, 'Two Miles
'East from *Brecknock*, is a Meer, called *Llinsavathan*, which (as the People
'dwelling there, say,) was once a City; but the City was swallowed up by
'an Earthquake, and this Water or Lake succeeded in the Place: The Lake
'is encompassed with high steep Hills, *&c.*---

'Near *Falkirk*, saith *Lithgow*, remains the Ruines and Marks of a Town,
'*&c.* swallowed up into the Earth by an Earthquake, and the void Place is
'fill'd with Water.---- *Pliny* also, in the 88th Chap. of his 2d Book of Nat. Hist. records a like Instance. *Mox & in his Montem Epopon cum repente flamma ex eo emicuisset campestri æquatum planitie. In eadem & oppidum haustum profundo alioq; motu Terræ Stagnum emersisse. Et alio provolutis Montibus insulam extitisse Prochytam, &c.* 'Presently the Mountain *Epopon* (when suddenly a
'Flame had shon out of it) was levelled with the Plain; and in the same
'Plain a Town was swallow'd up into the Deep, and by another Motion of
'the Earth became a Lake. And in another Place, the Mountain being
'tumbled down, the Island *Prochyta* arose, *&c.*

The Dead Sea also in *Palestine*, was the Production of a most terrible Earthquake, and a Fire sent from Heaven: For, methinks, the Relation of the sad Catastrophe of those Four Cities, *Sodom*, *Gomorrha*, *Zeboim* and *Adma*, mentioned in Scripture, seem somewhat like that I have newly related out of *Kircher* of St. *Euphemia*. There are a multitude of other Instances which I could bring on this Head, of the sinking of Mountains and Hills into Plains, and all these into Lakes: Of which *Pliny* gives several Instances, in the 90, 91, and 92 Chap. of his Second Book. The *Pico* in the *Moluccas*, accounted of equal Height with that of *Tenariff*, was by a late Earthquake quite swallow'd into the Earth, and left a Lake in its Place. *Vesuvius* and *Strongylus*, are by late Earthquakes reduced to almost half their former Height. Many of those vast Mountains of the *Andes* in *Chile*, were by an Earthquake, *An.* 1646. quite swallow'd up and lost, as *Kircher* relates. I could add many Histories of the fatal Catastrophe's of many Towns, and other Places of Note; but these, I hope, may suffice to shew this kind also of Mutation in the superficial Parts of the Earth, to be effected by Earthquakes.

Nor

The second Species of those Effects under the second General.

Nor does Earthquakes only sink Mountains and Inland Parts; but such Parts also as are near to, equal with, and under the Surface of the Sea. Of this we have Instances near home, of *Winchelsea* and of the *Goodwin-Lands*, and of the Towns in *Freezland*, that have been about 400 Years since swallow'd up by the Sea; and nothing but some Towers, and the *Goodwin-Sands*, are now to be found of them. The like happen'd to several Parts of *Scotland*, as *Hector Boethius* relates. *Linschoten*, in his History of the *West-Indies*, relates among many other Histories of the Effects of Earthquakes, this considerable Passage. 'Since, in the Year 1586. in the Month of *July*, fell another 'Earthquake in the City of *Kings*, the which, as the Vice-Roy did write, 'had run 170 Leagues along the Coast, and athwart in the *Sierra* 50 Leagues. 'It ruin'd a great Part of the City. It caus'd the like Trouble and Motion 'of the Sea, as it had done at *Chile*, which happen'd presently after the 'Earthquake; so as they might see the Sea to fly furiously out of her Bounds, 'and to run near 2 Leagues into the Land, rising above 14 Fathom. It co-'ver'd all the Plain, so as the Ditches were filled and Pieces of Wood that were 'here, swam in the Water. There are multitudes of Instances of the like Effects in several other Parts of the World, which have been wrought by Earthquakes, which may be found in Natural Historians; which, for Brevity-sake, I omit, they serving only to prove a Proposition, which, I suppose, will be granted by any that have either seen or heard of the Effects of Earthquakes.

The third Species of Effects under the second General.

Now, though I find a general Deficiency in Natural Historians, of Instances to prove that the submarine Parts have likewise suffer'd the like Effects of sinking, they lying out of view, and so cannot without some Trouble and Diligence be observed; yet if we consider from how great a Depth these Eruptions proceed, and how little Distinction they make between Mountains and Plains, as to the weight of removing, we may easily believe, that the Bottom of the Sea is as subject to these Mutations, as the Parts of the Land. And since, by the former Relations, we have many Instances of the raising of the Bottom of the Sea, 'tis very probable that what Quantity of Matter is thrown to and raised in one Place, is sunk, and falls into that Cavity left by another. An Island cannot be raised in one Place, without leaving an Abyss in another. And I do not doubt, but there have been as many Earthquakes in the Parts of the Earth under the Ocean, as there have been in the Parts of the Dry Land: But being, for the most part, till of late unfrequented by Mankind, and even now but very thinly, 'tis almost a 1000 to 1, that what happen are never seen; and a 100 to 1, if they have been seen, whether they be recorded: For how few Writers are there of Natural History? There is somewhat of Probability in the Story related by *Plato*, in his *Timæus*, of the Island *Atlantis* in the *Atlantick* Ocean, which he says was swallow'd up by an Earthquake into the Sea. And 'tis not unlikely, but that most of those Islands that are now appearing, have been either thrown up out of the Sea by Eruptions, such as the *Canaries*, *Azores*, St. *Helena*, *&c.* which the Form of them, and the Vulcanes in them, and the Cinders and Pumice-stones found about them, and the frequent Earthquakes they are troubled with, and the remaining Hills of extinguish'd Vulcanes, do all strongly argue for: Or else, that they are some of them at least some Relicts of that Great Island which is now not to be found; and yet we have no Records hereof. That there is as great Inequality in the Depth of the Sea, as there is in the Height of the Land, the Observations of Seamen, experimented by their Sounding Lines, do sufficiently inform us: For Hills, we have deep Holes; and for Mountains and Pikes, Abysses and Malstroons: And that these must have in all Ages been filling with Parts of the Earth, tumbled by the Motion of the Waters, and rowling to the lowest Place, is very probable; and so they would in time have been fill'd up, had not Earthquakes, by their Eruptions and Tumblings, created new Irregularities. And therefore that there are still such Places, is an Argument, that there have been of later Ages Earthquakes in some of them. Of these I shall mention one or two Instances, which I meet with in Voyages, and Relations of Travellers.

In

In the Relation of the Circum-navigation of Sir *Francis Drake*, speaking of the Straights of *Magellane*, he says, Pag. 35, 'They saw an Island with a very high *Vulcano*; and the next Page, he says, 'They had need to have carry'd no-'thing but Anchors and Cables, to find Ground, the Sea was so very deep: 'Which Depth is explain'd more express, Pag. 42. where 'tis said, 'Being 'driven from our first Place of anchoring, so unmeasurable was the Depth, 'that 500 Fathoms would fetch no Ground. And in Page 99. of the same Relation, the Author tells, how their Ship struck upon a Rock, which Page 102. he says, at low Water was but 6 Foot under Water, and just by it no Bottom to be found, by reason of the great Depth.

Mr. *Ricaut*, in a Letter of his to the Royal Society, dated from *Constantinople*, *Nov.* 1667, says, 'That the Water runs out of the *Euxine* Sea into the *Pro-'pontis* with a wonderful swiftness, which is more wonderful in regard of the 'depth of the *Bosphorus* being in the Channel fifty or fifty five Fathom Wa-'ter, and along the Land in most places the Ships may lye on the Shore with 'their Heads, and yet have twenty Fathom Water at their Sterns.

The third General Head or the third sort of effects of Earthquakes.

Besides these effects of raising and sinking the parts of the Earth, there is a third sort, which is the transposing, converting, subverting and jumbling the parts of the Earth together; overthrowing Mountains, and turning them upsidedown, throwing the parts of the Earth from one place to another, burying the superficial parts, and raising the Subterraneous. Of these kinds of changes there are many instances in the former Relations I have mention'd, as particularly that of *Linschoten* of the Earthquake in the *Terceras*, and that of *Josephus Acosta*, of the Earthquake upon the Coast of *Chile*. And there are a multitude of others I could here set down, but I shall only mention some of them. 'Soon after, (says *Josephus Acosta*, in the same place I mentioned be-'fore) which was in the Year 1582, happened that Earthquake of *Arequipa*, which in a manner overthrew the whole City. And a little before in the same place, he tells of a terrible Earthquake in *Guatimala*, in the Year 1586, which overthrew almost all the City, and that the Vulcan for above six Months together continually vomited a Flood of Fire from the top of it. And a little after, the same Author, in the same place, says, 'In the Year of our Lord '1581, in *Cugiano*, a City of *Peru*, otherwise call'd the *Pear*, there happen'd 'a strange accident touching this Subject; a Village call'd *Angoango* (where 'many *Indians* dwelt that were Socerers and Idolaters) fell sudenly to ruine, 'so as a great part thereof was raised up and carried away, and many of the '*Indians* smothered; and that which seems incredible (yet testified by Men 'of Credit) the Earth that was ruined and so beaten down, did run and slide 'upon the Land for the space of a League and a half, as it had been Water or 'Wax melted, so as it stopt and fill'd up a Lake, and remain'd so spread all 'over the whole Country.

Nor are there wanting Examples of this kind even in this Island. Mr. *Childrey* in his *Britannia Baconica* has collected several out of *Cambden*; as that in *Herefordshire*, 'Where, in the Year 1571, *Marcley* Hill in the East part of 'the Shire, with a roaring noise, remov'd itself from the place where it stood, 'and for three Days together travell'd from its old Seat. It began first to 'take its Journey *Feb.* 17. being *Saturday*, at six of the Clock at Night, and 'by seven the next Morning it had gone forty Paces, carrying with it Sheep 'in their Cotes, Hedge-Rows, and Trees, whereof some were overturn'd, 'and some that stood upon the Plain, are firmly growing upon the Hill; 'those that were East were turned West, and those in the West were set in 'the East; in this remove it overthrew *Kinaston* Chappel, and turn'd two 'High-ways near a hundred Yards from their old Paths: The Ground that 'they remov'd was about twenty six Acres, which opening itself with Rocks 'and all bore the Earth before it for four hundred Yards space, without any 'stay, leaving Pasturage in places of the Tillage, and the Tillage overspread 'with Pasturage. Lastly, overwhelming its lower parts, it mounted to a 'Hill of twelve Fathoms high, and there rested after three Days travel.

'At *Hermitage* in *Dorsetshire*, says *Stow* in his Summary, *January* the third '1582, a piece of Ground of three Acres remov'd from its old place, and was 'carried over another Close where Alders and Willows grew, the space of 'forty Rods or Pearches, and stopt up the high-Way that led to *Cerne*, a 'Market-Town, and yet the Hedges that it was inclosed with enclose it 'still, and the Trees stand bolt upright, and the place where this Ground 'was is left like a great Pit.' And 'tis not a little observable, that at the same time that these changes happened in *America*, the like also happened in *England*, of which I shall hereafter give divers other Instances, and shall also deduce Corrolarys, that may otherwise seem very strange, and yet I question not to prove the truth of them. *Maximus* (says *Pliny*, Cap. 48. Lib. 2. Hist. Nat.) *Terræ memoria mortalium extitit motus Tiberii Cæsaris principatu.* XII. *urbibus Asiæ una nocte prostratis.* 'The greatest Earthquake that ever happen'd in the 'Memory of Man was in the Reign of *Tiberius Cæsar*, twelve Cities of *Asia* 'being thrown down by it in one Night.' And again, *(Cap.* 83. ibid.*) Factum est semel* (says he) *quod equidem in Hetruscæ disciplinæ voluminibus invcni, ingens terrarum portentum L. Martio, Sex. Julio Coss. in Agro Mutinensi namq; montes duo inter se concurrerunt, crepitu maximo assultantes recedentesq; inter eos flamma fumoq; in cœlum exeunte interdiu, Spectante evia Æmilia Magna equitum Romanorum familiarumq; & viatorum multitudine: Eo concursu villæ omnes elisæ, animalia permulta quæ intra fuerant exanimata sunt, anno ante Sociale bellum. Quod haud scio an funestius ipsi terræ Italiæ fuerit quam Civilia. Non minus mirum ostentum & nostra cognovit ætas. Anno Neronis Principis Supremo, sicut in rebus ejus exposuimus, prætis oleisq;, intercedente via publica in contrarias sedes transgressis, in Agro Marrucino Prædiis Vectii Marcelli Equitis Romani res Neronis Procurantis.* Thus English'd. 'There happen'd once (which I found in the Books of the *Tuscane* 'Learning) within the Territories of *Modena*, *L. Martius* and *S. Julius*, be- 'ing Consuls a great wonder of the Earth; for two Hills encountred each 'other charging one another with a great crash, and retiring again, a great 'Flame and Smoak in the Day-time issuing out from between them to the 'Sky, while a great many of the *Roman* Knights, their Friends and Travel- 'lers beheld it from the *Æmilian* Road. With this conflict and meeting to- 'gether, all the Country Houses were dasht to pieces, many Animals that 'were between them perish'd. This happen'd before the *Social* War. I 'know not whether it were not more pernicious to *Italy* than the Civil-Wars.' 'No less a wonder was that in our Age, in the last Year of *Nero* (as we have 'shewn in his Acts) when Meadows and Olive-Trees (the publick Road lying 'between them) went into the contrary places, in the *Marrucine* Territory, in 'the Lands of *Vectius Marcellus*, a *Roman* Knight, Procurator under *Nero*.

There are many the like Instances to be met with in Authors, of the placing Parts perpendicular or inclining, which were before horizontal; so the turning of other parts upside downwards, of throwing parts from place to place; of stopping the Passage of Rivers, and turning them another way; of swallowing some Rivers, and of producing others a new; of changing Countries from Barren to Fruitful, and from Fruitful to Barren; of making lands join to the Continent, and separating parts of the Continent into Islands. There are other Relations that mention the vast spaces of Ground that have been all at once shaken and overturned, some of five Hundred Miles in length, and a hundred and fifty in bredth. Of the communication of Vulcanes (which are as it were the Nostrills or constant Breathing places of these Monsters) tho' plac'd at a very great distance one from another by Subterraneous Caverns. Other Relations furnish us with Instances of the Substances they vomit out; such as Pumice Stones, and several other sorts of calcin'd and melted Stones, and Rocks, Ashes, Minerals, hot Water, Sulphur, Flame, Smoak, and various other Substauces.

The fourth general Head of the Effects of Earthquakes.

In others we find instances of Liquefactions, Vitrifications, Calcinations, Sublimations, Distillations, Petrifactions, Transformations, Suffocations and Infective or deadly Steams destroying all things near them, which possibly may be one cause of the scarcity of Relations where 'tis probable there have been so very many effects wrought in the World of this kind. But these I shall not

not insist upon, having I fear too long digress'd on this part to shew the variety of effects produced by Earthquakes.

There is only one thing more that I think pertinent to our present purpose, and that is the universality of this active Principle: There is no Country almost in the World but has been sometimes or other shaken by Earthquakes, that has not suffered some, if not most parts of these Effects. *Seneca* says in the Preface to the 6th Book of his Natural Questions. *Omnia ejusdem sortis sunt, etsi nondum mota tamen mobilia; erramus enim, si ullam terrarum partem, exceptam immunemq; ab hoc periculo credimus, omnes sub eadem jacent lege, nihil, ita ut immobile esset, Natura concepit: Alia temporibus aliis cadunt; & quemadmodum in urbibus magnis nunc hæc domus nunc illa suspenditur, ita in hoc orbe Terrarum, nunc hæc pars facit vitium nunc illa. Tyrus aliquando infamis ruinis fuit. Asia duodecim Urbes simul perdidit. Anno priore Achaiam & Macedoniam quæcunque est ista vis mali quæ incurrit, nunc Campaniam læsit: Circuit fatum, & siquid diu præteriit, repetit. Quædam rarius, solicitat, sæpius quædam. Nihil immune esse & innoxium sinit. Non homines tantum, qui brevis & caduca res nascimur; Urbes oræque terrarum & Litora & ipsum mare in servitutem fati venit. Quo ergo nobis permansura promittimus bona fortunæ, & felicitatem (cujus ex omnibus rebus humanis velocissima est levitas) habituram in aliquo pondus & moram credimus? Perpetua sibi omnia promittentibus in mentem non venit: Id ipsum supra quod stamus stabile non esse. Neque enim Campaniæ istud aut Achaiæ, sed omnis soli vitium est, male cohærere & ex causis plurimis resolvi; & summa manere partibus ruere.* Which I English thus. 'All things are subject to the same chance; tho' they are 'not yet moved, they are movable; for we err, if we believe any part of 'the Earth excused and free from this hazzard; all are subject to the same 'Law; nothing is made by Nature so fixt as to be unmoveable; some sink at 'one time, some at another: And as in great Cities, now this House, now 'that House hangs tottering on Props; so on the great Face of the Earth, 'now this part fails, now that: *Tyre* formerly was remarkable for its De'struction: *Asia* lost at once Twelve Cities. Whatever the Power may be, 'the former Year *Achaia* and *Macedonia* felt it now *Campania*: Fate goes 'round, and repeates what it had long before acted: It brings some things 'often on the Stage, some seldom; but suffers nothing absolutely free and 'untouch'd. Not we Men only are brought forth short Liv'd, frail Beings: 'Cities, Countries, Shores, nay the Sea itself are the Slaves of Fate. Why 'therefore do we flatter our selves that the gifts of Fortune will stick by us, 'or that Happiness will observe any Rule or Measure, Happiness the most 'fleeting of all humane Things? They that promise to themselves all things 'fixt, surely never think that the very Ground we stand on is it self unfixt. 'Nor was that the frailty only of *Campania* or *Achia*, 'tis the same in all 'Soils and Countries, to be loosely join'd and compacted, but easily and by 'many ways dissolved; the whole remains while each part changes and sinks 'into Ruine and Alteration.'

Of the Universality of this active Power or Principle.

Thus we see all Countries in the World are subject to these Convulsions, but those most of all that are most Mountainous: Such are usually all the Sea Coasts, therefore *Pliny* says, That the *Alps*, and *Appnnine* Mountains have very often been troubled with Earthquakes. *Maritima autem maxime quatiuntur* (says he) *nec montosa tali malo carent. Exploratum est mihis Alpes Appenninumq; sæpius tremuisse.* Martine places are most shaken, nor do the Mountainous escape, for I have often found the *Alpes* and *Apennines* tremble.

For most probably those that are most Mountainous, are most Cavernous underneath them; to countenance which Opinion, I remember to have taken notice in certain very high Cliffs towards the Sea side, where the Hills seemed, as it were, cleft asunder, the one half having been probably foundred and tumbled down into the Sea, and the other half, as it were remaining, that at the bottom, near the Water, for almost the whole length, there were very many large Caverns, which, by several Circumstances, seem'd to be made before the access of the Sea thereunto, and not by the washing and beating of the Waves against the bottom of these Cliffs; for I observ'd in many of them, that the Plates or Layers, as I may so call those parts between the Clefts in

Rocks

Rocks, and Cliffs to lean contrary ways, and to meet, as it were, at the top like the Roof of a House, and others of them in other forms, as if they had been Caverns left between many vast Rocks tumbled confusedly one upon another. And indeed I cannot imagine, but that under these Mountains, Islands, Cliffs or Lands, that have been much rais'd above their former level, there must be left vast Caverns, whence all that Matter was thrown, where probably may be the Seat or Place of the Generation of those prodigious Powers. But this only by the Bye; for I intend not here to examine the causes of their beginnings, force, and powerful Effects, nor of their remaining, ceasing, renewing, or the like. It being sufficient, for my present purpose, to shew, That they have been certainly observ'd to produce those extraordinary Effects from what Cause soever they proceed. That they have been heretofore in many places where they have now ceas'd for many Ages; and that they have lately happen'd in places, where we have no History that does assure us they have been heretofore. That they have turn'd Plains into Mountains, and Mountains into Plains; Seas into Land, and Land into Seas; made Rivers where there were none before, and swallowed up others that formerly were; made and destroy'd Lakes, made Peninsuls Islands, and Islands Peninsulas; vomited up Islands in some places, and swallowed them down in others; overturn'd, tumbl'd and thrown from place to place Cities, Woods, Hills, *&c.* cover'd, burnt, wasted and chang'd the superficial Parts in others; and many the like strange Effects, which, since the Creation of the World, have wrought many very great changes on the superficial Parts of the Earth, and have been the great Instruments or Causes of placing Shells, Bones, Plants, Fishes, and the like, in those places, where, with much astonishment, we find them.

Concerning the Vicissitudes that places are subject to, in relation to Earthquakes, I find a memorable Passage sent by *Paul Ricaut* Esquire, now Consule of *Smyrna*, Dated *November* 23. 1667. ‘ *Constantinople*, says he, is not now so ‘ subject to Earthquakes as reported in former times, there having not hap‘ pen'd in the last seven Years, in which I have been an Inhabitant there, above ‘ one of which I have been sensible; but within these twenty Days in *Smyrna* ‘ fell out an Earthquake which dangerously shook all the Buildings, but did ‘ little or no harm; the Ships in the Road, and others at an Anchor, about ‘ three Leagues from hence, were sensible of it. It is reported that this ‘ City hath been already seven times devoured by Earthquakes, and it is pro‘ phesied, that it shall be so again so soon as the Houses reach the old Castle ‘ upon the top of the Hill, on the side of which remains the Ruins of the old ‘ City and the Tomb of St. *Polycarpus*, St. *John*'s Disciple, still preserv'd by ‘ the *Greeks* in great Veneration.

The Motion of the Water another cause of alterations on the Earth.

Another Cause there is which has been also a very great Instrument in the promoting the alterations on the Surface of the Earth, and that is the motion of the Water; whether caus'd 1*st*. By its Descent from some higher place, such as Rivers and Streams, caus'd by the immediate falls of Rain, or Snow, or by the melting of Snow from the sides of Hills. Or, 2*dly*. By the natural Motions of the Sea, such as are the Tides and Currents. Or, 3*dly*. By the accidental motions of it caus'd by Winds and Storms. Of each of these we have very many Instances in Natural Historians, and were they silent, the constant Effects, would daily speak as much. The former Principle seems to be that which generates Hills, and Holes, Cliffs, and Caverns, and all manner of Asperity and irregularity in the Surface of the Earth; and this is that which indeavours to reduce them back again to their pristine Regularity, by washing down the tops of Hills, and filling up the bottoms of Pits, which is indeed consonant to all the other methods of Nature, in working with contrary Principles of Heat and Cold, Dryness, and Moisture, Light and Darkness, *&c.* by which there is, as it were, a continual circulation. Water is rais'd in Vapours into the Air by one Quality and precipated down in drops by an other, the Rivers run into the Sea, and the Sea again supplies them. In the circular Motion of all the Planets, there is a direct Motion which makes them indeavour to recede from the Sun or Center, and

and a magnetick or attractive Power that keeps them from receding. Generation creates and Death destroys; Winter reduces what Summer produces: The Night refreshes what the Day has scorcht, and the Day cherishes what the Night benumb'd. The Air impregnates the Ground in one place, and is impregnated by it in another. All things almost circulate and have their Vicissitudes. We have multitudes of instances of the wasting of the tops of Hills, and of the filling or increasing of the Plains or lower Grounds, of Rivers continually carrying along with them great quantities of Sand, Mud, or other Substances from higher to lower places. Of the Seas washing Cliffs away and wasting the Shores: Of Land Floods carrying away with them all things that stand in their way, and covering those Lands with Mud which they overflow, levelling Ridges and filling Ditches. Tides and Currents in the Sea act in all probability what Floods and Rivers do at Land; and Storms effect that on the Sea Coasts, that great Land Floods do on the Banks of Rivers. *Ægypt* as lying very low and yearly overflow'd, is inlarg'd by the sediment of the *Nile*; especially towards that part where the *Nile* falls into the *Mediterranean*. The Gulph of *Venice* is almost choak'd with the Sand of the *Po*. The Mouth of the *Thames* is grown very shallow by the continual supply of Sand brought down with the Stream. Most part of the Cliffs that Wall in this Island do Yearly founder and tumble into the Sea. By these means many parts are covered and rais'd by Mud and Sand that lye almost level with the Water, and others are discover'd and laid open that for many Ages have been hid.

Of this kind the Royal Society received a memorable Account from the Learned Dr. *Brown* concerning a petrified Bone of a prodigious bigness, discover'd by the falling of some Cliffs; the words of the Relation are these. 'This Bone (which he presented the Royal Society, and is now in the Repository) was found last Year 1666. on the Sea Shore, not far from *Winterton* in *Norfolk*; it was found near the Clift after two great Floods, some thousand Loads of Earth being broken down by the rage of the Sea, as it often happens upon this Coast, where the Cliffs consist not of Rock but of Earth. That it came not out of the Sea may be conjectur'd because it was found near the Cliff, and by the colour of it, for if out of the Sea it would have been whiter. Upon the same Coast, but as I take it, nearer *Hasborough*, divers great Bones are said to have been found, and I have seen a lower Jaw containing Teeth of a prodigious bigness and somewhat petrified. All that have been found on this Coast have been found after the falling of some Cliff, where the outward Crust is fallen off, it clearly resembles the Bones of Whales and great Cetaceous Animals, comparing it with the Scull and Bones of a Whale which was cast upon the Coast near *Wells*, and which I have by me, the weight whereof is 55 Pounds.' Thus far he on this Subject. To this may be added the *Chartham* News, or the discovery of River-horse, or the *Hippopotamus* Teeth printed in the *Philos. Transactions*. N. 272. p. 882.

Nor are these Changes now only, but they have in all probability been of as long standing as the World. So 'tis probable there may have been several vicissitudes of changes wrought upon the same part of the Earth; it may have been of an exact spherical Form, with the rest of the Earths or Planets, at the Creation of the World, before the eternal Command of the Almighty, that the Waters under the Heaven should go to their place, which before cover'd the Earth, so as that it was ἀόρατος καὶ ἀκατασκεύαστος καὶ σκότος ἐπάνω τῆς ἀβύσσου καὶ πνεῦμα θεοῦ ἐπεφέρετο ἐπάνω τοῦ ὕδατος, invisible and incompleated, and the Darkness of the Deep was over it (being all over cover'd with a very thick shell of Water which environ'd it on every side, it being then in all probability created of an exact Spherical Figure, and so the Waters being of themselves lighter than the Earth, must equally spread themselves over the whole Surface of the Earth) and where the Breath of the Lord moved above or upon the Surface of these Waters. It may, I say, in probability have been then a part of the exact Sphœrical Surface of the Earth, and upon the command that the Waters under the Air or Atmosphere (which seems to be denoted by στερέωμα or Firmament; for the Hebrew Word signifies an Expansum) should

should be gathered together into one place, and that the dry Land should appear. It may have been by that extraordinary Earthquake (whereby the Hills and Land were rais'd in one place, and the Pits or deeper places, whether the Water was to recede and be gathered together to constitute the Sea were sunk in another) rais'd perhaps to lye on the top of a Hill or in a Plain, or sunk into the bottom of the Sea, and by the washing of Waters in motion, either carried to a lower place to cover some part of the Vale, or else be cover'd by adventitious Earth, brought down upon it from some higher place; which kind of alterations were certainly very great by the Flood of *Noah*, and several other Floods we find recorded in Heathen Writers. If at least there were not somewhat of an Earthquake which might again sink those Parts which had been formerly raised to make the dry Land appear, and raise the bottom of the Sea, which had been sunk for the gathering together of the Waters (which Opinion *Seneca* ascribes to *Fabianus*) *Ergo* (says he) *cum affuerit illa necessitas temporis multa simul fata causas movent nec sine concussione Mundi tanta Mutatio est ut quidam putant inter quos Fabianus est.* His description of the Manner and Effects of a Flood, is fine and very suting to my present Hypothesis. This Part being thus covered with other Earth, perhaps in the bottom of the Sea, may by some subsequent Earthquakes, have since been thrown up to the top of a Hill, where those parts with which it was by the former means covered, may in tract of time by the fall and washing of Waters, be again uncovered and laid open to the Air, and all those Substances which had been buried for so many Ages before, and which the devouring Teeth of Time had not consumed, may be then exposed to the Light of the Day.

Two other Causes of the changes on the superficial parts of the Earth: first from overflowing of the Streams and Inundations of the Sea.

There are yet two other Causes of the mutation of the superficial Parts of the Earth, which have wrought many great changes in the World, and those are either the Sea's overflowing of a Country or Place, when forced on it with some violent Storms or Hurricans of Wind, or from the over-flowing of Rivers from great falls of Rain, or from something stopping their Course, of these we have many Instances in Voyages, and we have very often times here at *London* felt the effects of the Wind driving in the Tide with such great force, as that it has oft times overflow'd the Banks, fill'd the Streets and Cellers to the no small damage of the Inhabitants. ‘At *Chatmoss* in *Lankashire* (saith *Childery*) is a low mossy Ground very large, a great part of which (saith *Cambden*) not long ago, the Brooks swelling high carry'd quite away with them, whereby the Rivers were corrupted, and a number of fresh Fish perished. In which place now lies a low Vale watered with a little Brook, where Trees have been digg'd up lying along, which are suppos'd by some to have come thus. The Channel of the Brooks being not scower'd, the Brooks have risen, and made all the Land moorish that lay lower than others, whereby the Roots of the Trees being loosned by reason of the bogginess of the Ground, or by the Water finding a passage under Ground, the Trees have either by their own weight, or by some Storm, been blown down, and so sunk into that soft Earth and been swallowed up: For 'tis observable, that Trees are no where digg'd out of the Earth but where the Earth is boggy; and even upon Hills such moorish and moist Grounds are commonly found, the Wood of these Trees burning very bright like Touchwood (which perhaps is by reason of the bituminous Earth in which they have been so long) so as some think them to be Fir-Trees. Such mighty Trees are often found in *Holland*, which are thought to be undermin'd by the Waves working into the Shore, or by Winds driven forwards and brought to those lower places where they settled and sunk. *Brit. Bac.* Page 167, 168.

‘The Sea (as is said before) has eaten a great part of the Land away of these Western Shires. There are on the Shore of this Shire (*Cumberland*) Trees discovered by the Winds sometimes at low Water, which are else covered over with Sand; and it is reported by the People dwelling thereabouts, that they dig up Trees without Boughs out of the Ground in the

places

'places of the Shire. *Child.* p. 171. Many Trees are found and digged out 'of the Earth of the Isle of *Man. Ide.* p. 178.'

'In divers places of the Low Grounds and Champian Fields of *Anglesy*, the 'Inhabitants every Day find and dig out of the Earth the Bodies of huge 'Trees with their Roots, and Fir-Trees of a wonderful bigness and length. 'Page 150.

'At the time when *Henry* II. made his abode in *Ireland* were extraordinary violent and lasting Storms of Wind and Weather, so that the Sandy Shore 'on the Coasts of the *Pembrockshire*, was laid bare to the very hard Ground, 'which had lain hid for many Ages, and by further search the People found 'great Trunks of Trees, which when they had digged up, they were apparently Lopped, so that one might see the strokes of the Ax upon them, 'as if they had been given but the Day before; the Earth look'd very black, 'and the Wood of these Trunks was altogether like Ebony. At the first 'discovery made by these Storms, the Trees we speak of lay so thick, that 'the whole Shore seem'd nothing but a lopped Grove. Whence may be gather'd, saith *Childry*, that the Sea hath overflow'd much Land on this 'Coast, as it has indeed many Countries bordering upon the Sea, which is 'to be imputed to the ignorance of the *Britans* and other barbarous Nations, 'which understood not those ways to repress the fury of the Sea which we 'now do. p. 142. 143.

'In the low Places on the South side of *Cheshire*, by the River *Wever*, Trees 'are oft times found by digging under Ground, which People think have lain 'buried there ever since *Noah*'s Flood. p. 129. 'St. *Bennets* in the *Holme* hath 'such fenny and rotten Ground, that (saith *Cambden*) if a Man cut up the 'Roots or Strings of Trees it flotes on the Water. Hereabout also are 'Cockles and Periwinkles sometimes digged up out of the Earth, which makes 'some think that it was formerly overflowed by the Sea.' Divers of these Effects do seem to be caused by Inundations of the Sea, tho' there are others of them that do rather seem ascribable to Earthquakes, than to Inundations caus'd by Storms; for that Earthquakes have produced such Effects as the burying of Trees and Plants, divers of the formerly mention'd Histories do sufficiently manifest.

An Account of Lignum Fossile *and other Subternaneous Matters.*

The *Lignum Fossile* which is found in *Italy*, of which we have a good account given by *Francesco Stelluti* (tho' by that Author it be supposed to be generated out of the subterraneous Parts of the place where it has been found; yet) from many remarkable circumstances in this History, it seems very probable to me to have been first buried by some Earthquakes, and afterwards to be variously metamorphosed and changed by the Symptoms which usually follow Earthquakes, and which this place is much vexed with, as is indeed almost all the Country of *Italy*, to wit, the emitting of hot Steams and Smoaks proceeding from subterraneous Fires, which do their often shift their places, burn the parts of some of those Trunks into black and brittle Coles; melt a kind of Ore into the Pores of others; petrify the Substance of another sort; bake the Dirt and Clayish Substances which have soaked into the Pores of a fourth sort into a kind of Brick; rot the Parts of others, and convert them into a kind of Dirt or Muddy Earth; and so act variously and produce differing Effects upon those buried Substances, according to the Nature of the Earths, Minerals, Waters, Salts, Heats, Smoaks, Steams, and other active Instruments casually applied to the parts of the buried Trunks, by the confusion of the Earthquakes, and by immediate application, and long continuance and digestion, as I may call it, in this Laboratory of Nature, transformed into other Substances, and exhibit all those admirable Phænomena mentioned by that Author, whereby the bury'd Bodies are transformed. Nor is it so much to be wondered at, that such Substances as Vegetables (which being exposed to the Vicissitudes of the Air and Water, are quickly corrupted and consumed, and many of them much sooner if buried in the Earth) should after so many Ages perhaps, remain intire, and rather more substantial sound and permanent than if they were newly cut down. Since if we consider the Nature of the decaying and corruption in all kind of Animal and Vegetable Substances

Whence the decay of Bodies.

Substances, we shall find that the chief cause of it seems to be from the Action of the fluid Parts upon the solid for the dissolving of them: and wheresoever the Internal Fluid is either first changed or altered by the mixture of some other heterogenous Substance, so as to loose that dissolving property as by the intermixture of Salt, Spirit of Wine, *&c.* or by incorporating with it and hardning it into a solid Substance, as in Petrifactions, *&c.* Or, secondly, exhaled by a gradual and gentle degree of heat, and so the solid Parts only left alone, and kept either dry, or fill'd with a fluid of an heterogeneous Nature, such as unctuous and spicy Juices with watery Substances. Or, Thirdly, Congealed and hardened either by cold or the peculiar Nature of the Juice itself; such is freezing and the hardning of Coralline Plants, or Submarine Vegetables, Horns, Gums, Bones, Hair, Feathers, *&c.* wheresoever, I say, Bodies are by these means put into such a Constitution, that the Parts act not upon one another, and continue in that state by being preserved by adventitious Moisture or soft'ning by homogeneous Fluids, they are, as it were, perpetual, unless by extraordinary Heat, many of those otherwise solid and unactive Substances are made fluid by such active Disolvents; and unless they be immersed in such Liquors or Menstruums as do of themselves dissolve and work on them; we shall not, I say, wonder at the lastingness of these buried Substances, if we consider also the various Juices with which several parts of the Earth are Furnish'd, Unctuous, Watery, Styptick, Saline, Petrifactive, Corrosive, and what not. There are some Juices of the Earth which do, as it were, perpetuate them by turning them into Stone. Others do so deeply pierce and intimately mix with their parts, that they wholly, as it were, change the Nature of those Substances, and destroy that property of Congruity which all Bodies generated in the Air and Water seem to have, which are very apt to be dissolved and corrupted by innate aerial and aqu ous Substances. Such are all kinds almost of oleaginous and sulphureous Substances, and divers saline and mineral Juices. Others indeed do not preserve the very Substance of those Vegetables, but insinuating into the Pores, and there, as it were, fixing, they retain and perpetuate the Shape and Figure, but corrupt and dissolve the interpos'd part of the Vegetable; of all which kinds I have seen some Specimina, as I have also of divers other Substances Pickled, Dried, Candyed, Conserv'd, preserv'd, or Mummify'd by Nature: where therefore the Substances have happen'd to be bury'd with preservative Juices, they have withstood the injury of Time; but where those Juices have been wanting, there we find no Footsteps of these Monuments of Antiquity.

A 2d Cause of alterations on the Earth beside Earthquakes, is violent motions of the Air.

But to return to what I was prosecuting, another cause which may make alterations on the Surface of the Earth, is any violent motions of the Air, whereby the parts of the Earth, in dry Weather, are transported from place to place in the Form of Dust. Of this kind Travellers tell us very strange Stories of the removal of the Sands in the Deserts of *Arabia*, and other Deserts in *Africa*; and we have some instances of it here in *England*, to wit, in *Norfolk* and *Devonshire* (in the former of which there are often found natural Mummies which have been buried alive by those removing Sands, and by their drineſs preserv'd) But these greater and more suddain removals of Sand and Dust are not so universal, and therefore not so much to my present purpose; tho' possibly they may have been more frequent heretofore, which the Layers of Sands to be found in digging Pitts and Wells seem to hint: But that which is most universal, is very slow, and almost inperceptible, and that is the removing of the Dust from the higher Parts, and settling in the lower by the Wind or motion of the Air. This tho' its effects be almost insensible, yet being constant, must needs, in length of time, much promote the levelling and smoothing of the Surface of the Earth.

3dly, A gradual sinking of heavy Bodies into the Surface.

I might name also another cause of the transposition of the superficial Parts of the Earth; and that is from the gradual subsiding or sinking into the Earth of the more heavy, and the Ebullition or respective rising of the more light Parts upwards. Hence we may observe, that many old and vast Buildings

and

and Towers have sunk into the Earth. And the like we judge of those vast Stones in *Salisbury* Plain, and we find constantly almost in all Stone Monuments placed in Church-yards, and in all old Churches unless placed on a very high place, and founded on some Rock. The Cause may possibly have great Influence where the Earth is very soft, spungy, or boggy; and possibly many of those Trees which are found in boggy Grounds, may have been buried, by having been either fell'd, or blown down by Wind, or wash'd down by some Inundation well impregnated with mineral Juices, and so made heavier than the subjacent Earth, and swallowed into it. Several of the former Relations do indeed prety well agree with this Hypothesis; and I am very apt to think that where the Surface of the Earth has not been much alter'd since the Creation, if any such there be, if it were search'd into it would be found that the lightest Parts, lye next the Surface, and so heavier in lower Parts, which makes me imagine that the natural place of Minerals is very deep under the Surface of the Earth, and (possibly) to be found under every step of Ground, were search made under it to a sufficient depth; and that the reason why we find it sometimes near the Surface of the Earth, as in Mountains, is not because it was there generated, but because it has been by some former Subterraneous Eruption (by which those Hills and Mountains have been made) thrown up towards the Surface of the Earth. And as Gold is the heaviest, so it is the scarcest of all Mettals. And I do not at all question but that there may be other Bodies or Mettals as much heavier than Gold, as Gold is then common Earth. To make these Conjectures the more probable, see what Sir *Philiberto Vernatti* writes from *Batavia* in the *East-Indies*, in answer to some Queries sent him by the Royal Society. 'I 'have often (says he) felt Earthquakes here, but they do not continue long. 'In the Year 1656, or 57, (I do not remember well the time) *Batavia* was 'covered in one Afternoon about two of the Clock, with a black Dust, which 'being gathered together, was so ponderous, that it exceeded the weight 'in Gold. It is here thought that it came out of a Hill that burneth in *Sumatra* 'near *Endrapeor*.

These fiery Eruptions in all probability come from a very great depth and with a great violence; and possible even that golden Powder that is sometimes thrown up may have somewhat conduced to the cause of the violence of it. We know not what Method Nature may have to prepare an *Aurum Fulminans* of her own, great quantities of which, being any ways heated and so fired, may have produced the Powder. However, whether so or not, it were very well worth trial to examine, whether the Flower that may be catch'd in a Glass Body, upon fulminating a quantity of such Powder gradually by small parcels, would, by being ordered as common Gold, make again an *Aurum Fulminans*: Or whether this Fulmination, which is a kind of Inflaming of the Body of the Gold, does not make some very considerable alteration in the Nature and Texture of it. Since we find that kind of Operation, to wit, inflaming or burning does considerably alter the Texture of all other Bodies so wrought on. This only by the way.

The last Argument to prove the sixth Proposition from the Shells, &c. found on, and in the Earth.

But to proceed to the last Argument to confirm the 6th Proposition I at first undertook to prove, namely, that very many parts of the Surface of the Earth (not now to take notice of others) have been transform'd transpos'd and many ways alter'd since the first Creation of it.) And that which to me seems the strongest and most cogent Argument of all is this, That at the tops of some of the highest Hills, and in the bottom of some of the deepest Mines, in the midst of Mountains and Quarries of Stone, *&c.* divers Bodies have been and daily are found, that if we thoroughly examine we shall find to be real shells of Fishes, which for these following Reasons we conclude to have been at first generated by the Plastick faculty of the Soul or Life-principle of some animal, and not from the imaginary influence of the Stars, or from any Plastick faculty inherent in the Earth itself so form'd; the stress of which Argument lies in these Particulars.

1st. Proof that they are true Shells. First, That the Bodies there found have exactly the Form and Matter, that is, are of the same kind of Substance for all its sensible Properties, and have the same External and Internal Figure or Shape with the Shells of Animals.

2d. Proof. Next, That it is contrary to all the other acts of Nature, that does nothing in vain, but always aims at an end, to make two Bodies exactly of the same Substance and Figure, and one of them to be wholly useless, or at least without any design that we can with any plausibility imagine. The Shells of Animals, to our Reason, manifestly appear to be done with the greatest Council and Design, and with the most excellent contrivance, both for the Convenience and Ornament of that Animal to which it belongs, that the particular Structure and Fabrick of that Animal was capable of: Whereas these if they were not the Shells of Fishes, will be nothing but the sportings of Nature, as some do finely fancy, or the effects of Nature idely mocking herself, which seems contrary to her Gravity. But this perhaps may not seem so cogent, tho', if it be thoroughly consider'd, there is much weight in it.

3d. Proof. Next therefore, Wherever Nature does work by peculiar Forms and Substances, we find that she always joins the Body so fram'd with some other peculiar Substance. Thus the Shells of Animals, whilst they are forming are join'd with the Flesh of the Animal to which they belong. Peculiar Flowers, Leaves, and Fruit are appropriated to peculiar Roots, whereas these on the contrary are found mixt with all kind of Substances, in Stones of all kinds, in all kinds of Earth, sometimes expos'd to the open Air without any coherence to any thing. This is at least an Argument that they were not generated in that posture they are found; that very probably they have been heretofore distinct and disunited from the Bodies with which they are now mixt, and that they were not formed out of these very Stones or Earth, as some imagine, but deriv'd their Beings from some preceding Principle.

4th. Proof. Fourthly, Wherever else Nature works by peculiar Forms, we find her always to compleat that form, and not break off abruptly. But these Shells that are found in the middle of Stones are most of them broken, very few compleat, nay, I have seen many bruised and flaw'd, and the parts at a pretty distance one from another, which is an Argument that they were not generated in the place where they are found, and in that posture, but that they have been sometimes distinct and distant from those Substances, and then only placed, broken and disfigured by chance, but had a preceeding and more noble Principle to which they ow'd their Form, and by some hand of Providence, were cast into such places where they were filled with such Substances, as in tract of Time have condensed and hardened into Stone: This, I think, any impartial Examiner of these Bodies will easily grant to be very probable, especially if he take notice of the Circumstances I have already mention'd. Now, if it be granted, that there have been preceding Moulds, and that these curiously figured Stones do not owe their form to a plastick or forming Principle inherent in their Substances; why might not these be supposed Shells, as well as other Bodies of the same Shape and Substance, generated none knows how, nor can imagine for what.

5th. Proof. Further, if these be the apish Tricks of Nature, Why does it not imitate several other of its own Works? Why do we not dig out of Mines everlasting Vegetables, as Grass for instance, or Roses of the same Substance, Figure, Colour, Smell? *&c.* Were it not that the Shells of Fishes are made of a kind of stony Substance which is not apt to corrupt and decay. Whereas, Plants and other animal Substances, even Bones, Horns, Teeth and Claws are more liable to the universal Menstruum of Time. 'Tis probable therefore, that the fixedness of their Substance has preserved them in their pristine Form, and not that a new plastick Principle has newly generated them

them. Besides, why should we not then doubt of all the Shells taken up by the Sea-shore, or out of the Sea (if they had none when we found them) whether they ever had any Fish in them or not? Why should we not here conceipt also a plastick Faculty distinct from that of the Life-principle of some Animal; is it because this is more like a Shell than the other? That I am sure it cannot be. Is it because 'tis more obvious how a Shell should be placed there? If so, 'twould be as good Reason to doubt if an Anchor should be found at the top of a Hill, as the Poet affirms, or an Urn or Coins buried under Ground, or in the bottom of a Mine, whether it were ever an Anchor, or an Urne, or a coined Face, or made by the plastick Faculty of the Earth, than which what could be more absurd: And those Persons that will needs be so over confident of their Omniscience of all that has been done in the World, or that could be, may, if they will vouchsafe, suffer themselves to be asked a Question, Who in form'd them? Who told them where *England* was before the Flood; nay, even where it was before the *Roman* Conquest, for about four or five thousand Years, and perhaps much longer; much more where did they ever read or hear of what *Changes* and *Transpositions* there have been of the parts of it before that? What History informs us of the burying of those Trees in *Cheshire* and *Anglesy?* Who can tell when *Tenariff* was made? And yet we find that most judicious Men that have been there and well considered the form and posture of it, conclude it to have been at first that way produced. But I suppose the most confident will quickly upon examination, find that there is a defect of Natural History; if therefore we are left to conjecture, then that must certainly be the best that is backed with most Reason, that Clay, and Sand, and common Shells can be changed and incorporated together into Stones very hard. I have already given many instances, and can produce hundreds of others, but that I think it needless, that several parts of the bottom of the Sea have been thrown up into Islands and Mountains. I have also given divers Instances, and those some of them within the Memory of Man, where 'tis not in the least to be doubted but that there may be found some Ages hence several Shells at the tops of those Hills there generated; and as little, that if Quarries of Stone should be hereafter digged in those places, there would be found Shells incorporated with them; and were they not beholding to this inquisitive and learned Age for the History of that Eruption, they might as much wonder how these Shells should come there, and ascribe them to a plastick Faculty, or some imaginary Influence, as plausibly as some now do. I have also shewed, that Water and divers other fluid Substances, may be, in tract of Time, converted into Stone and stony Substances; and so such Liquors penetrating the Pores of these Shells, and especially if they be assisted by the benumming Steams that sometimes issue from Subterraneous Erruptions, may very much contribute to the preservation of those Shells from Corruption and crumbling to Dust under the crushing Foot of Time. Besides, that the Shells themselves are so near the Nature and Substance of Stone, that they are little subject to the injuries of the Air or Weather; so that these small pyramidal Houses of Shell-Fishes seem not less lasting Monuments than those vast piles of Stones erected by the antient Inhabitants of *Egypt*, which outvye all the more curious Fabricks of *Grecian* and *Roman* Architecture both for their Antiquity and present Continuance. Nor do they exceed the Works of Architects for lasting only, but for Ornament, for Strength, and for Convenience.

Now if all these Bodies have been really such Shells of Fishes as they most resemble, and that these are found at the tops of the most considerable Mountains in the World as *Caucasus*, the *Alps*, the *Andes*, the *Appennine*, and *Pyrrenean* Mountains, to omit other Hills nearer and of less note, and that tis not very probable that they were carried thither by Mens Hands, or by the Deluge of *Noah*, or by any other more probable way than that of Earthquakes; 'tis a very cogent Argument that the superficial Parts of the Earth have been very much chang'd since the beginning, that the tops of Mountains have been under the Water, and consequently also, that divers parts of the bottom of the Sea have been heretofore Mountains: For tho' I

confess

confess I have but few Instances to prove it, besides that of *Plato*'s *Atlantis*, and some others that I have already mention'd; yet 'tis very probable, that whensoever an Earthquake raises up a great part of the Earth in one place, it suffers another to sink in another place; for Gravity is a Principle that will not long suffer a space to remain unfill'd under so vast a pile of Earth as a Mountain, unless the Substances, so thrown up, be of very hard, close and vast Stones that may, as it were, vault it: In which cases 'tis very probable (and *Kircher* and divers other Authors that write of Mines and Quarries, gives us many instances to confirm it) that these Cracks and Cliffs so left, are fill'd up with such Petrifying or Mineral Waters as do make great varieties of Stones, Marbles, Sparrs, Caulks, and Ores, and so there is made a transposition as well as a transformation. Which supposition (by the way) I think will furnish a very probable Reason of the shape of the Veins and Cracks of speckled Marbles and other Stones, of the form also of the Veins of Ores, Stones, Clays, *&c.* of the Earth, and of their so mixing together; of the lying of Mettals in Mountains and other Mines, *&c.* but of these only here by the Bye, because I refer what I have to say of that to another Subject, *viz.* A History of the Forms and Proprieties of Minerals and Metals. To proceed then.

The seventh Proposition confirmed.

The Seventh Proposition that I undertook to make probable, was, That 'tis very probable that divers of these Transpositions and Metamorphoses have been wrought even here in *England*: Many of its Hills have probably been heretofore under the Sea, and divers other parts that were heretofore high Land and Hills, have since been covered with the Sea. Of the latter of these I have given many Instances already, and that which makes the first probable, is the great quantities of Shells that are found in the most Inand Parts of this Island; in the Hills, in the Plains, in the bottoms of Mines and in the middle of Mountains and Quarries of Stones. Of this kind are those Shells, which any inquisitive Man may find great quantities of in *Portland*-stone, *Purbeck*-stone, *Burford*-stone, *Northamptonshire*-stone, out of which I have often pick'd Muscles, Cockles, Periwinkles, Oysters, Scallop, and divers other Shells that are buried in the very Body and Substance of the Stone; and indeed they may be found of some kind or other in almost all kinds of Stone. That the *Kainsham* Snail Stones, and those found in several onher parts of *England*, have been the Shells of Fishes, I hope the Arguments I have already urged may suffice to evince. As also, that those Helmet Stones (of which sort I my self have found in many places of *England*, and others have furnish'd me with many more found in other parts of it) are nothing but the fillings of the Shells of a sort of Echini or Egg Fishes.

Now 'tis not probable that other Mens Hands, or the general Deluge which lasted but a little while, should bring them there; nor can I imagine any more likely and sufficient way than an Earthquake, which might heretofore raise all these Islands of Great *Britain* and *Ireland* out of the Sea, as it did heretofore, of which I have already mention'd the Histories; or as it lately did that Island in the *Canarys* and *Azores*, in the sight of divers who are yet alive to testifie the Truth and Manner of it: And possibly *England* and *Ireland* might be rais'd by the same Earthquake, by which the *Atlantis*, if we will believe *Plato*, was sunk. And I doubt not but any inquisitive Man that has opportunity of traveling and examining several of the Mountianous Parts and Cliffs, and of the Mines, Quarries, and other subterraneous Parts of *England*, will meet with a great many other Arguments to confirm this Supposition, besides those I have already alledg'd: But those I hope may suffice for the present to excite Men to this Curiosity, which was the chief reason of this present exercise. And this makes way for the Eighth Proposition, which is

The eighth Proposition confirmed.

Eighthly, That most of these Mountains and Inland places whereon these kind of Petrify'd Bodies and Shells are found at present or have been heretofore, were formerly under the Water, and that either by the descending of the Waters to another part of the Earth by the alteration of the Center of Gravity of the

the whole bulk, or rather by the Eruption of some kind of Subterraneous Fires or Earthquakes, great quantities of Earth have been deserted by the Water and laid bare and dry. That divers places have been thus raised by Earthquakes has been already proved from many Histories; and then why may not all of them have the same Original, especially since there is no other more probable Cause that we know of, that should convey and place those Shells on the tops of Mountains? That they really are Shells, and have been the receptacle of Fishes, I hope the Arguments I have already alledg'd may suffice to persuade: If then they have been Shells, and have been there placed, why should we not conclude that That part hath been under the Water with as much reason as seeing Towers, *&c.* under the Water near-------we do that those parts have been heretofore above Water, which Histories inform us of, or as we might have done if we had had none even from what the thing itself speaks. I think we may with as much reason doubt if an Urn should be digg'd up full with old Coins, stamped with the same impression, made of the same Substance and Magnitude of those used by the ancient *Romans*, or any other Nation, of which we have good History; First, Whether ever those Coins were made by Mens Hands, or by a plastick Faculty of Nature; for it is certainly no more difficult a task for Nature to imitate the one than the other. And, Secondly, Whether ever that Urn were made and those Coins were put into it and shaped by Mens Hands, or that they were shap'd and thrown into it meerly by Nature; perhaps those suppositions might not be impossible, but sure all Men will judge them very improbable: And I think the Case in this particular I am speaking of very much the same. First, That there is much greater reason to imagine the Shells so found to have been the *Exuviæ* of some living Creature, and next, that they have been placed there where they are found when that part was under Water, and that part to have since been rais'd up to that height above the Sea by some preceding Earthquake. There is no Coin can so well inform an Antiquary that there has been such or such a place subject to such a Prince, as these will certify a Natural Antiquary, that such and such places have been under the Water, that there have been such kind of Animals, that there have been such and such preceding Alterations and Changes of the superficial Parts of the Earth: And methinks Providence does seem to have design'd these permanent shapes, as Monuments and Records to instruct succeeding Ages of what past in preceding. And these written in a more legible Character than the Hieroglyphicks of the ancient *Egyptians*, and on more lasting Monuments than those of their vast Pyramids and Obelisks. And I find that those that have well consider'd and study'd all the remarkable Circumstances to be met with at *Teneriffe* and *Fayale*, do no more doubt that those vast Pikes have been raised up by the Eruption of Fire out of their tops, than others that have survey'd the Pyramids of *Egypt*, or the Stones on *Salisbury* Plain do doubt that they have been the effects of Man's Labours. And they do it with as much reason; for all Conclusions that are not immediately grounded on Sense, or the result of it are but Hypothetical and from a Similitude; for since it has been heretofore and lately seen, that such Eruptions have produc'd such kind of Hills and Islands, and that the tops of these Hills do as yet burn, and that there are all about the sides of them huge Stones and Rocks, and even Mountains lying in Postures as if they had been tumbled down from the top; 'tis a rational Conclusion to say, that 'tis very probable these have had the same Original with those.

Change of the Earths Center of Gravity hinted.

But as to those vast tracts of Ground that lye very far from the Sea, it may perhaps to some seem not impossible, that the Center of Gravity or Method of the attraction of the Globe of the Earth may change and shift places, and if so, then certainly all the fluid parts of the Earth will conform thereto, and then 'twill follow that one part will be cover'd and overflow'd by the Sea that was before dry, and another part be discover'd and laid dry that was before overwhelm'd. Now, tho' this Conjecture may at first reading seem a little extravagant, yet if we consider, that as great alterations have been really observ'd, we may a little moderate a two severe Cen-

sure; That the Magnetical Poles and Meridians of the Earth have been alter'd, and that they do at this present continue to do so is granted almost by all, and confirmed by a multitude of Observations made in divers Parts of the World, and by collecting and comparing the Observations I have met with: I suppose the Pole of the Magnetism to be at a certain distance from the Pole of its daily Motion, and that it does move round that Pole at a certain distance in a certain number of Years, and that it does annually proceed in this Circle some parts of a Degree: So that whereas the Magnetical Pole was formerly North-East of *Russia*, it is now grown North-West of it, and a little to the Westward even of *England*'s Meridian: Monsieur *Petit* Engenier to the *French* King, is of Opinion, That the Pole of the diurnal motion of the Earth alters, but I confess I cannot in the least assent to it from any of those Arguments that he alledges, but I do rather think that divers of them do make against his Hypothesis; yet 'tis not impossible but that a very great Earthquake altering the Center of Gravity, may also alter the Pole of Rotation; for we find by experience, that if any thing be laid upon one side of a large *Lignum Vitæ* Ball suspended by a String, and that Ball be turned round upon the String, it shall not turn exactly about the Point by which 'tis suspended, but about some other Point. Besides this, we know that the direction of these Poles, as to the Heavens, doth vary, for whereas, it pointed at a part of the Heavens many degrees distant from the Star in the top of the tail of the little Bear, now it points almost directly towards it. Besides this, we find that the Points of the Intersection of the Æquinoctial and Ecliptick varies, and possibly even the motions of all may vary. A diurnal Revolution of the Earth may perhaps have been made in a much shorter time than now; possibly there may have been the same alterations in the Annual, and then a Year, or a Day at the beginning of the World would not be of so long a duration as now when those motions are grown slower; for if the motions of the Heavens be analogous to the motion of a Wheel or Top, as I think I can by very many Arguments make probable, then if the Earth were (as it were) at first set up or put into a rapid circular Motion, like that of a Top, 'tis probable that the fluid Medium in which it moves, may after a thousand Revolutions, a little retard and slaken that motion, and if so, then a longer space of time will pass while it makes its Revolution now than it did at first.

Possibly the old Patriarchs lived no longer in some sense than Men do now.

Hence possibly the long Lives of the Posterity of *Adam* before the Flood, might be of no greater duration then Mens Lives are ordinarily now; for though perhaps they might number more Revolutions of the Sun, or more Years than we can now, yet our few Years may comprehend as great a space of time; this perhaps might deserve to be inquired into had we a certain measure of time, such as some would have a standing Pendulum of a certain length; but since we are upon suspecting, we may even doubt whether the power of Gravity itself may not alter in time; we find that the Poles of the Loadstone may be changed, that it does take up more at one time than another; that its virtue may be wholly destroyed by Fire, and some other ways; and besides that, one of these changes is really wrought in the Earth, and therefore 'tis not impossible but that even the attractive Power of the Earth (tho' I confess I think it quite differing from that of the Loadstone) may be intended or remitted; if so then the Pendulum will be no certain Standard for the examination of the length of Time by; for the more the gravitating Power is increas'd, the quicker will be the Vibrations of any Pendulum and the more weak it is, the slower are the Vibrations: But this Digression only by the bye. To return then, I say, tho' somewhat may be said for this Supposition I have started, yet I confess I do more incline to believe that what Mutations there have been of the Superficial Parts, have been rather caus'd by Earthquakes and Eruptions, which ushers in my Ninth Proposition. Namely,

That

That it seems very probable, that the tops of the most considerable Mountains of the World have been under Water, and that most probably they seem to have been raised to that height by some Eruption: So that those prodigious piles of Mountains are nothing but the effects of some great Earthquakes. This the Poets seem'd to vail under the feign'd Story of the Giants, those Earth-born Brothers waging War with the Gods, where they are said to heap up Mountains upon Mountains, *Ossa* and *Olympus* upon *Peleon*, and to cast up huge Stones and Fire at Heaven, but that at last overcome by *Jove* with his Thunder, they were buried under Mountains, the chiefest of them, namely, *Typhœus* under *Sicily*, according to *Ovid Metamorph.* Lib. 5. *The ninth Proposition confirmed.*

Vasta Giganteis injecta est Insula membris
Trinacris, &c.-------

Thus English'd by *Sandys*.

Trinacria *was on wicked* Typhon *thrown,*
Who underneath the Islands weight doth groan;
That durst attempt the Empire of the Skies:
Oft he attempteth, but in vain to rise.
Ausonian Pelorus *his right Hand*
Down weighs; Pachyne *on the left doth stand;*
His Legs are under Lilybæus *spread;*
And Ætna's *bases charge his horid Head:*
Where, lying on his Back, his Jaws expire
Thick Clouds of Dust, and vomit flakes of Fire.
Oft times he struggles with the weight below,
And Towns and Mountains labours to overthrow.
Earthquakes therewith: The King of Shadows dreads
For fear the Ground should split above their Heads, &c.

And that nothing else but an Earthquake is understood by that Gigantomachia of the Poets seems yet plainer from what *Virgil* in the Third Book of his *Æneis*, speaks in his Description of the Shores of *Sicily*.

Portus ab accessu ventorum immotus, & ingens
Ipse, sed horrificis juxta tonat Ætna Ruinis,
Interdumq; Atram prorumpit ad Æthera nubem
Turbine fumantem piceo & candente favilla,
Attollitq; globos flammarum & sidera Lambit
Interdum scopulos Avulsaq; viscera montis
Eiicit eructans, liquefactaq; saxa sub auras
Cum gemitu glomerat fundoque exæstuat imo.
Fama est Enceladi semiustum fulmine Corpus
Urgeri mole hac, Ingentemq; insuper Ætnam
Impositam, ruptis flammam expirare caminis:
Et fessum quoties motat Latus, intremere omnem
Murmure Trinacriam & cœco Subtexere fumo.

Thus English'd by *Ogilby*.

The Port was great and calm with shelt'ring Shores,
But near from horrid Ruins Ætna *roars;*
There in black Whirlwinds pitchy Clouds aspire,
With sparkling Cinders mixt with blazing Fire,
And Globes of Flame high as the Stars are born;
Out are the Mountains Marble Entrails torn,
Then upwards vomited, and melted Stones
Belcht from his Stomach, hot with horrid Groans.
Enceladus *with Thunder struck, they tell,*
Under the weight of this huge Burthen fell,
Above him was the mighty Ætna *laid,*
Who now breaths Fire, through broken Trunks (convey'd
And as he weary turns, a Thunder crack
Sicilia *shakes, and Heav'n is hung with black.*

And as the Poets above-mention'd had particular Stories and Giants for *Sicily* and *Ætna*, so had they also for other Vulcans, and from the frequency of them in former Ages, about *Greece* and the other Parts of the Mediterranean, *Sophocles* calls them ὁ γηγενὴς στρατὸς, γιγάντων the Earth-born Army of the Giants; and that nothing but Earthquakes were deciphered by these Giants may be further collected from the place where they were said to be bred, namely, the *Phlegrean* Fields in *Campania*, a part of which is now called the Court of *Vulcan*, a place that is the vent of many Subterraneous Fires. 'Tis (says *Sandys*) a naked Level, in form Oval 1246 Foot long, and 1000 broad, environ'd with high cliffy Hills that fume on each side and have their sulphureous

'sulphureous Savour transported by the Winds to places far distant; you 'would think the hungry Fire had made this Valley with continual feeding, 'which breaks out in a number of places. Here the Fire and Water make a 'horrible rumbling, conjoining together as if one were Fuel to the other, 'here and there bubling up, as if in a Cauldron over a Furnace, and spouting 'aloft into the Air at such time as the Sea is inrag'd with Tempests, &c. Besides, how well do their Actions agree with the Effects of Earthquakes, for they are said to throw up burning Trees against Heaven, and huge Rocks and vast Hills, which falling into the Sea became Islands, and lighting on the Land became Mountains. Nor does the manner of their Generation speak less, for they are said to be generated by the Blood of Heaven falling down on the Earth, that is, by the heat or influence of the Celestial Bodies operating within the Bowels of the Earth, and brought forth of her Womb in revenge to the Gods, or that they break forth with such horror and violence as if they threatned the Heavens. And he that shall read the Description of the most notable of them *Typheus*, and compare it with the natural Description of an Earthquake, will easily explicate the several parts of the Poets mystical Descriptions.

This Theory which I have endeavoured hitherto to evince, tho' indeed it be very hard positively to prove, we being, as I instanced before, very deficient in Natural History, yet if we consider what has been already said, and compare it with the late Observations of divers Travailers over them, we may find it altogether more than probable. I have been inform'd by several worthy Persons, that there are great store of Shells found at the tops of the *Alps*, *Appenine* and *Pyrenean* Hills, which are by much the highest of *Europe*. And I have now by me several of those Shells which have been dug out of them and brought into *England*. If therefore these have been real Oyster-Shells and Scallop-Shells as upon viewing the Substance and Make of them, I see not the least cause to doubt; and that there are great quantities of them to be found in divers Parts which lye buried in the Cliffs and incorporated with the Stones; and if that these Mountains have been infested with Earthquakes both formerly and lately, as we have several Histories that testifie; and if that other Eruptions and Earthquakes have raised Mountains even out of the bottom of the Sea, and that the power of included Fire is sufficient to move and raise even a whole Country all at once for some hundreds of Miles, as Historians assure us: If to this we add the universal silence in History of any part of *Europe*, or any of other certain places of the World before the Flood, or indeed for almost two hundred Years after the Flood, I think there will be much less scruple to grant it propable that the *Alps*, and divers other high Mountains, on whose tops are found such numbers and varieties of Sea-Shells, may have been heretofore raised np from under the Sea, and now sustain'd by the sinking of other Parts into the places from whence they were raised. This the very form of them will also very much argue for; for I have been inform'd by several that took diligent notice of it, that the parts are continually tumbling down from the higher parts to the lower, and that some of them do seem to overhang very strangely, which cannot in any probability be imagin'd to be the form of the first Creation, it being contrary to that implanted Power of Gravity, whereby all the parts of it are held together and equally drawn towards the Center of it, and so all the parts of it ought to have been placed in their natural position which must have constituted an exact Sphere, the heaviest lowest, and lighter at the top and the Water must have covered the whole Surface of the Earth, which seems to have been indeed their first position, according to the Description of *Moses* in *Genesis*, besides all those Hills that have been made by subterraneous Eruptions are of the like Structure; such as the *Pike* of *Tenariffe*, the *Pike* of *Fayale*, the new Mountain in *Italy*, *Ætna* and *Vesuvius*; all which seem to have been made up of great Stones thrown up out of the Mouth of their several Vulcans, many of which lie in such tottering postures that oft times they tumble down to the bottom, and make great destruction of the parts beneath; of this we have lately had several memorable Examples: To mention only two or three, we are inform'd by Historians, that among the

Alps

Alps in the *Grisons* Country, a Town named *Plura*, seated in a Plain at the Foot of the *Alps* near the River *Maira*, and continuing by estimation at the time of its fatal Catastrophy, at least fifteen hundred People was, by the falling down of a great part of a huge high Mountain that hung over the said place upon the twenty sixth of *August* 1617, together with the Inhabitants, in a moment crusht and buried deep in the Earth, and that there is nothing now left in the place thereof but a vast abyss or bottomless Gulf. And we are now newly inform'd by Letters brought out of *Italy* that a great part of the City of *Ragusa* has been this Year destroyed by the like falling down of some part of the Mountain above it.

The Tenth and last Conjecture which I shall at present mention (as reserving some others which will seem at first sight much more strange and extravagant, till I can by a sufficient number of Observations make them more plausible) is, that it seems not improbable but that the greatest part of the inequality of the Earths Surface may have proceeded from the subversions and overturnings of some preceeding Earthquakes. *The tenth Proposition confimed.*

And for making this Conjecture probable, I might repeat all the Arguments I have already urged to make probable the Generations of Islands, Mountains, Abysses, *&c.* but that I suppose will be needless, they having been so lately mention'd. I could also instance in a multitude of other smaller effects produced by Earthquakes, of making the Surface of the Earth irregular; but those are so numerous, and so very well known in those places where Earthquakes are more frequent, as in *Italy*, *Turky*, the East and West *Indies*, &c. that I shall not insist on them. To this I might add the universality of Earthquakes, there being no part of the World of which we have any good account, but we find to have been some time or other shaken by Earthquakes; and 'tis very probable had we receiv'd any certain account of the State and Constitution, and being of the Earth in its Infancy (as I may say) or first Being of the Earth after its Creation, when 'tis not improbable but the parts of it that lay uppermost and next the other were more fluid and soft, we might have had a thousand otherobservables. Of which I shall say more hereafter when I mention some other Conjectures.

Thus much only I shall add at present, that from what I have instanced about Petrifactions and the hardning of several Substances, it seems very probable, that in the beginning the Earth consisted for the most part of fluid Substances, which by degrees have setled, congealed, and concreted, and turn'd into Stones, Minerals, Mettals, Clays, Earth, *&c.* And that in process of time the parts of it have by degrees concreted and lost their Fluidity, and that the Earth itself doth wax old almost in the same manner as Animals and Vegetables do; that is, that the moisture of it doth by degrees decay and wast either into Air, and from thence into the Æther; or else by degrees the Parts communicating their motion to the Fluidether either grow moveless and hard, almost in the same manner as we find the Bodies of Animals and Vegetables when they grow old in their several proportinate times, all the Parts tend and end in solidity and fixtness, the Gelly becomes Gristles, and the Gristles a Bone, and the Bone at length a Stone, the Skin from smooth and soft grows rough and hard, the motions grow slow, and the moveable Parts and Joints grow stiff, and all the Juices decay and are deficient. The same thing happens in Trees and other Vegetables. If therefore the Parts of the Earth have formerly, in all probability, been softer, how much more powerful might Earthquakes be then in breaking, raising, overturning, and otherwise changing the superficial Parts of the Earth? Besides, 'tis not unlikely but Earthquakes might then be much more frequent before the Fuels of those subterraneous Fires were much spent. That the Parts of the Earth do continually grow harder and fixt and concrete into Stone, I think no one will deny that has consider'd the Constitution of Mountains, the Layers and Veins of them, the Substances mixt with them, the Layers of the several Earths, Sands, Clays, Stones, Minerals, *&c.* that are met with in diging Mines and Wells, The Nature of Petrifying Waters, the shapes of Crystals, Ores, Talks, Sparrs, and most kind of precious Stones, Marbles, Flint,

Chalk, and the like, every of which are by their forms sufficiently discover'd to have been formerly fluid Bodies, and whilst fluid, shaped into those forms: One or two undeniable Instances I shall add of the fluidity of Flints, and that shall be that I have now by me, a Flint that has so perfectly filled the Shell of an *Ecknius*, and inclosed it also that it has received all the impressions of the cracks of the Shells both on the Concave and Convex Part thereof, and has exactly filled all the Holes and Pores thereof, and has so perfectly received all the shape thereof as if it were nothing but Plaister of *Paris* tempered, Wax, or Sulphur that had been melted and cast on it; notwithstanding which it is a Flint so hard as to cut Glass very readily, and is of a very singular and uniform Texture; to this I might add many others of the like kind, which have the impressions of these and other Shells, and yet are some Marble, some Pebbles, some Agats, some Marchasites, some Ores, some Crystals, *&c.* Some Flints I have marked with impressions as exactly as if they had been soft Wax stamp'd with a Seal.

Further, That the Subterraneous Fuels do also wast and decay, is as evident from the extinction and ceasing of several Vulcans that have heretofore raged; which Considerations may afford us sufficient Arguments to believe that Earthquakes have heretofore, not only been much more frequent and universal, but much more powerful. If to this we do add what I formerly mention'd, that there seems to be no other more probable and intelligible Cause in Nature of the inequality of the Earths Surface, the natural Principle of Gravity reducing the Parts of it as near to an exact spherical Figure as their Solidity and forc'd Postures will permit, and consequently (as I mention'd before) the natural form produc'd by Gravity would be a multitude of Spherical Shells concreted of the several Substances of which it consists, incompassing each other, not unlike the Orbits or Shells (for we have no proper name for that kind of hollow Spherical Figure) of an Onion, or as the *Ptolemaiick* Astronomers do fancy the solid Orbs of the Heavens, ranged every one in its distinct Order according to its Density and Gravity; that is, that which hath been heaviest would have approach'd nearest the Center, or at least nearest to that part which is attractive and the cause of Gravitation, if such a Body there be in the middle of the Earth, and the next lighter in the second place, and so on to the third, fourth, fifth, *&c.* according to their several degrees of Gravity and Density, they would have taken their several Quarters, and so Water would always have covered the Face of the Earth, and the lightest Liquor would always have been at the top, and the Air above that, and Æther above that; and as in Fluids so also in Solids, the Shells of Gold would have been the lowest of any Body we yet know, that of Quicksilver next, that of Lead next, and so the rest in their order, which seems also really to have been the form of the Earth, till disturbed by Earthquakes, which I conceive to be the reason of the scarcity of those heavy Bodies of Metal near the Surface, and of the greatest scarcity of Gold which is the most heavy, and that it is not to be found but in such places where there have in probability been great subversions by Earthquakes, as in Mountains, or in Rivers running out of Mountains, or in Earth washt and tumbled down from Mountains, and such like places, as by many Circumstances may be guest to have been formerly deeper under the Surface of the Earth.

There is yet one Argument more that to me seems very good, and that is fetcht from no less distance than the Moon and the Sun by the help of Telescopes. These Bodies, as I have formerly hinted in the latter end of my Micrography, seem to have the same Principle of Gravity as the Earth, which, as I have there argued, seems probable from their Spherical Figure in general, and the several inequalities in particular, visible by the help of Telescopes on the Surface of the Moon, and the several Smoaks, and Clouds, and Spots that appear on the Surface of the Sun; and as they have that Principle in common with the Earth, so it seems to me that they are not free from the like motions with those of an Earthquake: For as to the Moon 'tis easily to be perceiv'd through a Telescope, that the whole Surface of it is covered over with a multitude of small Pits or Cavities which are incompassed round with a kind of protuberant Brim, much like the Cavities

or

or small Pits, which are left in a Pot of Alabaster Dust boyled dry by the Vapours which break out of the Body of it by the heat of the Fire; and all the inequalities that appear on the Surface of that Body, seem, by their form, to have been caus'd by an Eruption of the Moon, somewhat Analogous to our Earthquakes; all those Pits in the Moon being much like the Caldera or Vent at the top of Vulcans here on the Earth, or like those little Pits left at the top or surface of the Alabaster Dust by the natural subsiding of that Dust in the place where the Vapours generated within the Body of it break out. I need not, I think, spend time in urging Arguments to prove the sufficient powerfulness of the Cause to produce Effects as great as any I have ascribed to it, as being able to raise as great and high Mountains as those of the *Alps*, *Andes*, *Caucasus*, *Montes Lunæ*, &c. especially since even of late we are often informed of as great effects elsewhere, and even of the shaking and moving those vast Mountains by our latter and more debilitated Earthquakes, tho' those Mountains are now in probability much more compacted and tenacious by the since acquired Petrifaction, than they were before their first accumulation; and tho' 'tis not unlikely but the Fuel or Cause of the Subterraneous Fire may be much wasted and spent by preceding Conflagarations; Yet possibly there may be yet left in other Parts sufficient Mines to produce very great effects if they shall by any accident take Fire; and 'tis not impossible but that there may be some Causes that generate and renew the Fuel, as there are others that spend and consume it.

From all which Propositions, if at least they are true, will follow many others meer Corollaries which may be deduced from them.

First, That there may have been in preceding Ages, whole Countries either swallowed up into the Earth, or sunk so low as to be drown'd by the coming in of the Sea, or divers other ways quite destroyed; as *Plato*'s *Atlantis*, &c. *The Corollairs from the foregoing Propositions.*

Secondly, That there, many have been as many Countries new made and produced by being raised from under the Water, or from the inward or hidden Parts of the Body of the Earth, as *England*. 2.

Thirdly, That there may have been divers Species of things wholly destroyed and annihilated, and divers others changed and varied, for since we find that there are some kinds of Animals and Vegetables peculiar to certain places, and not to be found elsewhere; if such a place have been swallowed up, 'tis not improbable but that those Animal Beings may have been destroyed with them; and this may be true both of aerial and aquatick Animals: For those animated Bodies, whether Vegetables or Animals which were naturally nourished or refresh'd by the Air would be destroy'd by the Water. And this I imagine to be the reason why we now find the Shells of divers Fishes Petrify'd in Stone, of which we have now none of the same kind. As divers of those Snake or Snail Stones, as they call them, whereof great varieties are found about *England*, and some in *Portland*, dug out of the very midst of the Quary of a prodigious bigness, one of which I have weighing near Pound weight, being in Diameter about Inches, which I obtain'd from the Honourable *Henry Howard* of *Norfolk*: We have Stories that there have been Giants in former Ages of the World, and 'tis not impossible but that such there may have been, and that they may have been all destroyed, both they and their Country by an Earthquake, and the Poets seem to hint as much by their *Gigantomachia*. 3.

Fourthly, That there may have been divers new varieties generated of the same Species, and that by the change of the Soil on which it was produced; for since we find that the alteration of the Climate, Soil and Nourishment doth often produce a very great alteration in those Bodies that suffer it; 'tis not to be doubted but that alterations also of this Nature may cause a very great change in the shape, and other accidents of an animated Body. And this I imagine to be the reason of that great variety of Creatures that do properly belong 4.

to

to one Species; as for instance, in Dogs, Sheep, Goats Deer, Hawks, Pigeons, *&c.* for since it is found that they generate upon each other, and that variety of Climate and Nourishment doth vary several accidents in their shape, if these or any other animated Body be thus transplanted, 'tis not unlikely but that the like variation may follow; and hence I suppose 'tis that I find divers kinds of Petrify'd Shells, of which kind we have none now naturally produced; of this sort are many of those Helmet Stones which have been made by the Petrifactions of Substances in the Shells of several sorts of *Echini*, whose sorts have been destroyed by the alteration of the Nature of that part of the Sea where they were produced; and hence 'tis we find scarce any Shell-Fish in our *English* Sea that has a Shell like those sorts of *Nautili*; from whence our *Keinsham* and other sorts of Snake-Stones are produced.

5. Fifthly, 'Tis not impossible but that there may have been a preceding learned Age wherein possibly as many things may have been known as are now, and perhaps many more, all the Arts cultivated and brought to the greatest Perfection, Mathematicks, Mechanicks, Literature, Musick, Opticks, *&c.* reduced to their highest pitch, and all those annihilated, destroyed and lost by succeeding Devastations. Atomical Philosophy seems to have been better understood in some preceding time, as also the Astronomy evinc'd by *Copernicus*, the *Ægyptian*, and *Chinese* Histories tell us of many thousand Years more than ever we in Europe heard of by our Writings, if their Chronology may be granted, which indeed there is great reason to question.

6. Sixthly, 'Tis not impossible but that this may have been the cause of a total Deluge, which may have caused a destruction of all things then living in the Air: For if Earthquakes can raise the Surface of the Earth in one place and sink it in another so as to make it uneven and rugged with Hills and Pits, it may on the contrary level those Mountains again, and fill those Pits, and reduce the Body of the Earth to its primitive roundness, and then the Waters must necessarily cover all the Face of the Earth as well as it did in the beginning of the World, and by this means not only a learned Age may be wholly annihilated, and no relicks of it left, but also a great number of the Species of Animals and Plants. And 'tis not improbable but in the Flood of *Noah*, the Omnipotent might make use of this means to produce that great effect which destroyed all Flesh, and every living thing, save what was saved alive in the Ark.

7. Seventhly, 'Tis not impossible but that some of these great alterations may have alter'd also the magnetical Directions of the Earth; so that what is now under the Pole or Æquator, or any other Degree of Latitude may have formerly been under another; for since 'tis probable that divers of these parts that have such a Quality may have been transpos'd, 'tis not unlikely but that the magnetick Axis of the whole may be alter'd by it, after the same manner as we may find by experiment on a Loadstone, that the breaking off and transposing the parts of it, do cause a variation of the magnetick Axis.

I could proceed to set down a great many other Corollarys that would naturally follow from these Principles if certainly proved. But this Essay I intended only as a hint or memorandum to such Gentlemen as travel or any other inquisitive Persons, who for the future may have better opportunities of making Observations of this kind, that they may be hereby excited, or at least intreated to take notice of such Phænomena as may clear this Inquiry tho' never so seemingly mean and trivial, since it seems not improbable but that they may discover more of the preceding duration and alterations of the World than any other Observations whatsoever, and that thence may flow such instructions as may be of some of the most considerable uses to humane Life and Society, to which end all our Philosophical Studies and Inquiries tend. Ended *Sep.* 15. 1668.

The

THE preceeding Discourse of Earthquakes was wrote, Anno. 1668, *as appears by the Date at the end thereof, and lay by the Author for a considerable time, till afterwards he took the Subject into consideration again, and read several Lectures in confirmation of his former* Hypothesis, *and in them produced several Observations and Collections quoted from divers Authors Ancient and Modern, and answered many Objections, which I shall in the next place present the Reader with as near as I can in the order they were read to the Royal Society, not doubting but the Curious will find Entertainment and Satisfaction in them. The first that I find to this purpose, is a Lecture which was among his other Papers, tho' I know not the exact time when it was read, yet since it contains several Arguments to prove that the figured Stones found in many parts of the World are real Petrifactions, I shall here give it in the first place.*

R. W

A Vindication of the Royal Society.

I Am not, I suppose, the only Person who hath heard some Persons (with what Reason I dispute not) ask what the *Royal Soriety hath done for so many Years* as they have met. And other Persons as confidently affirm that they have done *just nothing*. Nor am I ignorant that the same Reflections have been made upon me in particular with more severe Aggravations. As to what concerns my self I shall not now spend time in answering, designing to do it by another way. But as to what concerns this Honourable Society, I conceive it might be a satisfactory Answer to assure such Objectours that this *Society* have been imployed in collecting such *Observations*, and making such *Experiments* and *Trials* as being fitly apply'd and judiciously made use of, will very much tend to the advancement of *Natural Knowledge*: And tho' the things so collected may of themselves seem but like a rude heap of unpolish'd and unshap'd Materials, yet for the most part they are so qualified as that they may be fit for the beginning, at least of a solid, firm and lasting Structure of Philosophy.

But because some of those may doubt whether really there be any such Collection made, and more of the practicableness of making such a Use and Application of them, and will not acquiesce and be satisfied with the effects hereof that future times may produce, but are desirous to see some *Specimen* of what may be hoped for, by seeing the Ground designed and set out, the Foundation laid, and the Workmen beginning to raise the Walls, and make use of the Materials that are said to be got in readiness for such a Fabrick.

I conceive, it may not be altogether unseasonable this following Year nor improper for this *Honourable Society's Care* to make some attempt of that kind by shewing some *Specimen* of such a Structure raised from Observations and Collections of their own, that it may appear that they have not disquieted themselves in vain, in heaping up such a Treasure which they know not who shall enjoy or make use of; that is, to see whether any of these things they have been collecting, will afford sufficient Evidence to ground a deduction of a higher Nature upon, such as is more obscure to be seen, or more difficult to be ascertained of, to see whether, when a weight comes to be laid open the Stones or the Bricks, the natural Observations, or the Artificial Trials and Experiments, they will not crush under it, and fail of sufficient Solidity; and if they do, whether such may not be fit for other places, and whether it will not be necessary to seek out for some others that may be more firm and solid, and such as are of a closer and better concocted qualification, which may be more powerful to sustaine a higher Superstructure, and a greater weight of Argument to be laid upon them.

What makes a Collection of Experiments Observations useful.

In order to this it is necessary (for the Architects at least) to know, 1*st*. What are the particular qualifications necessary for the several Materials of their designed Fabrick. 2*dly*. The Methods by which these qualifications may be examin'd. 3*dly*. The place where, and the means how Materials so qualified may be proved, without which præmeditated Design, Knowledge,

and Care; a Collection, tho' very great, made at a venture must needs contain abundance of such as will be of little use for the end aimed at, and not only so, but will also prove a great Obstruction and Confusion in finding out such as are proper, and in separating the Good from the Bad.

The Structure aimed at, is a true and certain knowledge of the Works of Nature, and this is designed to be attained as fast as may be, and to be perfected as far as may be; or the end of the Inquisition is the promotion and increasing of Natural Knowledge.

The Analytick Method.

The methods of attaining this end may be two, either the Analytick, or the Synthetick. The first is the proceeding from the Causes to the Effects. The second from the Effects to the Causes: The former is the more difficult, and supposes the thing to be already done and known, which is the thing sought and to be found out; this begins from the highest, most general and universal Principles or Causes of Things, and branches itself out into the more particular and subordinate.

The Synthetick Method.

The second is the more proper for experimental Inquiry, which from a true information of the Effect by a due process, finds not the immediate Cause thereof, and so proceeds gradually to higher and more remote Causes and Powers effective, founding its Steps upon the lowest and more immediate Conclusions.

An Inquisition by the former Method is resembled fitly enough by that Example of an Architect, who hath a full comprehension of what he designs to do and acts accordingly: But the latter is more properly resembled to that of a Husbandman or Gardener, who prepares his Ground and sows his Seed, and diligently cherishes the growing Vegetable, supplying it continually with fitting Moisture, Food, Shelter, *&c.* observing and cherishing its continual Progression, till it comes to its perfect Ripeness and Maturity, and yields him the Fruit of his Labour. Nor is it to be expected that a Production of such Perfection as this is designed, should in an instant be brought to its compleat Ripeness and Perfection; but as all the Works of Nature if it be naturally proceeded with, it must have its due time to acquire its due form and full maturity, by gradual Growth and a natural Progression; not but that the other method is also of excellent and necessary use, and will very often facilitate and hasten the progress to Perfection. An Instance of which kind I designed some Years since to have given this Honourable Society in some of my Lectures upon the motions and influences of the Cælestial Bodies, if it had been then thought fit; but I understand the same thing will now be shortly done by Mr. *Newton* in a Treatise of his now in the Press: But that will not be the only Instance of that kind which I design here to produce, for that I have divers Instances of the like Nature wherein from an *Hypothesis* being supposed or a premeditated Design, all the *Phænomena* of the Subject will be *a Priori* foretold, and the Effects naturally follow as proceeding from a Cause so and so qualified and limited. And in truth the *Synthetick* way by Experiments Observations, *&c.* will be very slow if it be not often assisted by the *Analytick*, which proves of excellent use, even tho' it proceed by a false position; for that the discovery of a *Negative* is one way of restraining and limiting an *Affirmative*.

But not to spend more time at present upon the more particular explications of These Methods, which would make of it self a very large Discourse, I shall proceed to the Subject which I began to discourse upon the last meeting, premising only in general what I think necessary thereunto, an Explication of what I understand by natural Knowledge, or the Knowledge of Nature.

What Knowledge is and how acquired.

By *Knowledge* then in the highest *Idea* of it, I understand a certainty of information of the Mind and Understanding founded upon true and undeniable Evidence.

True

True and undeniable Evidence is afforded either immediately by *Sense* without Fallacy, or mediately by a true Ratiocination from such Sense.

I call that *Sense* without Fallacy, where the *fallacies* of Sense being detected and known, the Evidence produced thereby is examined and found to be free and clear of all such *Fallacies*.

I call that true *Ratiocination* from such Sense, where being sure of the Premises, the Conclusion necessarily follows from them; which is the method of Reasoning made use of it *Geomotry*, and by which we arrive at as great a certainty of things unseen as seen. Thus *Ovid* describes the method of *Pythagoras*, in scaling the Heavens. *The true Method of Reasoning.*

——Isq; licet cœli Regione Remotus
Mente Deos adiit, & quæ natura negabat
Visibus humanis, oculis ea pectoris hausit.

Now tho' in Physical Inquiries, by reason of the abstruseness of Causes, and the limited Power of the Senses we cannot thus reason, and without many Inductions from a multitude of Particulars come to raise exact Definitions of things and general Propositions; yet by comparing of varieties of such Inductions we may arrive to so great an assurance and limitation of Propositions as will at least be sufficient to ground Conjectures upon, which may serve for making *Hypotheses* fit to be enquired into by the *Analytick* method, and thence to find out what other Experiments or Observations are necessary to be procured for the further progress in the *Synthetick*, which will questionless so far inform us of the general and universal progress of the Operations of Nature, that nothing but what is really the truth shall be proposed but the absurdity and insufficiency thereof will presently be detected and proved. *The difficulty thereof in Natural Philosophy.*

So that tho' possibly we may not be able to produce a *Positive* Proof, yet we may attain to that of a *Negative*, which in many cases is as cogent and undeniable, and none but a willful or senseless Person will refuse his assent unto it. Thus much I thought was necessary to premise in order to what I have further to propound to the Consideration of this noble Society upon the Subject I have discoursed of formerly only by way of Queries; it being my aim at present to see what *Positive* or *Negative* certainty at least may be attained concerning the same, either from the information of Sense freed from Fallacies or from the superstructures of Reasoning. *A Negative many times as cogent as an Affirmative.*

I propounded then two Hypotheses for the solution of the *Phænomena*, observ'd in *Petrified Bodies*, of the resemblance of Animal and Vegetable Bodies; such as the Shells and Bodies of Fishes, the Bones, Teeth, Hornes, *&c.* of Fish, and also of Terrestrial Animals, the Wood, Leaves, Bark, Roots, and Fruits of Plants and Vegetables; which resembling Bodies are found to be of variety of Substances, sometimes of Stone, as Flint, Marble, Black, White, Gray, and of various other Colours, of Free-stone, *Portland*-stone, Chalk, and an infinite variety of other Stone, some harder, some softer: Of various kinds of Clay, Earth, Sand, *&c.* they have been found near the tops of the highest Hills, and the bottom of the lowest Wells and Mines, in the middle of the solid Quarries of Stone and other Minerals, and those the most remote, or at least very far distant from the Sea. Some of these have the perfect representation of the Figure of such Creatures and other Substances as are now well known, others of such as have some analogy and likeness to them, yet different from what are known of those Species to which they seem to belong, either in Magnitude, Figure, Colour, *&c.* yet retain such characteristick marks as seem to indicate them to belong to this or that Species of Animals or Vegetables. Some of these are nothing but perfect Stones of several kinds, others are inclosed with a Substance seeming to be the same, with that of the very Animal or Vegetable they resemble. Add to this, that in as many varieties of places there have been found others of these Figured Bodies, *Of Petrified Substances.*

dies, which have as to Sense the very same Substance and Figures with those of the corresponding Species of Animals or Vegetables, and do not seem to be at all of a petrify'd and stony Substance, but rather of an Animal or Vegetable; of every of which Particulars I have viewd and examined Instances. And if it were not for detaining you too long, could have here produced a more particular Account and Description. But they being so generally known at least so universally almost spread over the whole Earth, so that no Country almost but doth afford them, I thought it would be needless.

How to come to ascertain knowledge of them.

The Question now is how we shall come to a certainty of Knowledge concerning them, by which we may be able to understand what they really are: And Secondly, What was the Cause of them. Thirdly, How they came to be disposed, placed, or made in those parts where they are, or have been found. Fourthly, These Discoveries being made to satisfaction, of what use or benefit will it be to Mankind, or how shall we be the wiser, or how will this Knowledge be an improvement of Natural Knowledge? Which is the aim of this Society.

For Answer then to these several Queries I shall propound these following Considerations.

To know what Substance they are of.

First, As to the way of knowing of what Substance they are, I conceive there can be no better way than what we generally use when we inquire into the true Nature or Substance of any other Body when it is delivered to us to be examined or denominated; for instance, if a peice of Metal be delivered to be examined, it will first be viewed to see what Metal it resembles in Colour and Consistence, or in such other obvious and sensible Qualifications as may enable one to judge or guess what kind of Metal it is; as suppose it resembles Gold for closeness and ponderousness, these give intimation enough of examining it yet a little more curiously, since all is not Gold that glisters, and it may be that some Counterfeit in those more obvious Qualifications has mimicked that noble Metal, to do this, it is tried further by being put into good *Aqua Fortis*, to see whether that will dissolve it, for if it doth, it cannot be Gold. Secondly, The Specifick Gravity thereof is more curiously and exactly found by the help of Scales and Weights, by which it is weighed in and out of Water, because if thereby it be found to be lighter than Gold it cannot be Gold. Thirdly, By Hammering and a Gold Beater, 'tis found to be Malleable, and by looking through the Leaf, 'tis found of a transparent Greeness and reflects a true Golden Colour, then 'tis tried by copelling and found fixed in the Fire, then it tarnishes not in the Air, and Amalgams Readily with *Mercury*, then its Solution in ARtinges, the Skin and Nails red, and a further trial shews it to tinge Glass of a Ruby Colour. Now if it bear all these several ways of Examination, and answers to the properties of Gold, it may safely be concluded to be true Gold, and whoever shall deny it to be such must be looked upon as one that doth it without Reason, unless he can produce a further Criterion by which it shall be found to be very differing from it. Now, tho' this Metal were found at the bottom of a Mine a hundred Foot under Ground, or at the top of a Hill a hundred Foot above the Level of the Plain; or in the Pores of a growing Vegetable; or in the Tooth or Thigh of an Animal, tho' possibly it may be difficult to assign the Reason or Cause how it came to be placed there; yet the Examiner hath the Evidence of Sense to assure him that this Metal is Gold, and he ought to conclude and acquiesce in it, that such it is; otherwise there can be nothing at all known that it is this or that Body, and then there is an end of all further Inquiry or Experiment.

Now though there may not be known so many various ways of examining every other kind of Body, as, by reason of the value of it, there have been found out for Gold; yet in many Bodies at least a much less number will serve the turn to give assurance, that the Body so examined is of this or that kind and in many the very outward form as visible to the naked Eye, but especially if the inward visible appearance of the Substance be joined with it, will be

be assurance sufficient to force an Assent or Conclusion of what kind the Body is that is so examined, and it ought not to be denied to be such without as evident a manifestation to the contrary.

This Discourse I have been the larger in premising, because, till it be agreed what is sufficient evidence to prove a natural Body of this or that kind there can be nothing done. If Experimental Philosophy, and if Poofs of this kind will not suffice, I cannot expect that all that I shall bring to prove the *Hypothesis* will be of any validity. That then which I shall indeavour to prove is ;

First, That there have been, and daily are found, the real Shells of Fishes in such parts of the Earth as are much above the present Level of the Sea, and others buried at a very great depth under the Surface of the Earth, where notwithstanding, 'tis evident that they were not there placed by any humane Power or Design. *A Recapitulation of the Heads mention'd* Pag. 288. *Supra.*

Secondly, That many of these Shells are of a form differing from any of those Shells of that Species to which they seem to belong, which are commonly known at this Day.

Thirdly, That there are others of them which to all appearance are of the very same Species now known and to be found living.

Fourthly, That there are many of these Shells which are and have been in process of time, fill'd within and inclosed without with divers sorts of Earth, such as, Clay, Lome, Sea Sand, and divers other kinds of Sand, Mud, Chalk, *&c.*

Fifthly, That those filling and enclosing Bodies have been, and are by degrees, in process of time, petrify'd and hardn'd into Stones of differing Natures, Hardness and Contextures retaining the Impression, Form, or Signature of those Shells, so inclosed.

Sixthly, That those Shells so filled and inclosed, as above said, are according to the differing Nature of the Petrifactive Liquor or Juice: sometimes also Petrify'd retaining still the same Figure they were of when the Petrifactive Juice began to operate upon them.

Seventhly, That others of them remain yet perfect Shells without Petrifaction or Alteration, when as yet both the Substance that fills them, and that which encloses them is converted into Stone of differing Natures and Textures.

Eighthly, That many of these Shells are either by length of Time, or by the Nature of the Petrifactive Juice perfectly rotted and decayed so as to be easily frangible between one's Finger and Thumb into a very fine Powder and yet serve to give a perfect Mould or Shape to the inclosed and inclosing-Stone.

Ninthly, That in many cases the Shell is not only Petrify'd by the said Juice, but sometimes after the impression hath been made as aforesaid, the Shell hath been clearly dissolved and carried away from the inclosing and inclosed Substances, leaving only the Space empty where the said Shell hath been placed.

Tenthly, That it sometimes happens that the Substance that filled the Shell hath been Petrify'd, and after the Shell hath been rotted away, the Petrify'd Body that was inclosed and had received that Impression, hath been afterwards inclosed with a Substance which hath afterwards Petrify'd and so inclosed it in Stone.

Eleventhly, That these kinds of Shells or the Petrify'd Substances that have been formed by them, have been for all Antiquity, and are at this Day to be found in most parts of the known World.

Twelvethly, That they are most of them differing from one another, tho' all referable to some Species of Shell-Fishes now to be found; yet in many particulars each of them also differing from them; that is, those that are found in one Country or Region, are very differing from those of another Country or Region, and that not only as to the Nature of the Petrify'd Substance inclosed and inclosing, but also as to the Figure and Make of the Shells themselves; and many of those also differing from the shape even of

those Shell-Fishes which are now to be found in such parts of the Seas which are situated near to the places that they are found in.

Concurring to this Head I shall prove that Shell-Fishes of the same Species in differing Countries now to be found, have many differences one from another, as much as any one of those Petrify'd Bodies have from any of the present Shells.

The end of the Author's Discourses.

I have in my former Discourses explain'd the end and aim of these my Inquisitions, namely, to make some Use and Application of several Observations and Experiments that have been Collected in order to deduce some Doctrine from them, which may serve to direct such further Inquisitions as shall be necessary for the perfecting of the same, or at least to find whether such are wanting, and of what Kind and Nature they are.

The Doctrine aimed at, is, the Cause and Reason of the present Figure, Shape and Constitution of the Surface of this Body of the Earth, whether Sea or Land, as we now find it presented unto us under various and very irregular Forms and Fashions and constituted of very differing Substances.

Histories deficient, and why.

Now, because when we look into Natural Histories of past Times, we find very few, if any, Footsteps of what alterations or transactions of this Nature have been performed, we must be fain to make use of other helps than what Natural Historians will furnish us with, to make out an account of the History thereof: Nor are there any Monuments or Medals with Literal, Graphical, or Hieroglyphical Inscriptions that will help us out in this our Inquiry, by which the Writers of Civil Histories have of late Years been much assisted from the great curiosity of modern Travellers and Collectors of such Curiosities.

The great transactions of the Alterations, Formations, or Dispositions of the Superficial Parts of the Earth into that Constitution and Shape which we now find them to have, preceded the Invention of Writing, and what was preserved till the times of that Invention were more dark and confused, that they seem to be altogether Romantick, Fabulous, and Fictious, and cannot be much relied on or heeded, and at best will only afford us occasions of Conjecture.

Proofs of the foregoing Propositions mentioned Pag. 333.

For Proof then of the first Proposition that, *&c.* I could produce a multitude of Authorities fetched out of printed Authors, and as many others that I have received from the Relations of very credible Persons that have found them themselves, but it would be too long, I shall therefore only name one who was formerly a worthy Member of this Society, and well known to divers here present, and that was Dr. *Peter Ball*, he passing over the *Alps* to go into *Italy* by a narrow Passage, where there was on the one hand a prodigious high Cliff above him, and on the other hand, as prodigious deep Precipice below him, observed in the Cliff a Layer of Sea Sand and Shells for a very great length buried under that high Mountain above; he had the curiosity to take up and bring home with him into *England* divers of them which he dug out of the said Layer of Sand which he shewed me, and I found them to be true Oyster-shells, not Petrified but remaining perfect Shells, one of which he gave me, and had divers others which he kept; he observed also, that there were divers other Substances among the Sand as if it had been upon the Sea-shoar. To this I shall add an Observation of my own nearer Home, which others possibly may have the opportunity of seeing, and that was at the West end of the Isle of *Wight*, in a Cliff lying within the *Needles* almost opposite to *Hurst-Castle*, it is an Earthy sort of Cliff made up of several sorts of Layers, of Clays, Sands, Gravels and Loames one upon the other. Somewhat above the middle of this Cliff, which I judge in some parts may be about two Foot high, I found one of the said Layers to be of a perfect Sea Sand filled with a great variety of Shells, such as Oysters, Limpits, and several sorts of Periwinkles, of which kind I dug out many and brought them with me, and found them to be of the same kind with those which were very plentifully to be found upon the Shore beneath, now cast out of the Sea.

This

This Layer is extended along this Cliff, I conceive near half a Mile, and may be about sixty Foot or more above the high Water mark.

Another Instance I observed nearer this place, and that was in St. *James's Fields*, where St. *James's* Square is now built, in which place when they were making Bricks of the Brick Earth there dug, they had sunk several Wells, which I judge might be near twenty Foot in depth, to procure Water for that purpose; going down into several of those, I found, at the bottom, a Layer of perfect Sea Sand, with variety of Shells, and several Bones, and other Substances, of which kind I dug out enough to fill a small Box and shewed them to Mr. *Boyl*, and also to this *Society*. And I was informed also, that the same kind of Substances were found in digging of a Snow Well in St. *James's Park*; and I doubt not but whoever shall sink any where thereabout to that depth will find the same things. Now whoever will consider the Positions and Circumstances of the said places, will easily grant, I suppose, that they could not be there placed by the Industry of *Man*, but must be ascribed to some other cause to be fetched from *Nature*.

As to the second Head, That, *&c.* I shall produce several Oyster and Cockle Shells which have been and are to be found in many Parts of *England*, which in many particulars of their shape, do differ from those of the Oysters and Cockles now to be found; yet upon examination of them they may be found to be true and perfect Shells by all sensible Qualities, except only their exact shape, and therefore I conceive that to be sufficient Evidence to prove them to be really such, because it is all the Evidence the Matter is capable of. If in digging a Mine, or the like, an artificial Coin or Urne, or the like Substance be found, no one scruples to affirm it to be of this or that Metal or Earth he finds them by trial to be of: Nor that they are *Roman*, *Saxon*, *Norman*, or the like, according to the Relievo, Impression, Characters, or Form they find them of. Now these Shells and other Bodies are the Medals, Urnes, or Monuments of Nature, whose Relievoes, Impressions, Characters, Forms, Substances, *&c.* are much more plain and discoverable to any unbiassed Person, and therefore he has no reason to scruple his assent: nor to desist from making his Observations to correct his natural Chronology, and to conjecture how, and when, and upon what occasion they came to be placed in those Repositories. These are the greatest and most lasting Monuments of Antiquity, which, in all probability, will far antidate all the most ancient Monuments of the World, even the very Pyramids, Obelisks, Mummys, Hieroglyphicks, and Coins, and will afford more information in Natural History, than those other put altogether will in Civil. Nor will there be wanting *Media* or *Criteria* of Chronology, which may give us some account even of the time when, as I shall afterwards mention. *See* p. 333.

As to the Proof of the third Proposition, *viz.* That, *&c*, All those Instances I have named are of sufficient evidence, for that those which I found in both those places I mentioned were of the same kinds with those that are now to be found near those places, as whoever shall examine will find.

And the fourth will also from the same, and hundreds of others be as evident, and therefore I suppose none will scruple to assent to this Proposition, *viz.* That, *&c.* Page 333, especially if the truth of the former be granted, which I conceive cannot be denied.

For Proof of the fifth Proposition, namely, That, *&c.* The place I mentioned before near the *Needles* in the Isle of *Wight* afforded a most evident and convincing one as could well be desired, which was from the following Observation. I took notice that the aforesaid Earthy Cliff did founder down and fall upon the Sea-shoar underneath, which was smooth and Sandy, and bare at low Water so as to be walked on, but at high Water a great part of it was covered by the Sea. I observed several great lumps of the said Founderings lying below, some whereof, which lay next the Cliff, tho' they were somewhat harden'd together more than they were above in the Cliff, were yet not

hard

hard enough to be accounted Stone; others of them that lay further into the Sea were yet more hard, and some of the furthest I could not come at for the Water, were as hard I conceived as *Purbeck* Paving (which is taken up from the Shore of *Purbeck*, lying just opposite to it on the West side of this Channel or Passage) divers of these Stones I observ'd to be made up of the peices of Earth that had foundred down from the Cliff, which I was assured of by carefully observing and finding divers of them to consist of the several Layers, and in the same order as I saw them in the Cliff; among the rest I found divers that had the Layer of Sea Sand and Shells which I had observed in the Cliff inserted in the Stone with the adjoyning Layers all petrify'd together into a hard Stone. Here I found multitudes of the said Shells I before mention'd to have observ'd in the Cliff, mix'd loosely with a Sea Sand; now together with the said Sand both fill'd, inclos'd, and petrify'd altogether, and I broke off many peices of the said Rocks, where I found the said Petrifactions, and found them much like other Stones I had seen from other Inland Quarries here of *England*, wherein I had observ'd also such kind of petrify'd Shells, tho' how they came there to be so Petrify'd I could not be so well inform'd. For that which I conceive was the cause of this suddain Petrifaction (for I conceive those that I examin'd had not been Stones for very many Years, which I judged by their distance from the present Cliff, and from the quantity thereof, which *Communibus Annis* did founder down) was that close by this Cliff, there is a vitriolate or aluminous Spring or Rill which runs into the Sea, where formerly those Salts have been made of it by boyling, but has been now omitted for many Years. These saline Springs or Rills I conjecture mixing with the Sea-Water, may be the cause of the said Petrifaction, and the want of it is the cause why other founderings in other parts of the said Cliff are not at all so Petrify'd. Now from the assur'd Observation of these Petrifactions, I cannot but judge that the truth of this Proposition will most evidently appear, and needs no other to confirm it. However I doubt not but that any one who should there lay a part of the said Cliff shaped and marked as he pleas'd for his own assurance, would find the same very hard Petrify'd in two or three Years, which may not be unworthy of farther Inquiry and Trial for such as have opportunity.

As to the Proof of the sixth Proposition, it will not be difficult, the preceding being once granted for that there may be thousands of Instances of that Nature found in the Stones dug out of divers of our *English* Quarries; some of which Stones are found full of such Petrifactions.

Upon this occasion I think it not improper to mention an Observation which I have often taken notice of, which is of the Flints which are generally found intermix'd with Chalk in Quarries of that kind of Stone. I have observ'd then that these Flints are nothing else but the Body of the Chalk united together, and, as it were, first diluted by a petrifick Juice, and by that dissolved into it, and so make a uniform close Body which by degrees doth all petrify and harden together into that solid hard Body of the Flint. This I found by taking notice of the Nature of those Flints when broken, and how the Grain, Colour and Hardness of them was situated especially towards the edges; for there where the Juice seem'd to be almost spent, the Flinty Body appears of a midling Nature between Chalk and Flint, besides I have observ'd sometimes other Bodies inclosed, and sometimes lumps of Chalk also, toward which the Limb-parts of the Flint were colour'd and terminated just as towards the incompassing Chalk. And from the curious and sharp running and mouldings which I have observed in Flints, I conceive that the first Liquid Substance of it was altogether as fluid as Water, tho' it were imbu'd with a Saline Sulphureous or other petrifactive Tincture. These Indications may be much more plainly manifested by such a peice of Flint than 'tis possible for any one to describe by words; and therefore I shall omit the farther mention of them till I can meet with a Flint to shew them. I mention this here only to shew that the petrifactive Juice is often found to insinuate itself into the closest Pores of Body, by reason of its great fluidity which inables it oft to petrify even the very Bodies and Substances of the Shells themselves.

But

But tho' some of these Petrifactive Liquors be thus fluid, yet they are not all; and thence it comes that many Shells remain unpetrify'd, tho' the Substances that fill'd them and enclos'd them be so wrote upon, which was the seventh Proposition I undertook to prove. This I can make evident by divers of the Petrifactions that are kept in this Repository, and by thousands of others which I have seen: And any one that will but diligently examine them will find the very Shells themselves preserved Shells, tho' inclosed in the middle of a Stone, as of *Portland*, *Purbeck*, and divers other Inland Stones here dug in *England*. And I am promised to have sent me a flake of a Stone which is very hard, which notwithstanding is all over full of Shells. I say Shells, for that I cannot call them any thing else, since to all sensible trials they are so, both as to Figure and Substance.

As to the Proof of the Eighth, I cannot produce a more pregnant one than the *Echinus* or Helmet-Stone, found by Mr. *William Ball* upon the Shore of *Devonshire*, near *Exeter*, which he presented to the Society, and I suppose may yet be seen in the Repository, for by that alone it will plainly appear, that there had been formerly a Shell that had caused both the formations of the containing and contained Flint, there being just the due thickness of such a Shell vacant between them, but there may be hundreds of others produced of the like kinds if it were needful.

A Proof of the Ninth and Tenth, *viz.* I think the large *Cornu Ammonis* may afford; for here it seems plain, that a great part of the Shell was wasted away before the perfect Petrifaction of both the inclosing and inclosed Stone, tho' part of the Shell be yet remaining sticking between them.

'Tis a hard matter to make a positive Proof of the Eleventh, *viz.* Because of the infinity of them that would be necessary, yet I think it would not be difficult to bring credible Testimonies enough to supply one for each Country, and that I suppose may suffice to make it probable that they may be found in all others, since, as I shall afterwards prove, they have been produced all by the same cause.

As to the Twelfth Proposition which I undertook to prove, *viz.* That most of those Shells or other Substances found as above, whether Petrify'd or not Petrify'd, are in the first place differing from one another in many particulars both of Figure and Substance, tho' yet they retain such particular Characteristicks as are sufficient to denote and show to what Species they belong, either of Vegetables or Animals, whether of Fishes or terrestrial Creatures, such as are now to be met with alive; that is, not only that such as are thus found in one Country, are differing from those which are found in another: And in Petrify'd ones this is not only remarkable in the Substance inclosing and inclosed, but also in the magnitude, Figure and Make of the things themselves; and in the second place many of them do considerably differ from the shape of those Shell-Fishes, and other Substances which are now to be found alive in such parts of the Seas as are nearest situated to the places where these Fossil or Land Shells are now to be found. For the proof of which I have no better means than to have recourse to the Substances themselves, which have been so found, of which there is an excellent Collection in the Repository of this Society, though I have also seen divers other instances in other Collections and Observations which I have elsewhere met with, which I cannot now produce. Yet one Instance for all I suppose may be this great Voluta which I have here produced, that was taken out of a Quarry in *Portland* (and I believe that those two other great ones in the Repository which I begg'd of the late Duke of *Norfolk* for the Repository are of the same kind and from the same place) for by these I think it plainly enough appears, that they are very differing from all the other Substances or particular Petrifactions that are in the Repository, both in Magnitude, Colour, Shape and Substance including and included, and even in the very Substance of that which I call, and shall prove the Shell; and not only do they thus differ from the Petri-

 factions

factions Fossile or Land found Shells, but they differ also from all the known sorts of Shells of that Species of Fishes, to which I would refer them, which are now to be found any where near that place alive, nay, in any part of the World that I yet knew of; notwithstanding all which, they do retain, I conceive, certain Characteristicks of their Form, which show them to have belong'd to that Species of Shell-Fishes which are call'd *Nautili*. These *Nautili* are describ'd by *Gesner*, *Aldrovand*, *Johnston*, and others, where you have their Names and a Picture or two of the Shells, and some Stones also tending to a Description of the Creature and two Species of them; but he that shall think to find any such Characteristicks by reading their Descriptions and seeing their Pictures of them, will be much mistaken. And indeed it is not only in the description of this Species of Shells and Fishes, that a very great Defect or Imperfection may be found among Natural Historians, but in the Description of most other things; so that without inspection of the things themselves, a Man is but a very little wiser or more instructed by the History, Picture, and Relations concerning Natural Bodys; for the Observations for the most part are so superficial, and the Descriptions so ambiguous, that they create a very imperfect Idea of the true Nature and Characteristick of the thing described, and such as will be but of very little use without an ocular Inspection and a manual handling, and other sensible examinations of the very things themselves; for there are so many considerable Instances that may by that means be taken notice of, which may be useful to this or that purpose for which they may be instructive, that 'tis almost impossible for any one Examiner or Describer to take notice of them, or so much as to have any imagination of them. It were therefore much to be wishht for and indeavoured that there might be made and kept in some Repository as full and compleat a Collection of all varieties of Natural Bodies as could be obtain'd, where an Inquirer might be able to have recourse, where he might peruse, and turn over, and spell, and read the Book of Nature, and observe the *Orthography*, *Etymologia*, *Syntaxis*, and *Prosodia* of Natures Grammar, and by which, as with a *Dictionary*, he might readily turn to and find the true Figure, Composition, Derivation and Use of the Characters, Words, Phrases and Sentences of Nature written with indelible, and most exact, and most expressive Letters, without which Books it will be very difficult to be thoroughly a *Literatus* in the Language and Sense of Nature. The use of such a Collection is not for Divertisement, and Wonder, and Gazing, as 'tis for the most part thought and esteemed, and like Pictures for Children to admire and be pleased with, but for the most serious and diligent study of the most able Proficient in Natural Philosophy. And upon this occasion tho' it be a digression, I could heartily wish that a Collection were made in this Repository of as many varieties as could be procured of these kinds of Fossile-Shells and Petrifactions, which would be no very difficult matter to be done if any one made it his care: For *England* alone would afford some hundreds of varieties, some Petrify'd, some not. There are few Quarries of Stone here in *England* I believe, but if they were look'd into some kind or other of these Petrifactions might be found in them: I have observ'd them in Marbles almost of all varieties of Colours, as Black, White, Red, and otherwise Speckled: I have seen them in great varieties of Flints and Pebbles, in various sorts of hard Stones, as *Purbeck*, *Portland*, *Yorkshire*, *Kentish*, *Northamptonshire*, &c. I have seen many of them of Coperose or Vitriol Stone, or *Pyrites*, and *John Bauhine*, and others have described many of them of that Nature. Others of these are found above Ground, and others also under Ground very deep. sometimes unpetrify'd and remaining perfect Shells, Bones, Woods, Roots, *&c.* and have been found by several sorts of trials to be truly so, not only in External Figure, but also in the Internal and Substantial Parts of them; so that in truth there is no manner of Reason to doubt them to be of those very Substances they so perfectly and fully resemble.

The Defect of Natural History.

But if yet there should be some one that should make a doubt of their identity or sameness with such Substances as they seem to resemble, I would willingly know what kind of Proof will satisfie such his doubt, and by what Indications or Characteristicks he will know a Shell of an unknown Species (for such

such may be shewn him) when it shall be presented to him, or a peice of Wood of some strange Tree brought from an unknown place; if he will say by the relation of the bringer, that I conceive is not becoming a good Naturalist; and so one might have been impos'd on by the Relation of the incombustible Linnen which was here examin'd; but if he will say by its Properties, which he finds the same with that of Shells, or Vegetables, or other resembling Substances, then I answer, that the same will in these be manifestly shewn. Now, the more of these certain Characteristicks of the several Species of Bodies there are known, the greater certainties and assurances will be afforded by the artificial and strict Examination of them. As for instance, the knowing the Existence and Form of the microscopical Pores of Wood, is a better Characteristick to know that a Substance is Wood than the outward Figure and Appearance thereof, which may be artificially or accidentally imitated, by which means I found that a peice of Lignum Fossile sent from *Italy* by Cavalier *Pozzo* to Sir *George Eut.* and by him supposed to be only Earth shaped into that form and not to be real Wood, as *Stelluti* also indeavours to prove. By the examination, I say, and discovery of the microscopical Pores thereof with a Magnifying-Glass to be like those of Firr, I produced a better Argument that it was really Firr than any *Francisco Stelluti* has argued to prove it Earth. Another was, that it burnt as Wood, and made Coles like those of Wood, with microscopical Pores; had I had enough of it I could have examin'd it by Distillation, and various other Chymical Probations; for the more of Testimonies and Confessions are fetch'd from these Examinations and Wracking, the greater will be the Evidence of the true Nature of those Substances so examin'd, tho' oftimes the Evidence afforded by some one, may be sufficient clearness to save all further Enquiries: Such as these the Lord *Verulam* call'd *Experimenta Crucis*, which serve to direct the Inquierer to proceed the right way in making his Judgment. These are such marks as I call Characteristicks, which expresly determine and limit the Nature and Species of the Body under Consideration. For Instance, I conceive that all those Petrify'd Substances which are call'd Snake-stones in *English*, from some resemblance imagin'd of a Snake coyled up; and in Latin (*Cornu Ammonis*, or Sand Horns possibly from their being found in those Sandy Deserts.

These Petrifactions, I say, I conceive to be nothing else but the Petrifactions of several sorts of Substances that the Shells of some sorts of *Nantili* happened to be mix'd with, whilst those Substances were yet very soft and Liquid, and before they came to be hardned into Stone by the Petrifactive Agent. This Conception I grounded upon these Characteristicks, which in examining a great many of them I have found. First, That in very many of them I have manifestly seen the the real moulding Shell there preserved, together with the moulded Substance.

Next I conceive, that this Shell did belong to the Species of the *Nautili*, or sailing Fish, from these Characteristicks. First, That the Shell is of a true Conical Figure from the *Base* to the *Apex*. Secondly, That this Cone is turned into a *Voluta* or Spiral Cone, so that the *Azis* thereof doth perfectly lye in the same Plaine. Thirdly, That this Spiral being a true proportional Spiral, is continually at certain distances intercepted by Diaphragmes; so that those Diaphragmes being taken as Bases of several Cones, the Cones shall be found to diminish in a series Geometrically Proportional. Fourthly, That every one of these Diaphragmes is perforated with a hole similar and proportional also according to a Geometical Series.

To these I might add other accidental Proprieties of the flating, crenating, depressing, ridging, stringing, and the like, ornamenting, as it were, of the outward sides of this voluted conical Body, and the undulation and foliation, as I may call it, of the Diaphnagme, and the Fringing and Ruffling thereof; all which are found of great variety in this or that Subalternate Species, as is also the Section of the Base, or that of the Diaphragme; but these are not to be looked upon as Characteristicks or Differences to denominate a new Species.

And

And here by the bye I cannot but take notice of the imperfect and inaccurate Description of this so curious a Fish as the *Nautilus* must needs be, if one may guess at the curiosity thereof from those descriptions, which I find in *Johnston* out of *Aristotle*, *Pliny*, *Bellonius*, *Piso*, *Cardan*, *Fauconerius*, and others, and from the curious make of the Shell, for by all those descriptions I cannot imagine any one can get any tolerable Idea or Notion, what the make of so wonderful a Fish must be that has such an admirable quality as to buoy himself as *Pliny* says, *ex alto mari* from the bottom of the Sea, and make himself to swim and sail upon the top of the Water, and at pleasure, or for fear presently to sink himself down again to the bottom. This will appear so much the more wonderful to one that shall consider the great pressure of the Water at the bottom of the Sea, and in how differing a state of compression this Animal must be at those two places, and by what power it becometh able to make itself so light at the bottom to rise and seem half out of the Water, and yet presently so heavy as to sink down to the bottom, and this without Finns or Tail to move itself. Now as this Property is peculiar to this Fish only, so is the make of the Shell differing from all the Species of Nature besides, and as I conceive is the Engine by which he performeth this admirable Exploit; for the whole Shell is divided into a multitude of Cells or Cabins separated and distinguished one from another by several Diaphragmes or Partitions without any other perforation, save one small one, through which passeth a small Pipe, which I take to be the Gut of the Animal; this Gut doth not fill a two hundred part of the Cavity through which it passeth, and the remaining part must either be filled with Air or Water. Now if it be filled with Water, as probably 'tis, when he sinketh himself to the bottom, 'tis prety hard to conceive how he filleth it with Air under so great a pressure and at such a distance from it as to buoy himself up, unless it be caus'd with such a fermentation of the Excrements of the Gut, or other Juices of the Body as doth produce an artificial Air, which serves for that purpose; which seems to me to be the true Cause, especially since I find *Gulielmus Piso* to add this Remark to his History and Description of it. *Cum damno meo Plinii Discriptionem verissimam esse compertus sum namdum talem pisciculum* (speaking of the *Nantilus* of *China*) *in mari captum imprudentius manibus meis contrectassem, tantus ardor manum invasit, tanquam si aqua ferventi suffusa esset, & nisi apposito statim allio conraso cum aqua mihi ipse subvenissem, procul dubio præ dolore in febrim incidissem: Unde ego ipsum piscem de Holothuriorum esse genere contenderim, ut quæ omnia in maria fluctuantia, eam aerem calorem attrectantibus inurunt quod & fallacissimi omnium mortalium* Chinenses *noverunt, qui illa Orjzæ miscent, ut liquorem suum Destillatitium (quem Arac hos hic vocamus) tanto callidius reddant, perniciosо invento, quod hinc miseri nostri Socii navales, sanguinis sputam, phthisin, marasmum deniq & ipsam tandem mortem incurrant.* By which it plainly appears, that the Juices or Excrements of this Fish are of a strange fermenting or burning Nature which may be the cause of so singular and wonderful an Indowment, which whether it be so or not, I could heartily wish that some Person curious in Anatony that has the opportunity of meeting with them alive would give us a more accurate Description of its external and internal Formations and Qualifications.

But to leave this Digression, which I have the longer insisted upon to shew the great imperfections of the Descriptions of the Species of Nature and their Qualifications and of the varieties of them (for that I have seen two Species of this sort not described or mentioned in any Author) and of how great use a good Collection and Description of them would be, as particularly concerning this very Fish I shall have occasion shortly to mention. To leave, I say, this Digression, we may from this perceive how little able we are from the want of this Knowledge and Collection, to conclude, that because we do not already know a Fish or Shell exactly of the shape of this or that *Cornu Ammonis*, therefore that it could never have been any such Shell, since it then cannot presently be proved that there is at present, or ever was any such Fish in being, which some possibly too confident of their Omnisciency may Object, because they know none such themselves, or have read of them; and therefore that there is more reason that such Arguments as are drawn from the examina-

tions

tions of the Substances, and the Characteristicks of the Form should be of sufficient evidence to evince that these Bodies that have these Qualifications could not be formed but for such purposes, as those Animals which we are informed of, we know have all parts fitted for each singular and surprizing use designed; for it is certain that Nature doth nothing *frustra*, but manifestly with an admirable and wise design, the truth of which Maxim will more and more evidently appear, the more the Works thereof are curiously examined and searched into; and no unprejudiced person that thoroughly examins them can fail of being convinc'd of the Truth and Certainty thereof, there being such a Harmony, Consent and Uniformity, as I may so speak, in all its Operations, and a gradual transition from one to another, that it is evident that all these kinds of Petrifactions have been moulded by some Animal or Vegetable Substance, as by Shells, Bones, Teeth, Fruits, Woods, *&c.* and that many of them are the Substances themselves, yet unaltered.

Now this being proved or granted, which I conceive the inspection and examination of the things themselves will most powerfully effect; it must follow as a Consequence of that Phænomenon, that all parts almost of the present Earth extant and appearing above the Sea, have been for some considerable time under it, and covered therewith. Since I conceive there is scarce any Country in the World where these Monuments of Antiquity, these Medals of Nature, or these Sea Marks and Evidences are not to be found either above, or at some depth under Ground, and some not very deep; particular Testimonies of which Truth I have collected many out of the few Natural Historians I have had the opportunity to peruse since I have had this Notion; and I doubt not but that abundantly more may be collected even out of Books. But inquisitive Natuarlists, if it were made an Head of Inquiry, would questionless meet with multitudes of other Instances almost every where not as yet handed by any Historian, of which truth I have been assur'd by many Testimonies from other Persons; but of this I have spoken already sufficiently.

From the comparing of which Evidences with several other pertinent Circumstances that may be observ'd may be deduced Conclusions very instructive as to the preceding and subsequent State also of this World. *Nam Res accendunt lumina Rebus*, and the understanding the History of the Course and Progress of Nature preceding will afford sufficient information of the Method of proceding, which in most things we may find to be very constant, uniform and regular. By such means we have arriv'd to the present Knowledge of Cælestial Motions, and by the like, to that we have of the Motions of the Seas and Winds, and tho' none of these are yet come to their highest perfection, yet Inquiry, and Ratiocination, and Comparison will carry us much further towards that end, which the comparison of the present state thereof with what it was two or three hundred Years since, will give us good reason to hope.

It remains then to inquire by what means these prominent Parts of the Earth which at present are dry Land, came to be so, since by these Testimonies it is, I conceive, evident that they have been for some time under the Water.

This could not be from Noah's *Flood.*

And here in the first place I think it will be evident, that it could not be from the Flood of *Noah*, since the duration of that which was but about two hundred Natural Days, or half an Year could not afford time enough for the production and perfection of so many and so great and full grown Shells, as these which are so found do testify; besides the quantity and thicknefs of the Beds of Sand with which they are many times found mixed, do argue that there must needs be a much longer time of the Seas Residence above the same, than so short a space can afford.

Nor from a gradual swelling of the Earth.

Nor could they proceed from a gradual swelling of the Earth, from a Subterraneous fermentation, which by degrees should raise the parts of the Sea above the Surface thereof; since if it had been that way, these Shells would have been found only at the top of the Earth or very near it, and not buried at

so great a depth under it as the Instances I mentioned of the Layer of Shells in the *Alps* buried under so vast a Mountain, and that near the *Needles* in the *Isle of Wight* found in the middle of an Hill, could not rationally be so caused.

Nor from the washing away by the Water.

Nor could it proceed wholly from a washing of the Water from off the Face of those parts of the Earth, for the same Reason, for how should the Mountain come to be placed on the top of them.

Now, if after all these topicks of Proofs, there shall yet remain some who will not allow any of them to have been Shells, because they are found in the middle of Stone; I have, as a suppliment, added my Observation of the Place where, and the Manner how they may be observ'd to be so inclosed into the Body of a solid Stone, namely, at a place near the *Needles*, at the West end of the *Isle of Wight*.

With such now as shall not think all, or any of these convincing Arguments to prove them Shells, I cannot, I confess, conceive what kind of Arguments will prevail, since these sensible Marks are, in all other things, the Characteristicks and Proofs by which to determine of their Nature and Relation, and why they should not be allow'd to be so in this particular Case I cannot well conceive.

The chief Objections.

The great scruples I find are these; First, That they know not how they could come to be placed where they are and have been found; some Conjectures at which I shall after shew.

And, Secondly, That many, nay most, of them are of somewhat a differing Shape, and of a much greater Magnitude than are the Shell-Fishes of the like Animals to be found upon the Coast of *Portland*, or near the places where they have been found; and indeed against this my Hypothesis or Assertion I find none more pressingly urged than this, that there is not one to be found either in the Seas near those Parts where such are found, nor in any part of the known World, any such Animals or Vegetables as those which are supposed to have afforded the Substances of some of them, or the Moulds of some other; and particularly it has very much been urged upon the Consideration of the Petrifaction or *Cornu Ammonis* taken out of the Quarry of Stone in the Isle *Portland*, whether it could be reasonably supposed that ever there were in the the World a Species of the *Nautilus* of this shape, and of so vast a bigness, of which it is supposed the World has not afforded an equal in a living Species. And I perceive that the very supposition is looked upon as very extravagant and ridiculous. However, it may be possibly worthy some Mens Considerations to inquire, First, Whether there may not yet be found in the World many Species of Shell-Fish they have not hitherto heard of, or seen in the Writings of Natural Historians, or in relations of Voyages, or by their own Experience.

Secondly, Whether the exceeding greatness of this Shell be a sufficient Argument to conclude it ridiculous to suppose, that there could be a living Fish that might fill so great a Shell, since I shew'd the last Day out of *Maudelslo* and *Olearius*'s Travels, an instance of Oysters found in *Java*, that seem'd much to exceed this Magnitude: And possibly some here present may have seen, as well as my self, the great pair of Shells in the *Musæum Harveianum* before the Fire in 1666. And that the Shells of a *Pinna Marina* are now to be seen in this Repository, which exceed the common bigness of a Muscle as much as this *Cornu Ammonis* doth the smaller sorts of *Nautili*, and varieth also as much from them in Shape: And that hotter Countries, such as are in the *Torrid Zone*, produce Turtles or Sea Tortoises, abundantly more exceeding the smaller sorts of these of colder Regions, of which there are Testimonies enough to be had both from Natural Historians and Travellers, which it were necessary I could produce.

But

But because it may be upon this Head further Objected, That all those extraordinary great Species are the productions of the *Torrid Zone*, or the hotter Climates, and not of the colder, and such as lie so far remov'd towards the Poles as *Portland* or *England* do, about which there are now no living Fishes to be found that any wise come near to that Magnitude, but are of much smaller size and of different shapes.

Therefore before the Opinion be wholly rejected, I would desire them to consider, whether it may not have been possible, that this very Land of *England* and *Portland*, did, at a certain time for some Ages past, lie within the *Torrid Zone*; and whilst it there resided, or during its Journying or Passage through it, whether it might not be covered with the Sea to a certain height above the tops of the highest Mountains. And further, how deep this may have lain below the Surface of the Sea, when it might have been in that Passage, and how long time it may have spent in such a state, and how long since it may have been emerged. Such as are better versed in ancient Historians than I ever have been or hope to be, may posibly resolve some of these Doubts, or at least may prove the impossibility thereof, which may save further trouble of inquiry: But if after inquiry it should be found that Natural History is defective in that particular, then I will indeavour to see what Helps and Histories will be pertinent towards the determination of these Queries.

That England *lay formerly in the* Torrid Zone, *and was there cover'd with the Sea.*

And in order to determine the Possibility or Impossibility of this Matter, I could wish it were well considered further, whether the Superficies of the Ocean be equally distant from a Central Point in the Bowels of the Earth, and whether any other perpendiculars to the Surface thereof, besides those of every single Parallel, and its Poles, do tend to any other Point of its Axis; and if there should be found more than one Point, then what are the limiting or terminating Points of a Line of such Points; that is, at what distance they must be from one another, or from a Central Point? This I mention'd in two of my preceding Lectures, the one read about ten or twelve Years since, and in the other about two Years since; in both which I indeavour'd to shew that the form of the Earth was probably somewhat flatter towards the Poles than towards the Equinoctial, since which I have met with some Observations that do seem to make a probability in my Conjecture and Hypothesis.

Q. Whether the Ocean be every where equally distant from the Center.

The *Antipodes* were once thought a Chimera, length of time hath made that notion more reconcileable to Sense and Reason; these may possibly at first hearing appear much more extavagant, and Time that brings all to Light, may possibly evidence them to be nothing but *Chimæra*'s; I will not prejudge, nor pre-possess, but leave them to their Fortune. However it were desirable by the Experience and Inquiry of a short time to dispatch and hasten the Growth and Ripenings of the Productions of Nature, since the Experience and Duration of a Man, whether he looks forward or backward, is very short in comparison of what seems requisite for this Determination; his Sight is weak and dim, his Power and Reach much shorter, yet may it be worth considering (tho' he cannot lengthen or prolong his limited time either past or to come), whether by Telescopes or Microscopes he may not see some hundreds of Years backwards and forward, and distinguish by such Microscopes and Telescopes Events so far distant both before and behind himself in time, as if close by, and now present? And whether by Instruments he may not extend his Power, and reach things far above his Head, and far beneath his Feet, in the highest parts of the Heavens, and the lowest parts of the Earth; for could he perform things of this Nature and Quality as they ought to be, he would lengthen his Life and increase the injoyments thereof by a multiply'd and condens'd knowledge of times past, and of times also yet to come.

But before we come to this last Expedient, I could wish we had a good Account and Collection of what Histories pertinent to this, or any other Natural Inquiry are to be found in Printed or Written Authors, which I conceive is yet a *Desideratum*; and that this is possible to be so I shall mention one Observation, tho' not pertinent to this present Enquiry, yet to another which I have read formerly before this Society, *viz.* about the Chinese Character and about the Chinese Printing. Inquiring then about *Tartary* and

and *China*, upon occasion of the Discourse that was here lately made, I found that in *Purchas* his Pilgrims there is a part of the Works of *Roger Bacon* publish'd, whereby I find that he so long since knew they had a way of Printing, and had a better account of their Character than any one, or all we have since that time. *Sciendum quod a principio Cataiæ Magnæ Nigræ usq; ad finem orientis Sunt principaliter Idololatræ sed mixti Sunt inter eos Saraceni & Tartari & Nestoriani, qui sunt Christiani imperfecti, habentes Patriarcham suum in oriente. This Cataia magna nigra* is one of the North Provinces of *China*, and the *Patriarcha* is the *Lamos* mention'd in the Voyage of *Verbiest*.

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Jugres qui habitant in terra ubi Impertor moratur,----Sunt optimi Scriptores, unde Tartari acceperant Litteras eorum & illi Sunt magni Scriptores Tartarorum & Scribunt a sursum in deorsum & a Sinistra in dextram, multiplicant Lineas & legunt. Zebeth Scribunt sicut nos & habent figuras Similes Nostris. Tanguæ Scribant a Dextra in Sinistram sicut Arabes & multiplicant Lineas ascendendo. Cataii orientales Scribunt cumpunctorio, quo pingunt Pictores, & faciunt in una figura plures literas comprehendentes unam Dictionem, & ex hoc veniunt Characteres qui habent multas Literas simul. Unde veri Characteres & Philosophici sunt, compositi ex literis & habent sensum Dictionum. Thus much concerning the Character, where I shall note only by the bye, that both the *Jugres* and *Cataians*, those of *Tebet* and *Tangut*, may be said to write all the same way with us, for that they differ only in the Position of the Page as to the Eye when read or writ. Next, as to the use of Printing, he says in the same Page, speaking of the Money of the *Cataians*. *Istorum Cataiarum moneta vulgaris est charta de bombasio in qua imprimunt quasdam Lineas.* This I suppose he took in part out of the Voyage of *Gulielmus de Rubriques*, a *French* Frier, who wrote an account of his Travels into those Eastern Parts to the King of *France*, and for divers Reasons I believe it to be a very true Relation, for I find in the thirty sixth Chapter of his Book as follows. ' The common Money of *Cataia* is Paper made of Bombast the ' length of an Hand, upon which they imprint Lines, like the Seale of *Man-* ' *gu*, they write with a Pensil wherewith Painters Paint, and in one Figure ' they make many Letters comprehending one word. The People of *Thebet* ' write as we do, and they have Characters very like ours. They of *Tangu* ' write from the right Hand unto the Left, as the *Arabians*, and multiply ' the Lines ascending upwards. *Jugur*, as aforesaid from above downwards. This is very much the same with *Roger Bacon*, whereby we had above four hundred Years since a hint of the Chinese Printing; as also that the Chinese Characters were compounded of certain Elements, which expressed both a literal and philosophical Word. I have one Observation more to add before I leave this Digression, and that is in answer to another Objection which was made against my Conjecture of the deducing the Name of *Cornu Ammonis*, or Sand Horns from a probability that they might possibly be found in those Sandy Deserts of *Pentapolitana* in *Africa*, now call'd *Barca*, which lieth West of *Egypt*, between that and *Africa Minor*, almost opposite to the *Morea* of *Greece*, a large and barren sandy Desert, troublesome to be travailed in, by reason of the instability of the Footing, and for that the Sand is thrown to and fro by the Wind, in the midst of which stood the Temple of *Jupiter Ammon* whose Effigies was adorn'd with Horns supposed to be Rams Horns, but I conjectur'd they might possibly be the resemblance of those petrify'd *Nautili*, found in that Sand. To this Conjecture I have only this to add, First, That *Lucan* in the describing this Idol, calls him *Corniger*, which seems to argue, that the Statue had Horns. But which seems more to agree with my Conjecture, is what is related of the form of this Idol by *Curtius*, that it was without the form of any Creature, but like a round Boss or Navel, (*Umbilicus* is the word) beset with Jewels; this was carried in Procession by the Priests in a guilded Ship hung with Bells on both sides, *&c.* by which it should seem that the very Idol itself was nothing but such a *Nautilus* Petrify'd, as I have produced, beset round with Jewels for ornament, and carry'd in a Ship possibly as a Hieroglyphick, to signifie the manner of some eminent Deliverance of that Country from a former Flood, or the use of Ships in that place, whilst an Island and that Desert was cover'd with Water. But this is only Conjectural, which I submit to further examination.

But

But to leave this Digression and proceed. I say, it were very desirable in order to the solution of this and divers other Inquiries in Natural Philosophy; that we had a Collection of such Observations as are to be found, already made and recorded in Natural Histories, to see what Light such Histories would afford, which may be perform'd by the joint Labour of many Persons who would peruse and collect such Matters; but possibly it may be believ'd that little can be found pertinent to this Inquiry, as indeed I fear there will be no great matter; yet *Pliny* in the tenth Chapter of his thirty sixth Book takes notice of a matter which is not altogether impertinent, affirming, that an Obelisk set up by *Augustus* for shewing the length of the Day, was found after some time to go false. *Searching of Natural Histories useful.*

But upon this I build no great matter, and I fear the ancient Observations will in general help us no great matter, though they may give us cause of suspicion, as particularly concerning the Latitudes of Places, of which Mr. *Vernon* takes notice that the present Latitude of *Athens* is near two degrees differing from that assign'd it by *Ptolomy*, which is remarkable, it being of a Place so eminently known in former Ages. But upon neither of these can much be built as to the accuracy of determining such a motion; tho' they may serve well enough for hints for Inquiry farther concerning them. Monsieur *Pettit* has also written a Treatise to prove that the Latitude of *Paris* is differing from what it was formerly. *Scaliger* also had a notion of some such matter, but I connot tell what he would have, nor do I believe he well knew himself. The place is quoted in *Chilmedes* English Edition of *Hues de Globis*; others also have mention'd it, but none have determin'd it or brought it to a certainty. I did therefore upon this occasion, where I am discoursing concerning the general Form and the proprieties or Motions of this great Body of the Earth, think fit to insert it as a thing worthy of determination; since 'tis not improbable but that there may be some such motion of the Earths *Axis* as may alter both the Latitudes of Places, and also the position of the Meridional Line. And that this may not seem so absurd, we may consider the alteration of the *Axis* of the Earth in respect of the fixt Stars long since discover'd, and the variation of the magnetical *Axis* discover'd first about fifty Years since by some of the Professors of this Colledge.

But now the Question is how these general Queries can be determin'd; that is, First, *Whether there be any alteration of the gravitating Center of the Earth.* *Some General Queries.*

Secondly, *Whether the Body of the Earth be of a true Spherical or Oval Figure, and thence whether it hath one or infinite Centers of Gravitation.* 2.

Thirdly, *Whether the Axis of its Rotation do change its Situation or Position in respect of the Parts of the Earth*; and thence, *Whether the Latitudes and Meridional Lines of places do differ in process of time*, and if so in the 3.

Fourth place to determine *What is the particular motion that causeth it, and by what steps it hath devolved for the time past, and will proceed for the time to come.* 4.

The CONTENTS.

THE beginning of this Lecture being lost I cannot certainly find when it was read, but judge it preceeded that which I have here placed after it. It contains several Positions to solve the Phænomena before-mention'd relating to the great alterations of the Figure and Motion of the Earth: Of these there are enumerated fifteen; tho' this be proposed only as an Hypothesis, yet the Author thinks it deserves examination before it be wholly rejected, the discovery of Truth being his only aim: And adds, That 1st. *'Tis not impossible for three Reasons.* 2dly. *'Tis no more Folly to invent this Hypothesis, than 'twas to invent several others.* 3dly. *'Tis not only possible but probable. He inlarges upon the Proof of two of them,* viz. *The prolated Spharoidical Figure of the Earth and Sea, and the variation of the Axis of Rotation.*

R. W

1. MY First Proposition then is this, That we should suppose First, That this Globe or Ball of the Earth was carried round the Sun in the plain of the Ecliptick, making an entire Revolution in that Plain once in a twelvemonth, and thereby making the Sun to appear to pass continually in the Ecliptick Line, as *Pythagorus*, *Aristarchus Samius*, *Copernicus*, &c, have supposed.

2. Secondly, That this Globe or Ball whilst it maketh one such Revolution, is likewise whirled round three hundred sixty and five times, and about $\frac{1}{4}$ upon an *Axis*, or imaginary Line passing through, or near the Center thereof, which *Axis*, is all the while kept in an Inclination to the said Plain of $23\frac{1}{2}$.

3. Thirdly, That this *Axis* doth continually keep a Parallelism to itself very near; all which *Axes* at present respect a Point in the Heavens, not far distant from the last Star of the Tail of the little Bear call'd the *Pole-star*, but heretofore 'twas at a greater distance from it.

4. Fourthly, That this *Axis* doth, in process of time, vary its respect to that Star or Point of the Heavens, and by degrees proceed nearer towards it, not directly, but in a Circle parallel to the Ecliptick, or whose Center is the Pole of the Ecliptick. Thus far I take the same with the Hypothesis of *Copernicus* and his Followers. But

5. Fifthly, I suppose yet further, that the *Axis* of the *Diurnal Rotation* of the Earth hath also had a progressive motion, and hath, in process of time, been chang'd in position within the Body of the Earth, and consequently that the Poler points upon the Surface of the Earth, have alter'd their Situation; so that the present Polar Points have formerly been distant from those Poles that were then; and consequently that those former Polar Points are now remov'd to a certain distance from the present, and move in Circles about the present.

6. Sixthly, I suppose that the Form of the Surface of the Water at least, is, and hath been, ever since the duration of the Earth, of an *Oval Form*, whose longest Diameters lye in the Plain of the Equinoctial, and whose shortest is the *Axis* itself of the said Rotation.

7. Seventhly, As a Consequent of this I suppose the Center of *Gravity* of the Earth to be drawn out into a Line into the *Axis* thereof, and consequently into infinite Centers, there being one for every Parallel Line upon the Surface of the Earth, and that no Perpendiculars but those of the Poles and Æquinoctial, respect or tend directly to the Central Point, but that all the Perpendiculars from the other Parallels respect certain Points in the opposite Parts of the *Axis* which are so much the further remov'd from the Center, by how

how much the nearer the Parallels approach the Polar Points; which Points of Gravitations and Position of Perpendiculars in respect of the *Axis*, may be determin'd both *a Priori* by Theory, and also *a Posteriori* by Experiments or Observations.

Eighthly, As a Consequent of these, I suppose, that in process of time there will be caused an alteration of the gravitating Power and Tendency of the Parts of the Earth, both Solid and Fluid, and that according as the Positions of them are alter'd in respect of the Polar Points, either present Precedent or Subsequent, there will be caused in the 8.

Ninth Place, an indeavour of sliding, subsiding, sinking and changing of the Internal Parts of the Earth, as well as External, tho' the latter will be more powerful, as being more affected by the Rotation thereof; and this may cause in the 9.

Tenth Place, an alteration in the Magnetical Power and Vertue of the Body of the Earth, especially of such Parts as are more loose and of a more fluid Nature. And 10.

In the Eleventh Place, may be a cause also of some of those *Tremores Terræ*, or Earthquakes which have in all Ages been in the Earth, tho' we have no Histories or Records that have preserved the Memory of them, but only such Signs and Monuments as they have left by the unequal ragged and torn Face of the Surface of the Land and the Bodies that are discovered; which proves that they had some time an other Position than they are found to have at the present. 11.

These two last notwithstanding I do not suppose the only causes of these Effects of Earthquakes, no nor the Principal, but only as concurring and adjuvant Causes which may have their Effects in some measure, but how far and how powerful they may be supposed, will be proper to be resolved under the Heads of Magnetisms and Earthquakes, and more especially under that of the Air. The same Principles or Suppositions will also produce in the

Twelfth Place; a more than ordinary swelling or rising of the Sea in those Parts which are near the Æquinoctial, and a sinking and receeding of the Sea from those which are near the Poles; so that as any Parts do increase in their Latitudes, so will the Sea grow shallower, and as their Latitudes decrease, so must the Sea swell and grow high; by which means many submarine Regions must become dry Land, and many other Lands will be overflown by the Sea, and these variations being slow, and by degrees will leave very lasting Remarks of such States and Positions, in the superfieial Substances of the Earth. 12.

And hence also will follow in the Thirteenth Place, a great alteration and variety of the Productions of those Parts which are thus alter'd in their Position, whether they are parts of the Sea or parts of the Land; for as there seems to be somewhat which is peculiar to this or that Soyl or Spot of Land whereby this or that Animal or Vegetable doth grow and thrive and increase both in Quantity and Quality, and the contrary: So is there also somewhat in the Climate and Position to the Sun and Heavens, which doth as powerfully at least, if not much more, affect the Productions, Propagations, *&c.* of Plants and Animals. And as 'tis a known Observation, that in the same Country, this or that Field, or Soil is more effective for this or that use; so 'tis as well known that the transplanting of animate Subjects to differing Climates, tho' the Soil seems of the same Nature, doth as effectually co-operate in the changing or alteration of them. And hereby a fruitful Land may be turned into Barrenness, and be made unfit for Production as well as Barren and Useless may be made Fruitful; for that the Temper and Constitution of a Soil may be such as to be fit for many purposes in some Climates, which in others is fit for nothing. 13.

From

14. From hence also will follow in the Fourteenth Place, That many places which by degrees are made Submarine, will be cover'd with various Coats or Layers of Earth; so that the former Surface of it, when Land will not only be drown'd with Water, but buried under Earth; for that, as the parts of the Land, are continually washed down, and by the Rivers carried into the Sea, and there deposited in the Submarine Regions, so much more powerfully and plentifully are the higher parts of the Submarine Regions by Tides, Currents, and other Agitations of the Water, removed and transported into the lower, partly by sinking out of the muddy Water, but principally by tumbling and rowling down from the higher, which sorts of covering or burying Earth must be posited in certain Layers or Stratifications of divers kinds of Substances according to the nature of those which are this or that way brought thither, and there deposited. Hence also it will follow, that the Earth itself doth, as it were, wash and smooth its own Face, and by degrees to remove all the Warts, Furrows, Wrinckles and Holes of her Skin, which Age and Distempers have produced.

15. And hence in the Fifteenth Place will follow, That such Regions as have for a time been Submarine, and produced Substances of Animals or Vegetables proper for them, when they come to be dry Land and to lye above the Waters, must produce Animals and Vegetables proper and peculiar to that Soil, Element and Climate they are then furnish'd with; preserving in the mean time the Characteristicks and Marks of the former Qualifications, when in another Condition.

But some possibly may be ready to say before a thorough examination, that this is only a supposition, and that there are no such Phænomena as here are put for the Supposition: Others, that 'tis foolish to make an Hypothesis for the solving of any one Phænomenon. Others may possibly demand how comes this to be now discover'd, which none hath hitherto known? Or how is this to be proved? By what History? By what Signs and Tokens? I must leave every one to his own freedom to judge as he sees cause, and censure as he pleases; however, I conceive it ἔργον μωμᾶσθαι ἢ μεμεῖσθαι easy to play the Momus or the Mimick. *Sed siquis quid rectius istus noscat, candidus impertiat.* But if he know better let him not, hold his Tongue but tell us. I shall not impose on any; I propound it only as an Hypothesis, and have shewed what will be the Consequences of it, whether there be Phænomena answerable to be observ'd let it be examin'd; and let there be produc'd another Hypothesis that will solve the various Phænomena that are to be every where met with better; for that I have no farther design in propounding it than to have it strictly examin'd, and in order thereunto to have such Observations made and taken notice of for the future as may ascertain the Truth whether for or against it.

Yet give me leave to add a word or two, before I wholly leave it to its Fortune.

The supposition 1st. not impossible. First then, I say, That what is here supposed is not impossible. First, 'Tis not impossible from the Natural History now to be met with of the things supposed; for that all things may be the same as they now appear, and yet this may be true; for no one Phænomenon, that I can think of, is contradicted by it, either fetch'd out of ancient Histories, or yet Collected by present Observation. As there are no Observations of Latitudes, or fixed, accurate meridian Lines, or Eclipses for the Oval Shadow of the Earth, or Mensuration of Degrees to find their difference in differing Latitudes. Nor Secondly, Is it impossible from the Nature of the things supposed, for that there is as yet no certain Cause assigned, why the Earth doth move upon the *Axis*, it now doth, and not upon another, nor why it should always continue and remain the same without change, contrary to all other motions in Nature. Nor is it impossible because not discover'd before, which yet is more than can be positively proved; for if so, then would Magnetical Motions fall under the same Censure, as also, Optick-glasses, Guns, Printing, and other new discoveries.

coveries. And by the same Argument the Motion of the Sun, and *Jupiter* upon their Axes, the Reality and Revolution of the Satellites of *Jupiter* and *Saturn*, the Ring of *Saturn* and the Belts of *Jupiter*, and the like might be condemned.

Secondly, I say for it, that 'tis no more folly to invent new Hypotheses to solve Phænomena in the Earth, than it was in *Pythagoras*, *Ptolomy*, *Copernicus*, *Ticho*, *Kepler*, and others in the Heavens; for that each of them conceiv'd by such Hypotheses to solve the Phænomena more agreeably to the other appearances of Nature; whereas yet no one of them has hit the right I conceive, and I shall, I hope, in due time demonstrate. 2dly, *Not ridiculous.*

But in the Third Place, for Affirmative, I say, 'tis not only possible, but probable, and altogether consonant and agreeable to the rest of the Works of Nature, and even to the very Constitution and Phænomena to be observ'd upon the Earth itself. 3dly, *'Tis probable.*

And First for the *Oval Figure of the Sea and Body of the Earth in some measure.* If the gravitating Power of the Earth be every where equal, as I know no reason to suppose the contrary, then must this Power be compounded with a contrary indeavour of heavy Bodies to recede from the Axis of its Motion; if it be supposed to be mov'd with a diurnal Revolution upon its Axis, and consequently a part of the gravity of such Bodies towards the Center must be taken off by this *Conatus*, which is every where oblique, but only under the Æquinoctial, which must therefore most diminish its Gravitation, and consequently the gravity will act the most freely and powerfully under the Poles, and the more powerfully the nearer the Bodies are plac'd to those Poles; and that Phænomena do answer to this Theory, has been verify'd, first by Mr. *Hally* at St. *Helena*, and since by the *French* in *Cayen*, and now lately in *Siam*, in all which places it is affirmed, that 'twas necessary to shorten the Pendulum to make it keep its due Time. *Of the Oval Figure of the Earth.*

In the Second Place for the *variation of the Axis of Rotation* in the Body of the Earth. I say it is consonant to all the other motions of Nature: For first it is found that the *Axes* of the *Ellipses* of the Planets do vary a little, I say a little (tho' Mr. *Street* only will have them not to vary at all) because all Astronomers have hitherto affirmed, that they do, and from my own Mathematical Hypothesis I collect the same, tho' it be but a little, yet it is somewhat, since there is some impediment in the Medium. Next there is also a motion in the Nodes, all which are very eminent in the Moon. And again, the direction of the *Axis* in the Earth is varied as to its respect to the Heavens, which the precession of the Æquinoxes do manifest. Nay yet further, the *Axis* of the Magnetical Motions which is within the very Body of the Earth, and seems even to go through its very Center, hath, about fifty Years since, been prov'd to vary also somewhat analogous to this which I have supposed, whereby both the Magnetical Latitudes, and Magnetical Meridians have most certainly been varied; which seems abundantly more difficult to be granted than this which I propound, did not certain Observations both here at home and all over the World confirm the truth of Matter of Fact, and that because this doth seem to prove a motion of a Magnetical Core or Magnetical Globe of the Earth, within this outward earthy and watery Shell; whereas this which I suppose is nothing but a progression of the *Axis* of Rotation, which may be caus'd by the visible accidental Mutations of the outward and superficial Parts, as well as by other unknown alterations which may succeed within the Bowels of the Earth. So that 'tis very probable that there is some such motion of the said *Axis*, since we are certain both of outward and inward changes. *Of the variation of the Axis.*

It only remains then Positively and Experimentally, or Historically to prove the Reality thereof. Now the motion of the Mutation thereof being but slow, as I conceive, and the Observations of the Antients Recorded in Histories necessary for this purpose, being so unaccurate and uncertain for such a determination as this, I fear they cannot be rely'd upon; but whatever shall be alledg'd as a proof of this Theory, will be attributed to a fault in the Antient Observation, as that *Ptolomy* puts the Latitude of *London* 52 10 and the longest Day 17 Hours. Nor will I insist on the Latitude of *Athens*

found by Mr. *Vernon*, to differ near a Degree: Nor on the Latitude of the *Herculean Streights*, which varies as much from the present, as that of *London*, tho' all these were remarkable places, as was also *Constantinople*; but rather rely upon Observations to be made for the future; the way of performing which I shall treat of hereafter, whereby I shall shew, how, in a short time, the same thing may be determin'd as well as by so long a time.

The CONTENTS.

THIS Lecture was read Feb. 2. 168⁶⁄₇, *and contains the Confirmation of what was offer'd in the preceding.* 1st. *As to the superficial Figure of the Sea; and for this purpose he proposes some Experiments, the success of which was shewn to the Royal Society; and next several Observations are brought to the same purpose, which are ranged under two Heads,* 1st. *Consequential Proofs.* 2dly. *More immediate Proofs.* 2dly. *As to the alteration of the Axis of the Earth's Rotation.*

R. W.

Suppositions as extravagant have been made.

WHat I propounded the last Day by way of an Hypothesis, may possibly be look'd upon not not only as very extravagant, but very improbable; from the last of which I hope I did then clear it; and as to its extravagancy, I hope I may be able to shew, that there have been suppositions altogether as extravagant, which yet have not only been made, but accepted and imbraced, and for many Ages as stifly defended as the most probable. My Instance shall be in the *Ptolomaick* Hypothesis of the Heavens, which, that you may the better judge of, I have here a Book to shew the whole Design and Intrigue of it, in which the same and all its parts are most curiously delineated, whereby all the Wheel-work may be at once discover'd; and if it be desir'd to be made in Clock-work, I have another Author that shall give the bigness of the Wheels, and the number of the Teeth and Pinions necessary to accomplish the same in Clock-work: And yet when all is done, there will want as many more to make out all the irregularities of appearances exact; the reason of which proceeded from one false Principle, that one Body was capable of no more than one simple motion, whereas in truth there is no body mov'd but is capable of, nay, actually mov'd by thousands.

But it may possibly be said that this *Hypothesis* was the Product of an Age not so inquisitive and able to judge as the present, which will hardly be impos'd on with such improbabilities; nor was all this clutter thought necessary at first, but the maintainers of that Opinion, to make out the appearances, as well as they could, have since found it necessary to help out the first Invention by additional Expedients; and if these were sufficient, I conceive it might yet be an acceptable *Hypothesis*, tho' we have no *Medium* to prove that there is any such thing in Nature as a *Solid Orbe*, or a moving *Genius*.

The like favour I hope may be allow'd to what I propound, if upon due examination the *Phænomena* are answerable to what the *Hypothesis* does hint.

Now what would be consequential to what I have propounded, I shew'd the last Day; it only now remains to examine whether Phænomena do answer.

1st. *Of the Figure of the Sea.*

First then to determine whether the Figure of the Sea from North to South be Oval, swelling towards the Æquinoctial and depress'd towards the Poles, it will be necessary to make some few Trials, Observations and Experiments.

Experiments to prove it.

And First for Experiments that may be made here. Let a Bowl or Bubble of Glass be made and melted in a Lamp, and when so melted let it be blown into a hollow Ballor Bubble, which will naturally form and Shape itself into a round and spherical Body, especially if the Substance be of an equal thickness and equal heat, which let be examin'd; then let the same be melted again as before, and as it is blowing, let it be mov'd round upon the Pipe, by which

which it is blown, by a pretty quick Circular Motion, and you will find that instead of the Spherical Figure it will receive an Oval one, such as I suppose the Surface of the Sea to have. This Experiment I shall by and by shew here (which was accordingly done).

Now in this Experiment here are evidently two kinds of Powers that cooperate in the production of this Form: The first is that of the Congruity of the Matter, which, as I have many Years since in a small Treatise, Printed in the Year 1660, proved, doth shape the Glass into a true Spherical Figure, and so maketh every part to indeavour towards the Center of the whole. The next is that of the vertiginous Motion, which giveth to every part, an indeavour to recede from the *Axis* of the vertiginous Motion; this driveth the shape of the whole into that Oval Form it receiveth and retaineth.

The same Experiment may be much better made at the Glass-house, where a greater quantity of Glass may be melted, and that more equally and a quicker Motion may be given, which will make the Experiment the more sensible, the Glass retaining its melted heat much longer. Besides, it may be there tried with a solid lump of Glass which will receive the same Figure from a vertiginous Motion about the Puntilion. And again, to make the Glass Oval the other way, the same is whirled round with a motion wherein the Puntilion is made the Radius of the vertiginous Motion.

A second Experiment to shew that the Water doth naturally recede from the Poles towards the Æquinoctial is this. Take a round Dish of Water, and let it be set upon a Stand where it may be gently mov'd round upon an an Axis passing through the Center of the Dish perpendicularly; first observe the Surface of the Water when it stands still without motion, there you find it smooth aud horizontal; then move the stand gently round by degrees, till you find the Water begins to receive the motion of the Dish; then examine the Surface thereof and you will perceive the Water to sink in the middle, and to recede and swell towards the Circumference of the Dish: And the better to satisfie you I have prepared the Experiment which I will by and by shew. The Experiments are plain and common, yet I humbly conceive not less instructive to the present Controversy, than the most pompous and more chargeable Experiments.

The Superficies of the Sea next the Poles possibly Concave.

This last Experiment doth hint, that the Convexity of the Sea near the Poles of the Earth must necessarily be much flatter than elsewhere, and not only less Spherical than the rest of the Sea, but possibly plain, nay, beyond a plain, possibly Concave, for that the Water cannot but have or receive from the vertiginous Motion, an endeavour to recede from the Center of that Motion, and the Gravity of the Earth working there more powerfully and freely. But this only by the bye. But which seems more material, I conceive that a Degree of Latitude, if there measured would be very much longer than a Degree of Latitude under the Æquinoctial, of which I shall speak more by and by.

Observations to prove the Theory.

In the next place then we are to consider what other Observations and Trials will serve to the direct and positive proof of this *Hypothesis*, *That the Figure of the Earth is that of a prolated Sphæroide, not of an oblong Sphæroide, nor of a Sphære.* And those may be ranged under two Heads, First, Such as are consequential Proofs drawn from the similitude in Nature's Operations, on other Bodies similarily affected. And Secondly, Those which more immediately and positively prove the Effects thereof upon the very Body of the Earth itself.

The first sort of Observations are to be fetch'd from the Cælestial Bodies, such as we are assur'd by Observation have a vertiginous Motion about their Axis, as Hypothetically only we suppose the Earth to have; such are the Body of the Sun Primarily and Principally, which was discover'd by *Galileo*, and prov'd and perfected by *Scheiner*; next the Body of *Jupiter*, which was first found to move about its own Axis, in the Year 1664, and which has since been perfected by *Cassini*. Now, if by exactly examining the true Diameters of the Sun when we are in the plain of its Æquinoctial (which is in the beginning of *June* and of *December*), if I say by Trial, we find that the Diameter *per Axin* of the Sun is shorter than the Diameter of its Æquator, then there will be a further

further probability that the like may be in the Earth if it be so mov'd, as is now generally supposed: The liketrial may be made of the like Axis of *Jupiter* though the Trials will be therein more difficult, as being much less sensible, from the smallness of the Difference; however 'tis worth examining, as it will be to examine also the Diameters of *Mercury* and *Venus* when they pass under the Sun, tho' we are not yet assur'd of their vertiginous Motion, and if Mons. *Gallets* Observation may be credited, such a *Phænomenon* was taken notice of by him in the late transit of ☿ *Sub Sole*, as appears by his account of the Passage of ☿ *Sub Sole*, Printed in a Treatise by itself, and in the Journal *des Scavans*. Now, if this Observation do answer in the Diameters of the Sun, it will afford us also a further information of the Nature of that Glorious Body, and will, I conceive, prove it to be of a fluid and yielding Substance, especially the shining and superficial parts thereof. Trial also may be made of the like Diameters of the *Moon*, tho' her vertiginous Motion in comparison of her bulk, be the slowest of all we yet know as turning round on her Axis but once in a Month. The like may be made of the Body of *Saturn*, when the Ring is so posited as that the Diameters that lye in the longer and shorter Diameters of the Ring may be plainly discover'd; what the reason of that Ring may be I shall discourse of elsewhere. These I suppose will be the easiest and soonest made, and if judiciously and accurately perform'd, with a due regard of Refraction, and the true position of the Axis, will give a great probability or improbability to this supposal, but still I confess it will afford no more than a probable Argument either for or against it: However, that probability being very great, and the trial not very difficult; it will be well to make the Observations, especially those of the Suns Diameter, with all imaginable accurateness, which may be done to a very great one, if there be fit Instruments and sufficient Care used therein, so as very many times to out strip all that I have hitherto met with of that kind, the whole method of which will be too long and tedious now to explain; however, if I can procure Assistance, I resolve to try it this following *June*, which is much the best time of the whole Year to avoid the inconveniency of Refractions, and the true Phænomena thereof I will produce here, without being biassed for this Hypothesis, for which I have no further concern than as it shall be found agreable to the truth of Appearances. Now, tho' I confess also, that I cannot expect that the difference of the longer Diameter in the Sun from the shorter will be very much in regard of the very strong power of Gravity in that Glorious Body whereby it is able to detain all the planetary Bodies in their Orbs from running from him, and even that of *Saturn* so vastly remov'd; yet when I compare that with the Magnitude of its Body, and the time of its Rotation, I am apt to think that accurate Trials may discover some sensible difference, which I must leave to Trial.

The second sort of Observations or Trials necessary to prove this Hypothesis, which are direct and positive, and may be truly call'd *Experimenta Crucis*, according to the Lord *Verulam* are principally two, which are sufficient to prove it thoroughly, tho' the other should fail; the first is to procure an exact trial to be made of the Time that a Pendulum Clock will keep under or near the Æquinoctial, which is adjusted exactly to the time by the Sun or Stars in a much greater Latitude; or the trial of such a Clock in two places very much differing in Latitude after the Clock hath been exactly adjusted in time, to one of those places; because such a difference if it be found and determin'd will be of sufficiency to determine the proportional co-operation of these two Powers. As for instance, this may be sufficiently examin'd by a Clock adjusted in *England*, and tried in the *Barbadoes*; if Care and Accurateness be used in both these places, which I conceive might be easily procur'd by the Favour and Assistance of this Honourable Society. The second which is a much more difficult Experiment, but yet much more positive and convincing than any other, is the measuring of the quantity of a Degree of Latitude upon the Earth, in two places very much differing in Latitude; the one as near as might be towards the Pole, as upon the Ice in the *Finniek Gulf*, as Monsieur *Thevenot* proposeth, which might be procur'd by Mr. *Hevelius* at *Dantzick*, or Dr. *Rudbeck* at *Stockholm* in *Sweedeland*, who might do it himself or procure

procure it to be done at the North end of that Gulf, which would be yet better, and by some Persons in *Jamaica*, or other parts nearer the *Æquator*. These last trials, if accurately made, would be undeniable Proofs of this supposition, if it should be certainly found that a Degree in the more Northern Countries were more large than a Degree in the more Southern Climate, and the Experiment with the Pendulum Clocks would likewise more exactly adjust the true Gravity of the Earth consider'd simply without the composition of the vertiginous Motion. And thus much for the first part of the Hypothesis, that the Figure of the Water above the Earth is that of a prolated Sphæroeid whose shortest Diameter is that of the Axis of its Rotation.

Next for the examination of the second Part thereof (namely, whether the Axis of its Rotation hath and doth continually by a slow progression, vary its Position with respect to the Parts of the Earth; and if so, how much, and which way, which must vary both the Meridian Lines of Places, and also their particular Latitudes) it had been very desireable, if from some Monuments or Records of Antiquity, somewhat could have been discover'd of certainty and exactness, that by comparing that or them with accurate Observations now made, or to be made, somewhat of certainty of information could have been procur'd: But I fear we shall find them all insufficient in accurateness to be any ways relied upon; however, if there can be found any thing certain and accurately done, either as to the fixing of a Meridian Line on some Building or Structure now in being, or to the positive or certain Latitude of any known place, tho' possibly those Observations or Constructions were made without any Regard or Notion of such an Hypothesis, yet some of them compared with the present state of things might give much Light to this Inquiry. Upon this account I perus'd Mr. *Graves* his Description of the great Pyramid in *Ægypt*, that being Fabl'd to have been built for an Astronomical Observation, as Mr. *Graves* also takes notice. I perus'd his Book I say, hoping I should have found, among many other curious Observations he there gives us concerning them, some Observations perfectly made, to find whether it stands East, West, North and South, or whether it varies from that respect of its sides to any other part or quarter of the World, as likewise how much, and which way they now stand; but to my wonder, he being Astronomical Professor, I do not find that he had any regard at all to the same, but seems to be wholly taken up with one Inquiry, which was about the measure or bigness of the whole and its parts, and the other matters mention'd, are only by the bye and accidental, which shews how useful Theories may be for the future to such as shall make Observations; nay, tho' they should not be true, for that it will hint many Inquiries to be taken notice of which would otherwise be not thought of at all, or at least but little regarded, and but superficially and negligently taken notice of. I find indeed, that he mentions the South and North sides thereof, but not as if he had taken any notice whether they were exactly facing the South or North, which he might easily have done. Nor do I find that he hath taken the exact Latitude of them, which methinks had been very proper to have been retain'd upon Record with their other Description. [Here by the bye because it agrees with a former Conjecture, I here proposed, concerning those stupendious Works, namely, that the Core of them was probably some natural Rock cut and shaped fit to be cased or cover'd with another sort of Stone, which was at that time much contradicted, by Affirmations, that the whole Country and Place of their Station was nothing but Sand. Give me me leave to take notice that Mr. *Graves* doth affirm, That the great Pyramid is founded upon a natural Rock which riseth above the rest of the Sand, and that the Rooms about the second Pyramid are hewen and shapen out of the natural Rock; and I doubt not but that if they were all examin'd, they would be found to be so and nothing else, which would much alleviate the stupendious Labour and Work of Men that must otherwise have been supposed to be made use of; but this only by the bye.] To proceed then where I left, I say that I conceive it were very desirable for the future, that those I have mention'd, and several other particular Observations, were purposely

2dly, *Of the alteration of the Axis of the Earths Rotation.*

made for that such would give a great light to judge and make a true valuation of the State and Nature of places and things, which in most Descriptions we find altogether wanting. As among many other things I could hint, I should be very glad to find such a Description of the Nature of the Sand of those Parts as would inform me whether it have not been all a Sea-Sand: I say, not only of this Country of *Ægypt*, which is so exceeding plain, and so exceeding Sandy, with many cragged Rocks rising out of it; but of *Arabia Deserta*, and *Arabia Petræa*, and all the parts near the *Tigris* and *Euphrates*, and all the parts on this side of *Egypt*, as the Region of *Barca* and *Pentapolitana*, and many other which are said to be all smooth and cover'd with Sand; for Observations designedly made, would easily discover whether such Sands had been owing to the Sea, or to some other Cause, which, by some curious Observations I have met with in the Travels of *Peter de la Valle* and *Belloni-us*, and others, I judge they have. I shall here present you with one of them. *Pietro della Valle parte terza Lettera* 11da *d'Aleppo* Aug. 5. 1625. *Vidi per terra molte Conchiglie marine, lustre dentro comme Madre Perle, parte intere, e parte spezzate, che in Luogo tanto lontano dal mare mi marvigliai come potessero trovarsi, vidi anco sparsi per tutto molti pezzi di Bitume, che in quell terreno salmastro, e che in qualche tempo dell anno per allagarsi d' acqua si genera, dei quali ne presi e tengo mostra appresso di me.* NB. This Place is betwixt *Bassora* and *Aleppo*, in the Deserts of *Arabia*, fourteen Days Journey from the Sea.

In *English* thus, 'I Saw on the Ground many Sea-Shells shining within like 'Mother of Pearl, some whole, some broken, I much wonder'd how they 'could be found in a place so far distant from the Sea; I saw also scattered 'every where many bits of Bitumen, which in this salt Earth and Soil is ge-'nerated and rises upon the Water at some times of the Year, of which I 'took some, and keep the Specimens by me to shew. Moreover, I hoped to have found something remarkable to my purpose in the Voyages of Sir *George Wheeler*, where he hath describ'd *Greece* and *Athens* in particular, and all the remarkable places about it, which are Places the best described of any thing of Antiquity, and more especially in his Description of the Temple of the Eight Winds, which is said by *Vitruvius* to be given to the City of *Athens* by *Andronicus Cyrrhastes*, and is remaining intire to this Day, all except the Vane or Weather-Cock at the top. I expected, I say, I should have met with some very exact and curious Observations, which methinks the very design of the place should have hinted, of the true Position of it as to those eight parts or *Plagæ mundi*; but I find nothing more to this purpose but that each Wind answer'd exactly to the compass, in the mean time not telling what was the variation of that compass at that time or place; however, he doth shew that the Position and Latitudes of places do much differ from what they had been described to us, but then how far we may relie upon antient Observations, will be a further doubt.

I should be glad that such as are better read in ancient Records would for the future at least take notice of any Observations they meet with which may afford some light to this Inquiry; and so for that Matter I must there leave it; for tho' I could accumulate many Observations which do seem to make for it, yet the uncertainty and unaccurateness of the Observations of the Ancients in this particular make me omit them.

And so I am reduced at last to such Observations as have been made in latter times, and with more accurateness and diligence, and with better Instruments, and to what may be purposely made with Instruments a hundred times more axact, and with designed and pertinent Observations for this very end; and such Observations will be principally of two kinds, First, Such as examine and state the exact Position of the Meridian Line of places evento a single second, or to a greater accurateness if required. And Secondly, Such as examine and state the true Latitude for that from some few such Observations accurately made, as they ought, more may be proved by seven Years Observations than by seven hunder'd YearsObservation of the Antients, nay tho' they were again multiplied by seven. But of this I shall discourse in my next.

The

The CONTENTS.

THis Lecture was read Feb. 9th. 168$\frac{6}{7}$, *the design of which is to prove that the diurnal Motion of the Earth must cause a recession of the Æquinoctial Parts thereof, and an accession of the Polar, and so make it of the suppos'd prolated Figure, and this is performed by a short and plain demonstration deduced from the Earths diurnul Motion: A principal of Motion premised,* viz. *That a Body moved will persevere to move with that velocity received in a strait Line; from hence some deductions are made, and a short and plain demonstration that the Figure of the Terraqueous Superficies is a prolated Spheroid, and that gravity tends no where to the Center but at the Poles and under the Æquator; and then the Author desires that Experiments may be made for that purpose. Next follows the proposal of a way to determine by accurate Observation, whether the Axis of the Earths Rotation changes or not.*

R. W.

I Hoped I had by my Discourse at the last meeting evidenced the first part of my Position which I deduced as a Corollary from the diurnal Motion of the Earth, namely, that such a motion must cause a recession of the Sea from the Polar parts towards the Æquinoctial, which must necessarily make the Surface thereof of a prolated Sphæroidical Figure. But I perceive some notwithstanding the Experiment, which shewed of the recess of the Water from the Center, do yet doubt of the Consequences thence deduced with reference to the Earth, and seem'd not to be satisfied that the two Methods which I propounded for the examination and determination thereof were sufficient.

Now that I might not leave any rub behind which might be a stumbling Block at the entrance, I have now prepared a short demonstration of the necessity and infallible certainty thereof, as it is a deduction from an Hypothesis which is now by most Philosophers and Astronomers granted, namely, the diurnal Motion of the Body of the Earth upon its Axis.

In order to which Demonstration I must premise this principle of Motion, That *every Body that hath received, or is moved with any degree of motion if it receives no other motion from any other Body whatsoever, will constantly persevere or continue moved with the same velocity in the streight Line of its tendency infinitely produced.* The reason of which is this, that no Reason can be assigned why its Motion should cease where there can be no impediment. Nor is there any reason why it should deflect to any side out of its direct way, since from the supposition there can be no new motion added to it from any other Body. Now this being a Principle will not admit of any other Demonstration than that of Induction from particular Observations in Natural Motions, by which all such Principles are made; for whosoever shall strictly and accurately examine and analyse all local Motions, will find hundreds of instances that after a due analysis is made do sufficiently evidence the universality and certainty of this Principle in all local Motions.

A Body moved will persevere in that motion.

From which Principle it will follow, that any Body moved Circularly with any degree of velocity (whilst some way continu'd to move about that Center) will at the instant that containing Power is remov'd, proceed to move directly forward in the straight Line of its tendency, which straight Line is a tangent to that Circle in which it aquired, or had its impreſt velocity; for the conteining Power, which by a continual atraction or otherwise towards the Center, kept it in that Circulation, ceasing, and no other Body whatsoever impressing any new motion upon it (as is supposed in the first Proposition) the Body must continue to move in the streight Line of its Direction without any Deflection, Retardation, or Acceleration.

From hence it will follow, that the farther it is moved in that Line, the more and more will it recede from that Center of Motion to which it was detained, and that for a short time with Spaces in a duplicate proportion of the times it spendeth, or of the Spaces it passes in that tangent Line, namely, in the proportion of the smaller Secants. This, as shewn by *Gelileo* and others, I pass over without farther proof.

From

Tab. 8. *Fig.* 1. From hence it will follow, that in all Circular Motions that make their Revolutions in equal times about the same Center, but in Circles of differing Radii, the recess in equal times will always be in the same proportion as the Radii of those Circles, or as the Tangents or Secants of the same Angle at the Center; this will be plain by the Scheme, where a represents the Center of the Motion, *eg*, *di*, *cl*, *&c.* Similar Arches of different Circles on the same Center *a*, the Bodies placed in *b*, *c*, *d*, *e*, are put to pass their respective Arches *bn*, *cl*, *di*, *eg*, all in the same time; now the Tangents *ef*, *dh*, *ck*, *bm* being in the same proportion with their respective Radii, and their respective Secants, their respective receding from the Center *a*, will be in proportion to their Radii.

Hence it follows, that the recess of the Parts of the Earth from the Axis of the diurnal Rotation will be in the same proportion as the Sines complement of the Latitude of those places, which recess is no where directly from the Center of Gravity, but under the Æquinoctial it being every where perpendicular to the Axis of Rotation.

Now the simple Gravity of the Earth as a Globous Body at rest can be no other than to the Center of that Globe, it being consider'd only as a Globe without any Circular Motion, as I shall prove when I speak of Gravity. And this Gravity every way equal, it will thence necessarily follow, that by the composition of those two Powers acting on Bodies, there will necessarily follow these Consequences, First, That every Meridian Line upon the Surface of the Sea, is of an Elliptical Figure, whose shortest Diameter is in the Pole, and whose longest is in the Plain of the Æquinoctial. Secondly, That the Gravitation of the Earth, as moved on an Axis, is in every Latitude different, the least under the Æquator and the greatest under the Poles.

Demonstration of the Figure of the Earth. *Tab.* 8. *Fig.* 2. Thirdly, That the Perpendiculars or Lines of Gravity or Descent do no where, except under the Poles and Æquinoctial respect the Center of the Earth; but other Centers in the Axis of its Rotation, let *Abc*, represent a quarter of the terrestial Globe Orthographically projected upon the plain of a Meridian, where let a, represent the Center, *b*, the Pole, *ab*, the Axis, ac, the Æquinoctial, let *αε βg γi* represent the Radii of certain parallels of Latitude, whose Rotation about the Axis *ab*, gives each of them a proportion of velocity corresponding to their length or distance from their Axis of Motion *ab*, that is in proportion to the Sine complement of the Latitude of the place or parallel. Let *c*, *g*, *b*, *r*, *n*, *y*, represent a very thin Superficies of the Globe of the Earth or Sea; let *ac*, *ae*, *ag*, *ai*, *ab*, represent the natural Lines or Rays of Gravity tending to the Center of the Earth all of equal length and equal power as to Gravity. The parts then in the Figure being understood, I proceed to the Exposition of the Doctrine, let *g*, then represent a Body somewhere placed upon the Superficies of the Earth; I say, this Body will be affected or moved with a double Power: First, By a Power gravitating towards the Center *a*, which is the same where ever the Body be placed; this gives it a power of descending from *g*, to *n*, in a certain space of time. Secondly, by a levitating power in the Line *βg*, whereby in the same space of time it would ascend from the Center of its motion *β*, from *g*, to *h*. Now draw, *no*, parallel and equal to, *gh*, and draw, *og*, and *oh*. Now because in both these Motions the acceleration is in duplicate proportion of the times it spendeth in passing them, it follows, that the Motion composed of both those Motions shall be made in a straight Line, namely, in the Diagonal Line *go*, for *g*, being by Gravity carried to *n*, and by Levity, as aforesaid, removed from *n*, to *o*, the place of the Body *g*, at the end of that time, shall be found *o*. The same Demonstration will serve for *c*, *e*, *i*, and *b*, *Mutatis Mutandis*; whence it follows necessarily, that the Lines of Descent of such a Body are not to the Center of the Earth at *a*, but to some other point of the Axis of Motion, as *t*, *v*, *&c.* Secondly, The Figure of the Water will be Oval, or truly Elliptical, as *x m*, *o*, *q*, *r*, because *xy*, *ml*, *on*, *qp*, *&c.* are all proportioned to their respective Radii. Thirdly, The power of this compounded Motion will affect all Bodies in differing Latitudes with differing Gravity, which were the proprieties to be proved.

From

From which demonstration it plainly appears, that the Consequences I have deduc'd from the Hypothesis of the diurnal Rotation of the Earth are necessary, and cannot, according to the Laws of Motion, be otherwise than what I have deduc'd, not frivolous Suppositions taken up at random to solve one Phænomenon, but such as will give light to many other considerable effects of Nature, as I shall demonstrate in explaining several other Phænomena both of the Earth and of the Heavens.

It further appears also, that the Experiments or *Criteria* I have propounded, are both pertinent and sufficient to determine and state this Enquiry without any other, and that they are neither impossible nor very difficult to be procur'd to be try'd with accurateness enough.

Now as these may easily enough be procur'd by the mediation of this Honourable Society; so I doubt not but they may, with little more trouble, procure such Observations and Experiments to be made as would afford great Light towards the perfecting several other parts of useful Knowledge, some few of which, if judiciously and pertinently contriv'd so as to be plain and easy, would give us the determination of many old, yea, and many new Theories possibly not hitherto thought of, some of which I shall hereafter have occasion to mention. Such Observations will be worthy the Care of this Society, and will be better than accidental and casual Trials, which, tho' surprising and pleasant, are at best but like those of the seekers of the Philosophers Stone and perpetual Motion, who generally make trials at a venture, to see if there good Genius or Fortune will direct them to meet with what they seek; whereas indeed all Experiments ought to be directed to some end for the examination of some supposed Truth, and for that end to take notice of all such Circumstances as may give any information concerning it, whether it be for Confirmation, or Confutation of such a Doctrine, and if so, the plainer and the more obvious the Experiments are, the better.

If yet there shall remain any doubt either in the deduction of this Conclusion, or the sufficiency of the Experiments to determine and state the truth thereof, I would very willingly explain any part thereof.

A Method of determining whether the Axis of the Earths Rotation alters.

The next part of my Hypothesis is, that by many Observations I conceive that there may be in the Rotation of the Body of the Earth, a change of the Axis of that Rotation, by a certain slow Progressive Motion thereof, whereby the Poles of the said Motion appear to be in superficial parts of the Earth, which heretofore were at some distance from the then polar Points or Parts. I have waved all the Observations that I have hitherto met with in Histories which might seem to favour this Hypothesis, as having found them irregular and unaccurate enough in Observations of this kind, and have put the whole stress of its Proof, or rather Examination, upon trials to be made for the future. But because this Motion, if any, seems to be very small and slow, and therefore since the Age of Man, which is very short comparatively, seems insufficient for such a purpose; I have therefore indeavour'd to carry Mahomet to the Mountain, since I cannot bring the Mountain to Mahomet, and that is by contriving such ways as may perform that in a short time, which, by the Methods of the Antients, could not be perform'd in less than some Ages. This Contrivance consists only in the exactness of Instruments, and the accurateness of making Observations; for if for instance we are not sure of the truth of the Latitudes of places recorded by *Ptolomy* and *Strabo* to a degree or two, as I can shew hundreds of places that differ more than that from the Truth; and if by any new Method we may be able to make Observations either of the Latitude of a Place, or of the true Meridian of any such place to a single second Minute, than we may by such a means arrive to a certainty in a three thousand six hundred part of the time that could be arriv'd at by such Observations as theirs are; wherein their Defects lay whether in their Instruments, or their way of using them, or their negligence in computing, or the want of our present arithmeticial Art, and of proper and accurate Tables, or in the Doctrine and Practise of plain and Sphærical Trigonometry, I do not inquire; but certain it is, we have at present a great advantage of them in all these particulars, but above all, most eminently by the Knowledge and Use of Optick Glasses, especially as they are

applied to Mathematical Instruments, for by them only we are truly made Gygantick, and our Eye from the little Ball of less than an Inch in Diameter is grown to be of fifty, sixty, nay a hundred Foot and more in Diameter, and may be made able to do some thousands of times more than what our bare Eye alone without the use of such helps can perform; and therefore tho' *Hevelius* might have some reason to be uneasy, and so to rail at me for asserting of this Truth to the World after he had publish'd his *Machina Cælestis* to shew he had made use of the best Instruments in the World for his Observation; yet why Dr. *Wallis* and his Adherents, some of which have made use of the very Contrivances which I Publish'd, should with so much Gall write against me for it, I cannot but wonder: But I doubt not but to prove to all the World in my own Vindication, that neither the one nor the other had any reason but ill Will for what they did, and at the same time to prove the truth of every particular which I have asserted in that Book to any that will believe his own Eyes; but not to trouble you any further with this Controversy at present, designing suddainly to publish my Answers to them where they may be seen more at large, I shall proceed to the Methods of making Observations both of the Meridian Line of any place, and also of its true Latitude in respect of the Heavens to the accurateness of a single Second.

And here only I have one or two Postulata to premise, which I suppose every one that hears it will readily grant; it is no more but these; First, That it is possible, nay, practicable, to find a Point below perpendicular, to a a Point above, tho' the distance between them be a hundred Foot, and to be certain of the truth thereof to the exactness of a Second Minute.

Secondly, That the Refraction of the Air at sixty Degrees Altitude above the Horizon does not at vary the Azymuth of a Body a single Second Minute.

A Third Truth I will put by way of a Postalutum, that 'tis possible, nay, easily practicable to distinguish the parts of a far remov'd Object by the help of Telescopes long enough, tho' they really appear to the Object Glass of that Telescope less than that of a single Second Minute.

These I conceive so easy and certain, that I have put them as *Postulata*; but yet if any doubt of their certainty, I do undertake to prove the Truth of either of them both by Experiment or Demonstration, which of the two shall be judg'd most convincing.

The next thing to be shewn is how to order a Telescope so that it may be made a sight, that the true Line in which the Object appears may be certainly determin'd, and this, be the Telescope sixty or a hundred Foot or more in length, and how to make by this, an Instrument as large as the said Telescope is a sight.

For the performance of these Qualifications there will be no greater difficulty, than the making a Tube for such a Telescope, or, if that be thought too much, it may be done by two small Scaffold Poles joyned together in the middle with convenient Lines to keep them streight, or if this be still thought too difficult, it may be done by fitting the Object Glass in one Cell, and the Eye Glass and Thread-sights in another, with Lines strained between them to keep them directly parallel to each other; but the best way is by a Telescope Tube of a due length and bigness for the Object-glass made use of.

Instruments for that purpose.

Supposing then a Telescope of sixty, eighty, or a hundred Foot in length thus fitted with a Tube, to find the true Line of Direction, I fasten to the Cell that holds the Object Glass a Needle with the point outwards against the middle of the Glass. And the like I also fix in a small sliding Plate, that lieth upon the Cell, that holdeth the Thread-sight together with the Eye-glass: This Plate, by a very fine Screw, I can cause to slip out or in at pleasure, till it be adjusted to a Line from the point of the Needle fasten'd to the Cell of the Object-glass: To adjust this Telescope then for a sight, I direct it to some very remote Object in the Horizon, and fix a Pin or Wire just touching the point of the Needle at the Object-glass; then having found and remarked some convenient Point of the Object in the Horizon, I move the Tube till the Thread of the sight exactly lie upon it; then inverting or turning the Tube, making the under side upermost, and the uper side undermost, the right the left,

left and the left the right; I cause the point of the Object-glass Needle, as also, that of the Cell of the Threads to touch the same Points as before inversion, then looking at the point of the Horizontal Object, I see whether the afore-said Line of it do cover the same part of the Object as it did before inversion. If it happen so to do, then I am certain that the Telescope is already adjusted; but if it do not, it will be adjusted by moving the sliding Plate with the Needle at the Eye-cell: When thus adjusted, these two Needles points become the Indexes to my Instrument, for exactly taking the visual Line of the Object, I observe to as great accurateness as is desired. Having thus prepar'd the sight for my Instrument, I make choice of some Tower of a convenient height for the resting the end of the Tube that holdeth the Object-glass, and order it so that the Needles point may touch a fixed point upon the same; then I make a Board below upon the Ground lying Horizontal, whereupon the other end of the Tube may be slid Horizontal and easily remov'd at pleasure. The Object I make choice of is the Polestar, or the Star in the tail of the lesser bear. I by this means observe its most Eastern and Western Excursion the same Night; or if it happen that one is in the Night and the other in the Day, by means of this Telescope I can plainly see it, tho' the Sun shine. Now the Needles point at the Object-glass touching in both Excursions, and the Needles point at the Eye-sight shewing the two Azymuthes of the said Excursions, wherein the Refractions can have no effect to make the Ray bent, it will be easy enough accurately to divide the space between the two Excursions into half, and as easy to fine the Point below perpendicular under the Point above marked by the Needles Point of the Object-glass, or which for this purpose will be better to find a point above upon some building of equal height with that of the Object-glass, by which two Points I direct my Telescope to the Horizon either Northwards or Southwards, and find what Object lies directly in the Meridian Line, which I diligently note and draw the Landscape of that part of the Horizon which appears through the Glass when so posited with the very point of the same cover'd by the Thread-sight; which done, I continue the said Landscape by the help of the Telescope till I bring in some remarkable known Object, by means of which I shall be able a Year or two after to find the same again, when the same trial is again to be repeated with the same care. In order to determine this Question, whether the Meridian Line upon the Surface of the Earth do change; by which means if it be alter'd but a Second or two, I shall be able to distinguish it in the Horizontal Landscape. Now tho' this Experiment upon the whole Matter may seem troublesome and difficult to be perform'd duely as it ought, yet if we consider the Importance thereof in this Matter, and how much can be done by the Care of one Man in a short space, which by the Method of the Antients was to not be expected from the performances of any one or many under the expectation of some Ages, I conceive the Experiment may be look'd upon in the whole as compendious, cheap and easy; there being nothing therein so difficult but that two Men may every day, for some days together, repeat the Observations and Trials after the apparatus is made ready and put in order, and need not spend above four Hours in twenty four to make them sufficiently accurate.

Nor will it be very difficult in this City to find a convenient Building or Tower for the resting the end of the Telescope of a hundred Foot long if it be made use of; or of finding a good prospect of a far distant Meridional Object in the Horizon, whether towards the North or South, they being both or either equally sufficient for this Observation: And if a fifty or sixty Foot Telescope be made use of, which will be able to perform the Observation accurately enough, with a little more Care and Circumspection, tho' with less Labour, and Pains, and Charge, there are Houses enough to be found of sufficient height.

Now this Experiment I conceive sufficient to perform what is design'd, or to be expected from it, as to this Inquiry, and all things consider'd, I conceive the best, tho' I could produce some others if there be occasion; and further, I conceive the same to be free from all material Objections: As First,

First, If it be Objected, that the Refraction of the Air doth make the Cælestial Objects to appear out of their true places. I say, that in this Experiment it can have no effect, because the Azymuth and Circle of Position only are sought and those the Refraction of the Air alters not; for the Star being only to be observ'd when it it is either ascending in its most Eastern Azymuth, or descending in its most Western Azymuth, the effect of any would be the same, since they are so found and observ'd at the same Altitude both ascending and descending; and tho' the Refraction should raise them, and the whole Circle, and the said Star to a sensible higher Position than the Truth, yet the Points to be observ'd being both of equal Altitude, the effect will be the same, which will no way disturb this Observation.

Next if it be Objected, that this Star doth alter its distance from the Polestar every Year, and that will make the Excursions less in the succeeding Year. I say, as to this Inquiry, it would have no effect, tho' it should alter ten times more, because the middle between the Excursions in the same day, is that which is sought in this Experiment.

If the parallax of the Earths Orb be Objected, which is the most material, I Answer, That the succeeding Experiments are to be try'd again when the Earth is in the same part of the Ecliptick, which will fully answer any Scruple thence.

And, upon the whole, I cannot think of any other,; but if any of this Honourable Society can think of any Material, I would desire to be inform'd of them, that I may think of some means of remedying them; or if they think of any other more convenient and certain, that I may put them in practise. Some other of my own I shall propound the next Day and leave them to the Judgment of the Society to chuse the most fit.

This, I hope, may save the Labour of searching into Records of Antiquity, of all which if I may be allow'd to judge by those I have met with, I believe they will at best afford us but uncertain and unaccurate Observations, and I do very much doubt whether ever there were above two thousand Years since, any Meridian truly set to the certainty of less than one Degree; so that tho' we had found by the great Pyramid, that there was either some considerable variety from the present Meridian, or that it were now in the very Meridian Line, the Conclusions drawn from either of them would have been but conjectural, since it might have been placed true, and have since varied, as it is found, or it might have been placed wrong, and since have mov'd to a Truth, or the contrary.

Whereas, since by this Experiment, we may be able to find the Meridian true to the three thousand six hundred part of a Degree, and these Observations may be made by one and the same Man, and with the same Instrument in the same place, and at the same time of the Year, and of the Day; I conceive that one Years Observation will more ascertain us in this particular, than if we had Records of Observations made, as those I have met with 3600 Years since, which is the Expedient I have thought of for redeeming or expanding the power of the short Line of the Life of a Man.

Other Methods of determining the same Question, read Feb. 16. 168$^{6}_{7}$.

In order to determine whether the Meridional Line of Places did alter, I did in my last Discourse wave all antient Observations, as fearing there might be wanting in them that certainty and accurateness of Observations that might be sufficient to assure us of the Matter of Fact, and that might be convincing as to the Reality or Nullity of such an alteration, as I suppos'd.

1st. *By ancient Buildings.* But because possibly there may be some Observations of a latter date which have been here made within our present reach, which are of more accurateness, I would propound it a thing not unfit to be examin'd, whether the Position of several of the most eminent Cathedrals built by the *Gothick* Architecture, wherein great regard, if not Religion, seems to have been had of the Position of them, according to the four quarters of the Horizon, *viz.* E, W, N, and S. And to this end, because nearest this place, I could wish it

it were tried at *Westminster Abby*, which is intirely built after that Mode; whether that be truly so plac'd that the four Ends or Fronts thereof do exactly face those Quarters, and if not, which way the variation may be, and how much it really is at this present. The same Observation may be procur'd to be made at several other Cathedrals, as at *Salisbury*, *Winchester*, *Chichester*, *York*, &c. where there are such Buildings, which will be with no great difficulty procur'd by the Mediation of this Society.

Among other places worth examining, I could wish that the great Dial-stone in the Privy Garden at *White-Hall*, were one, for that I conceive there was very great Care and Accurateness used in the placing thereof; and tho' this may seem, if compar'd with others of a very short continuance since its first placing, yet it may be with probability enough suppos'd to have been so much more accurately plac'd, that That alone may possibly make it preferable to any other whether Ancient or Modern.

Now because the ways publish'd for finding the true Meridian Line have really much of difficulty in them, and require both a great Apparatus and a considerable time to make the Observations necessary for this purpose, without which the Informations and Examinations will be very unaccurate and scarce to be rely'd upon, therefore I have contriv'd an Instrument by which, in a few Minutes of Time, the exact Meridian Line, at any place, may be easily and with accurateness enough, that is, to ten Seconds, if need require; and this free from Exceptions of Refraction, Declination, *&c.* by which the true Position of any Building, Monument, *&c.* may be presently discover'd and computed.

The first Instrument from this purpose, is a Telescope of what length shall be thought convenient to be easily used and manag'd; as suppose one of six, twelve, or fifteen Foot, this must in the first place be fitted with Eye-sights, plac'd upon a thin piece of Looking-glass Plate, on which must be drawn with a very fine Diamant, such Lines and Circles as I shall direct, the Center of all which Circles is to represent the true Polar Point in the Heavens, at the time of the Observation of which more by and by. 2dly. *By fit Instruments.*

This Sight-glass being fix'd in the Tube, the next thing to be done is to fix two pieces of Brass, or some other convenient Metal, which may have each of them a small hole to hold a small clew of Silk fit to bear a Plumbet or such other Instrument as I shall direct; these holes must be so place'd as that an imaginary Line drawn over the ends of them may be exactly parallel to the Axis of the Telescope which passeth through the Center of the Sight-glass.

Thirdly, Into these holes must be fitted small Silken Lines with Plumbets hanging at them, which two Plumb-Lines will (when the Axis of the Telescope passing through the Center of the Sight-plate is directed to the Polar Point) hang in the plain of the Meridian.

Fourthly, The Axis of the Telescope may be easily directed to the Polar Point, by bringing three or more Stars of the *English* Rose into their proper Circles and there fixing it.

Fifthly, The *English* Rose is a Constellation in the Heavens discoverable only by a Telescope, consisting of six Stars in the Rose itself, and several other in the Leaves and Branches, one of these is in the Center of the Rose, and five in the five green Leaves of the Knob: This I have somewhere describ'd about ten Years since, but have mislaid them at present; the way of finding them I then shew'd to Sir *Chr. Wren*, and some others of this Society at the time when my Instrument was fixed for that purpose.

The Instrument or Telescope being fix'd in this Position, the two Plumb-holes represent the true Axis of the Earth, and accordingly will serve to determine both the plain of the Meridian, and also the inclination of the Axis to the plain of the Horizon; so that by the same Observation both the Meridian Line may be determin'd, and also the elevation of the Polar Point,

which may be various ways most exactly measur'd and determin'd. Now this is a second way of determining the true Meridian Line to what accurateness shall be desir'd, for that the length of the Telescope is not limited, but may be us'd of what length soever may be made, tho' it may be three hundred or four hundred Foot, for that the Object-glass may be fix'd at the top of some Tower or Steeple, and the Sights and Eye-glass at the Ground. But on this I shall not at present inlarge, beeause, whenever there shall be occasion of trial, I can easily direct the whole Apparatus.

As to the second Use thereof, which is for taking the Altitude of the Polar Point above the Horizon; this way is far beyond any I have met with, and is liable to one only Objection (as I conceive) and that is the Refraction of the Air, which elevates the same somewhat beyond its due Limits, but then if compar'd with the best yet propos'd, I conceive it to be less subject than any other, and to come nearer to a certainty and exactness: However I grant it to have that Objection good against it; but if we consider the use of this Observation as it is design'd to examine the Latitude of one and the same place after the interval of some few Years, the Objection is of no validity, for that the Refraction of the Air at the height proper for *London*, viz. 51, 32, is hardly sensible; but then the difference between the Refraction of the first and second Observation is yet much less discoverable, so that for this purpose 'tis as effectual as the best.

But because some may yet further desire to free the Observation from Refraction, I have contriv'd another way, much less subject to it; which way will also find the true Meridian Line to great exactness: Not to make any long preamble to it 'tis this, Make choice of some notable fix'd Star that passeth over or near the Zenith of the place, as here, for *London* the *Lucida Draconis*, or the last Star in the tail of the great Bear; 'tis easy, by the way I have already publish'd in Print to find the Zenith, and the Meridian Line passing through it.

Having fix'd all things requisite for this, about an Hour or two before the Star comes to the Zenith or Meridian near it, find and observe exactly its bearing, which may be done with a Telescope of fifty, sixty, or more Feet in length, then by an exact Pendulum Clock number how many Seconds or half Seconds of Time pass before it arrive at the Meridian, which note and remember, then prepare to observe the place of the same Star after so many Minutes, Seconds, and half Seconds have pass'd, after the Star hath pass'd the Meridian, note the Point also. There are then given three Points, which, with the help of Calculation, the time being taken, it will give the Latitude of the place to a great exactness; and if a Line be drawn from the most Eastern to the most Western Observation, this will give the true E, and W, line; and if the same be divided in half and through the same, and the Meridional place of the said Star, a straight Line be drawn, this will give the true Meridian Line.

So much for the methods of observing the Latitudes and Meridian Lines of places for the time to come.

But because there have been some of our later Observations of the Latitudes of some places which have been with very great Care and Accurateness made; I could likewise wish that the Latitudes of those places where they have been so made, might be a new examin'd, to see whether any considerable difference can be found which cannot well be ascrib'd to the defect of the preceding Observations. As the Latitude of *Uraniburg*, *London*, *Paris*, *Rome*, *Bolonia*, &c. tho' yet I fear we shall be apt to ascribe what difference shall be found to the faileur of the preceding Observations.

This is all I have at present to propound concerning the external Figure of the Water and Earth. As to the motions thereof I shall propound some Conjectures after I have consider'd the Figure and Constitution of the next great Fluid in compassing the Earth, which is the Air; after which I shall propound some Conjectures at the various internal motions of those great Fluids, which concern the Currents and Tides in the one, and the Winds in the other.

The

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THIS Lecture was read March *the* 9th. 168⁶/₇, *and treats of the Figure of the Air or Atmosphere; and first three known Properties thereof are premis'd, from whence, and the tendency of the Lines of Gravity before proved, is demonstrated, that the Figure of Air is more prolatedly Spheroidical than that of the Earth, which, the Lecture being short, I forbear to Epitomise, and only observe that the Author concludes this Lecture with naming the two great internal Motions of the Earth, Gravitation and Magnetism; of the first he had before treated at the end of his Discourse of Comets, of the later he only gives here his Hypothesis in short.*

R. W.

I Have in my former Lectures propounded my Thoughts, and the Reasons of them concerning the Figure of the Body of the Earth, and the tendency of the Perpendicular Lines of Gravitation; as also concerning the probability of a variation of the Axis of Rotation in the Body of the Earth. I have likewise shew'd the influence of those Principles upon which I grounded those Thoughts, upon the Body of the Waters incompassing this Earthly Body.

I come in the next place to consider the Figure of the next great fluid Body, incompassing both the one and the other, and that is the Atmosphere or Mass of Air. *Three known properties of the Air premised.*

And here for the present I shall only consider so much of the Nature and Constitution of this Body, as seems necessary to the explication of the Figure thereof.

It is now very well known, that this Body is of such a Constitution, that a greater degree of Heat, or a lesser degree of Pressure will effect a greater degree of Expansion, that is, will cause the same parcel of Air to occupy or fill a larger space of rome; next that the same parcel of Air, when rarify'd, will weigh no more than when condens'd, tho' it fill a greater space, because the real quantity of the parts that compose this Air, are still the same, tho' there may be a greater quantity of other matter that fill the Interstitia or Spaces between them.

Thirdly, That the Atmosphere is compos'd of three kinds of Substances, one more fluid than the other, two of which, namely, the less fluid Cause considerable effects upon the subjacent parts of themselves, and upon other Aqueous and Terrestial Bodies by their Weight or Gravitation. These I only name at present, designing more fully to explain them and their Causes when I discourse of the Substance and Constitution of the Air.

These three things then for the present being taken as Suppositions, and the tendency of the Lines of Gravitation, being, as I have prov'd, to differing and various Centers, it follows that the Figure of the two lower parts of the Air must be of a prolated Sphæroidical Figure, and that much more considerably differing from that of a Sphærical Form than that of the Earth or Water. *The Atmosphere under the Æquator higher.*

For First, It is very evident, that the more gross Parts thereof are carry'd along with the subjacent Parts of the Earth, with an almost equal swiftness; say almost, because in the wide and open Ocean there is some kind of loss of swiftness and lagging behind, which, as I conceive, (as *Galileo* and many others have done) is the Cause and Original of the Eastwardly Winds within or near the Tropicks; from this Rotation then will follow a considerable levitation of such parts of the Air as are whirl'd round from West to East with such a Rotation; that is, those parts which are mov'd swiftest will have the greatest indeavour of Recess from the Axis of Motion; and those which are mov'd slower will have a less, as I shew'd before in my Explication of the Figure of the Water. 1st. *From its swifter motion*

Next

2ly. *From its springy Nature.*

Next it is evident from the springy Nature of the Air, that the less the pressing is upon the Body thereof, the more will it expand and stretch it self and possess a greater space. Now the quantity of Air towards the Æquinoctial, having a greater Levitation upwards, or less Gravitation towards the Earth, a greater quantity of the Air must go to make up the Cylinder that gives an equal Pressure, and consequently the Surface or Extent of the Air towards the Æquinoctial must upon this account be much higher than towards the Poles.

3dly. *From its greater heat there.*

But in the Third place this Oval Figure of the Air must necessarily be increas'd by the differing Degrees of Heat and Cold; for that a greater Degree of Heat doth expand, and of Cold doth condense the Body thereof. Now it is evident that the Degrees of Heat near the Æquinoctial are very great in comparison to what they are near the Poles.

And consequently, upon this account, also the Body of the Air towards the Æquator, must be very high and rarify'd, and the Body of it towards the Poles must be very low and condens'd; from which two Causes it will necessarily follow, that the Figure of the Body or Mass of Air, incompassing the Body of the Earth and Water, must be of a prolated Sphæroidical Figure, much more prolated towards the Æquator than that of the Water.

Reasons of different Phænomena in different Climates.

From which Considerations, I conceive, some Reasons may be drawn of several Phænomena taken notice of by Travellers; such as the frequency of Foggs and Mists and various sorts of *Parhelia* and *Paraselenæ*, in and near the Polar Regions; all which argue a dense and heavy Air. And of the Hurricanes, Tornadoes and the Storm call'd the *Bulls Eye*, which descends from a great height with great precipitation into the lower Regions of the Air, and of the frequent and violent Rains in the *Torrid Zone*; all which *Phænomena* are indications of an Atmosphere much more extended upwards, and of the vaporous Parts carry'd to a much greater height than elsewhere.

A Circulation of the lower & upper parts of the Air.

From these Considerations also will follow a necessary motion or tendency of the lower Parts of the Air near the Earth, from the Polar Parts towards the Æquinoctial, and consequently of the higher Parts of the Air from the Æquinoctial Parts towards the Polar, and consequently a kind of Circulation of the Body of the Air, which I conceive to be the cause of many considerable *Phænomena* of the Air, Winds and Waters, which I shall more fully explain when I come to consider the Constitution and Motion of the Body of this great Mass, whose Figure and external Form only at the present I am considering.

Nor shall I at present explain any thing farther concerning the two more fluid Substances that help to compose or fill the space which is taken up by the Atmosphere, because my present Subject leads me only to consider that part of the Air which is call'd the Atmosphere, and to speak only of the Figure thereof, of which I have no more to add at present, but shall return to consider the Nature and Motions of each of these three great Masses, *viz.* the Earth, the Water and the Air.

First then for the Internal motions of the Earth; there are two principally taken notice of; the first is that of Gravitation, the second is that of Magnetism.

Of the first of these I have some Years since discours'd more particularly, and therefore shall omit it at present.

Of the second of these, namely, Magnetism, I shall only propound my Hypothesis now and explain it more particularly in my next Discourses.

Hypothesis of Magnetism.

My Hypothesis then is this, First, That all magnetical Bodies have the constituent Parts of them of equal Magnitude and equal Tone.

Secondly, That the Motion or Tone of one Magnetical Body is convey'd to that of another by means of a Dense Medium.

Thirdly, That the motion of the Dense Medium is Circular and Vibrating.

From which three Suppositions all the *Phænomena* of Magneticks will be most evidently and clearly, even *a Priori*, deduc'd.

SInce the following Discourse treats of that surprising Experiment of the Mercuries standing so much above the usual standard, and gives our Authors Explication of that Phænomenon, I thought fit to join it to the foregoing of the Figure of the Atmosphere, and the rather because it also gives several very good hints of the Nature of that fluid, as likewise concerning the Æther. This Discourse was first read in one Thousand six hundred seventy odd to my Lord Brouncher, *and with some small alteration in the first Page produced again to the Royal Society* 1684, *as it is here Printed.*

R. W.

Of the standing of the Mercury *in the Tube to the height of* 75 *Inches, read* May *the* 28th. 1684.

THat *Theories* are not altogether uselefs, we may perceive by the happy invention of the ingenious *Galileo*, and the addition of the acute *Torricellius*, which two compleated the Experiment of the *Æthereal Vacuum*; the further Improvement and Observation of which hath produc'd the *Barometer*, now useful for predicting the variation of the Weather, and the *Pneumatick* Engine much more prolifick of discoveries; the causes of most of whose Phænomena are sufficiently obvious, and certainly known to be the Gravitation and Spring of that part of the *Atmosphere*, which is call'd *Air*, and agreed to by the most accurate of the Modern Philosophers. But Mr. *Hugens* about twenty Years since having tried Mr *Boyle*'s Experiment of making Water descend in a Tube, the Orifice of which was inclosed in an exhausted Receiver, found that if the Water were first well freed from the Air that is usually latent in it, and then inclosed, the Water would not descend in the Pipe, tho' the pressure of the Air were wholly taken off; this occasion'd the trial to be made here with *Quicksilver* instead of Water, and by many Experiments it was at last found by Mr. *Boyle* the Lord *Broucher*, and several others, that the *Quicksilver* also when the Tube was very well freed from the latent Particles of Air, would not part from the top of a Tube, tho' it were twice as high as the usual height the *Quicksilver* used to stand at; and tho' there were no more pressure upon the stagnant Vessel than was usual, and that the bottom of the Tube were as open and free for the *Mercury* to run out, as was usual for Experiments of the Mercurial Standard. This seem'd at first to overthrow the Theory of the Gravity of the Air, and was made use of by some *Antagonists* to that purpose, but with little reason; for it was observ'd, that in the making this Experiment if a little Jog were given to the Tube in which the *Mercury* thus remain'd suspended, the *Mercury* would immediately leave the top and fall down in the Tube to the usual height of about thirty Inches, and there exhibit all the same Phænomena as the common Mercurial Standard or Torricellian Experiment had been observ'd to do. However it could not but affect the inquisitive after the causes of things, with a disire of satisfying themselves with some probable Conjectures at the causes of this so strange an Effect, some supposing one thing, some another; what my Conjectures were, and still are, I shall in brief declare and leave them to be consider'd by such as have better Abilities, and shall please to trouble themselves with such inquiries.

Since I first made the Experiment, I saw an absolute necessity of a pressing Fluid very much more subtile than the Air, and yet consisting of parts of a determinate bulk, which would easily strain through and pervade the Pores of Glass, Water and other Bodies impervious to the Air, but could be kept out by the nearer Conjunction of some of the constiuent parts of those Bodies which constitute Pores of a much less Magnitude or Capacity, which fluid I suppos'd might be somewhat of the Nature of the second Element of *Descartes*, tho' for many Reasons drawn from Experiments, I suppos'd it to have many differing Proprieties from those which he ascribes to his, and I saw also a necessity of supposing a third Element consisting of a matter yet more subtile and fluid, *Proof of the Æther.*

as he supposes, and more then that, of several other fluid Matters, some more subtile than others, each of which have their proprieties distinct, and are the causes of this or that Phænomenon in the World, of which there hath as yet been no intelligible reason given of their Power and Original, as I may hereafter shew in the Explication of some of them. And I do believe, from that little insight I have had of the Operations of Nature, that all the sensible part of the World is almost infinitely the least part of the Body thereof, and but, as it were, the *Cuticula*, or outward Filme of things; whereas that which fills up and compleats the space incompass'd by that Filme consists of a multitude of insensible Bodies, each of them as distinct in their Natures and Operations, as Air and Quicksilver, or any other two sensible Bodies we can name; for so many, so curious, and so minute are the insensible workings of Nature, that without supposing some such Instruments as these we shall quickly find a *non plus* in the explication of any one appearance in Nature. But for the finding out the Number and Nature, of these Elements we can proceed but by slow and single steps, and 'tis not to be expected but from a long and close prosecution of Nature as we see that the pressure of the Air was not detected till *Galileo* and *Torricellius* happily light upon that Notion, and this second Element was not experimentally manifested till the making of this Experiment of the *Mercury*'s standing much above the height discover'd by *Torricellius*. The matter on which the Loadstone works will perhaps be found another, and that which causeth Gravity a Fourth. But this by the bye.

My Notion and Explication of this Phænomenon is this, That there is another fluid Body; this Fluid is the Menstruum or Liquor into which the Air is dissolv'd like a Tincture of Cocheneel into Water, which, as I have explain'd in the 15th Observation Microscopical, *Page* 96, and 97, doth penetrate the Pores of the Glass Water, and several other terraqueous Bodies (possibly all such as are transparent, for that I have not a sufficient supellex as yet to determine positively; nor is it material for the Explication of this Phænomenon, as other more curious and critical Experiments shall be found out, it will be time enough to determine it.)

Next that this fluid, as all other sensible fluids we meet with, hath a greater Congruity or Incongruity to this or that Body it is contiguous to, and therefore doth more readily join to this Homogeneous than to that Heterogeneous Body, whether Solid or Fluid, and doth more easily penetrate the small Pores of the Homogeneous, and not without some difficulty the Pores of the Heterogeneous Bodies. And in short, that this Congruity or Incongruity of it to other Bodies doth make it perform the same kinds of Effects with those we find perform'd by sensible Fluids and Solids, such as I have explicated in my sixth Mycroscopical Observation.

Thirdly, That this Fluid doth not at all penetrate the Body of *Quicksilver*, tho' *Quicksilver* may be penetrated by a great number of other more subtile Fluids, such as those which cause Gravity, Magnetism, Fluidity, *&c.* if at least it shall be found necessary by future Experiments to ascribe those three Properties to more than one fluid.

Fourthly, That several other Liquours whose greater Pores are penetrated by this Fluid, may yet be sustain'd by it above the level equivalent to twenty nine Inches of *Quicksilver*, so long as the Pores are not so far seperated as to admit the parts of this Fluid between them where they are more neerly contiguous, and have some more subtile fluid Body only between them. Of this kind Water well purged of Air may be one, as the Experiment of the not subsiding of Water purg'd of Air doth maaifest.

Fifthly, That this Fluid hath a pressure every way analogous to the pressure of the Air, and that this pressure is much greater than that of the Air.

Sixthly, That there is no need (for the explicating any Experiment I have yet heard of) of supposing it to have a springy Nature like that of the Air, since all the Phænomena may be solved without it.

For the more intelligibe Explication of this Solution, I shall indeavour to shew an Experiment very much like it, in sensible Bodies. I took then a small Glass Cane *a*, *b*, *c*, open at both ends, then having procur'd a long small Glass

Pipe

Pipe in a Lamp almost as small as a Hair, I brake it into a great many short ones and made of them a Stopple by binding them together Fagot-wise with thread, and melting Wax or Cement about them, so as that none of their Perforations were stopt, I put them into the end *a*, *b*, for a Stopple, then I had another Cane of Glass big enough to contain the former wholly as Def. which was fill'd with Water; then the first Tube with the open end downwards was immers'd into the said Tube Def. till the Water had fill'd the whole, and the ends of the small Pipes *iiiii*, then gently raising up the Tube *a*, *b*, *c*, out of the Water, I found I could raise it so high as that the Water in the Tube *a*, *b*, *c*, did stand above the Surface of *g*, *h*, the Water in the Glass Def. some Inches. Wherein 'tis observable, that tho' all the ends of the Pipes *iiii* were pervious to the Air, yet by reason of a greater Congruity of the Water to Glass than of Air, the Air was not able to force its way thorough without the help of the Gravity of the Cylinder of Water *a*, *g*, *h*, *b*; the same Experiment I tried also with *Quicksilver*, by making the Stopple *k*, of Brass, and instead of the small Pipes caus'd to be drill'd, thro' the same a great number of small holes, then by the help of *Aqua Fortis* I caus'd all those holes to be whited with *Quicksilver* then holding my Finger against those holes, and filling it with *Mercury*, and stopping the other end, and immerging it under other *Mercury* in a Dish, by degrees I rais'd the same, and found that the Air would not force its way in at the above-said drill'd holes, till the end *A*, *b*, was rais'd above the level of the *Mercury* in the Dish some Inches. *Tab.* 8. *Fig.* 3.

From both which Experiments 'twill not be difficult to understand my explication of this Phænomenon of the extroardinary hight of the *Mercury* in a Tube, well fill'd, and perfectly cleans'd of Air: For if we suppose in the former Experiment, that the Ambient Air doth represent the Ambient Fluid, whose pressure we do suppose, and that the Perforations of the small Pipes do represent the imaginary Pores of Glass, and that the Water with which it is fill'd doth represent the *Quicksilver* in the new Experiment, and that we suppose that *Quicksilver* hath a greater Congruity to Glass than the other, and that consequently it keeps the other from getting a Body within the hollow of rhe Tube by stopping it at its first entry, 'twill be easie to imagine how, tho' the Glass can be supposed all over Porous, through which the Æther can pass, the Ambient new Fluid can by its more free pressure on the Surface of the bottom, keep the *Mercury* suspended forty five Inches above the former Standard of thirty Inches.

Nor doth the second Experiment explicate it less naturally; for the Air represents the Æther, or what other name soever it be call'd by: The *Quicksilver* in the one represents the *Quicksilver* in the other. Immerse that Dish in a Bucket of Water, and you shall find that the top of the Tube will be rais'd considerably higher above the Surface of the *Mercury* in the Dish before the *Mercury* will leave the top; Then the Water, under which the *Mercury* is immers'd, will represent the Air or Atmosphere, and the holes in the Brass Stopper, the Pores of the Glass, the additional raising of the height of the *Mercury*, after 'tis put under Water will shew how part of the seventy five Inches is ascribable to the pressure of the Air, and the other height will shew how another part of it is ascribable to the pressure of the Æther. I think I need not explain it farther, only 'tis observable, that tho' the Air finds a difficulty to make its first entry into the small holes of the Glass Pipes, or of the Brass Stopper, yet after it hath got through, and that there is Air within the Tube as well as without, it very readily and freely maintains its Passage, and the same *Phænomenon* also happens in the *Quicksilver* Experiment, for as soon as ever the *Mercury* begins to seperate from the top of the Tube, and the Æther hath a Body within the Tube, it readily falls down to the height supported by the pressure of the Air. The Reason of the two preceding Experiments, to wit, of the suspension of Water in the Tube whose end is stopped with a bundle of small Glass Pipes, as also of the suspension of the *Mercury* in the Tube whose end is stopp'd with the perforated peice of Brass, will be, I think, sufficiently manifest to him that shall thoroughly consider the Nature of the Congruity and Incongruity of Bodies to one another; somewhat of my Thoughts concerning the same I have formerly deliver'd in the *Of Congruity & Incongruity.*

sixth

sixth Observation of my Micrography, which was indeed but a cursory Meditation for the solving of the Phænomenon then mention'd; but whosoever shall thoroughly examine the Nature and Power of it, will, I dobut not, find it much more universal. To me indeed it seems to be not only the cause of this extraordinary *Phænomenon*, but of the Conglobation and Tenacity of most Liquors of the Tenacity Springyness, Sonorousness, Malleability, *&c.* of all solid and hard Bodies: But of this elsewhere when I have occasin to examine what is the cause of Congruity itself, which I do not suppose a first Principle, but rather of a second, third, or fourth Rank, which being more universal, must be ascended to by degrees, after the Synthetick method. To proceed then, I did heretofore propound in the twentieth Page of my Micrography as a thing worthy trial to examine what Power was requisite to force a Liquor through holes of several bignesses made in a Heterogeneous solid, and fill'd with some Liquor Homogeneous to that solid; for were that accurately done I judge this Experiment of the extraordinary height of the *Mercury* above the usual Standard would give us a demonstration of the bigness of the Pores of Glass; for since we find that a hole of------of an Inch will make the *Mercury* stand suspended one Inch in height a hole of-----of an Inch will make it stand suspended two Inches; a hole of-----of an Inch will make it stand three Inches, it will follow that a hole of-----of an Inch will make it stand forty five Inches, and a hole of-----of an Inch will make it stand a hundred Inches, which minds me of several other Experiments worth trial, for determining this controversy; such as these;

Several Experiments hinted

First, Whether some Glasses are not more porous than others, and consequently whether the *Mercury* will not stand to a much greater height in Tubes made of Glass of a more opacous or more refracting Substance than in Tubes of a more transparent or less refracting Substance.

2. Secondly, Whether in a Tube made of Lead very intire from holes and perfectly cleans'd of Air and rubb'd with *Mercury* that doth every where stick to the same; if the said Tube be fill'd with very well cleans'd *Mercury*, the *Quicksilver* will not stand suspended to a much greater height than it doth in Tubes of Glass, for if Lead, Silver, *&c.* be impervious to this fluid Substance that so freely penetrates Glass, it seems not improbable, but that the *Mercury* may stand suspended to a very much greater height, and if so it will be a certain way of finding out the force or pressure of this fluid; from the determination of which will follow probably the reason of the Strength, Weight, Sonorousness and Springyness of Metals. And I am the more inclin'd to believe that this Experiment will succeed, because I judge that the same fluid that conveieth height, is the cause of this Phænomenon; and whatsoever Body is perfectly impervious to Light, is also impervious to this fluid. But herein I would be understood not to mean such Bodies, as by the thickness of their bulk and some degree of opacousness, do intercept the direct passage of this fluid Matter, and so by consequence cause a kind of opacousness, as a thick Body of Red and Blew, *&c.* Glass which notwithstanding are not perfectly opacous Bodies, because, when made very thin, they are transparent of a Red or Blew Colour: For such Bodies tho' they may intercept the direct passage of the Light, yet may they admit the fluid freely to pass through their winding Pores, and so may not perhaps keep the *Mercury* suspended much higher than a Tube of Crystal-glass; whereas I am very apt to think, that if there could be a Tube made of a Substance perfectly impervious to this fluid Matter, the *Mercury* may possibly remain suspended as many Feet as it doth now Inches; but this trial will more fully inform. Now that a Body may be pervious to some Liquors and yet not pervious to Light, is evident by the Experiment of forcing *Mercury* through the Pores of Wood, for if you take a Pipe of Beech, Elm, Oak, Firr, Ash, or the like, of four, five, six, eight, or ten Foot long, and stopping one end thereof, you erect it with the open upwards and fill it with *Quicksilver*, you shall find that the *Quicksilver* will as freely and plentifully pass through the Microscopical or Imperceptible Pores of the same, almost as it will be strain'd through the Pores

A way to discover the Microscopical Pores of Bodies.

Pores of Cloath, Linnen or Leather, and will thereby so fill the Pores of the Wood as to make it feel almost as heavy as Lead; by this way I have been able to force *Mercury* into the Pores of Charcole, and divers other Vegetable Substances, whereby the Pores of the same are made very conspncious, by placing small peices of those Substances at the bottom of a Glass Tube of four, six, eight, or ten Foot long, and filling the Tube with *Mercury* over them; for those and most other Vegetable Substances, will, by the pressure of such a Cylinder of *Mercury*, be fill'd with *Quicksilver*, and thereby plainly discover the Shape and Texture of their Pores. I have not had the opportunity to try Bones, Horns, Teeth, Hair, Quills, and the like animal Substances this way, tho' it seems to me very probable, that their Pores may be discover'd this way, at least by lengthing the Cylinder, and making the pressure yet greater, or by a condensing Engine: Nay, I am inclin'd to believe, that *Mercury* may be forc'd even through the Pores of Glass itself if the Cylinder pressing be sufficiently lengthned; for by this Experiment of the suspension of *Mercury* at seventy five Inches high, it seems that *Mercury* has a greater Congruity to Glass then the pressing Fluid or Æther hath to the same, and therefore 'tis not improbable but that a force as great in proportion to the bulk of *Mercury*, as the force of the Æther is to the bulk of the Æther, may force it through the Pores of Glass, that it may be subtile enough to do it, seems probable from this, that it doth so readily penetrate the Pores of Gold, Tin, Lead, Silver, *&c.* those Bodies with whom it hath a perfect Congruity even with meer apposition and contiguity; and therefore 'tis not improbable but that a degree of force may make it penetrate the Pores of Glass, which in probability are much greater than those of the congruous Metals, especially since we find it can be forc'd into the Pores of Wood, Cork, Pith, Coles, *&c.* so as to drive out the Juices contain'd in them; whereas those Juices having a greater Congruity, do penetrate them by meer apposition. Now that this penetrancy of *Mercury* into Glass is not meerly conjectural, I shall shew you by taking notice of certain Spots or Stains which I have found in polish'd Looking-glass-Plates after they have remain'd a long while foil'd, and then being unfoil'd, for I have very plainly seen with a Microscope that there hath been in the place, where spots appear, an infinite number of exceeding minute Parts of *Mercury* which seem to be gotten into the very Pores of Glass, and can by no kind of rubbing be fetcht out without wearing away so much of the very Substance of the Glass itself: What therefore is thus done accidentally by duration, might in probability be much better done by pressure, if we were able to make it considerable enough, as by letting down Glass in *Mercury* to a very great depth under Water, where that can be done; or to a considerable depth under the pressure of *Mercury*. It may possibly be Objected, that if *Mercury* hath a greater Congruity to Glass than this suppos'd Fluid, why doth not the *Mercury* without much force penetrate the Pores of Glass at first, and so running through it, make it appear opacous. To which I Answer, That tho' I suppose *Mercury* to have a greater Congruity to Glass than this Subtile Fluid, yet that it hath not a perfect Congruity, but rather an Incongruity in respect of other Fluids that are more Congruous, as Air. Nor hath that a perfect Congruity, but rather an Incongruity in respect of Water; for there may be infinite degrees of Congruity, as Water salt hath more Congruity to Glass than Water fresh, Waters than Vinous Spirits, Vinous Spirits more than Oils, Oils more than Airs and Fumes, and they more than *Mercury*, and *Mercury* than this fluid Æther, or what other Name soever we call it by; and in every one of these degrees of Congruity or Incongruity there may be a multitude of other Subdivisions; as for instance, under the first Head there may be a very great variety; I know some, acid Liquours that will of themselves, without any force, penetrate the Pores of Glass so as to dissolve it into a Powder, whereas others will not at all penetrate or dissolve it by any means I have yet found: But this part of Congruity and Incongruity by which solid Bodies become dissoluble by Fluids, and whereby Fluids readily penetrate each other, and unite with one part of a Fluid, and separate or precipitate another, belonging to another Subject, I shall pre-

termit at present, and only take notice of some things that may be pertinent to the Inquiry under Consideration; and those may be these;

First, That there is no difficulty at all in admitting, that within the same Liquor, which to the sight appears uniform, there may be a greater variety of Fluids of differing penetrancy, for we find in *Aqua Regis* for instance, that there are the *Sal Armoniack* parts that help to penetrate Gold; the *Nitrous* that penetrate Silver, Copper, *&c.* the *Flegme* that will penetrate neither: There have been few Experiments made of the penetrating of one Fluid by an other, beside that I formerly shew'd of Water and Oil of *Vitriol*, 'tis a copious Head, and contains much of information; Copper and Tin melted are an example of it. From which Observation we may without difficulty suppose the Air (as it is commonly taken) to be a Body consisting of a great variety of Fluids, of which this Æther we supppse may be one; and possibly the principal which takes up the greatest space, and whose Effects are the suspension of *Mercury* above the height suspended by the pressure of the Air and the like; tho' yet I suppose it not the subtilest, there being many Experiments that do seem to require a much more subtile and penetrant Fluid, of which more elsewhere. The Elastical Part of the Air that causes the Phænomena of Springing a Second, the Steams of Bodies a Third, the Nitrous part a Fourth, each of which have several degrees of penetrancy, and may possibly be several distinct Fluids, tho' when blended altogether they make that compound Body, which we call the Element of Air. Now as the Air consists of a variety of Fluids, so 'tis not unlikely but that each of these may differ in their proportionate quantity, and in their respective Gravity; so that if we should take the whole bulk of the Air or Atmosphere we might possibly find it made up of divers Fluids, as of the Fluids *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H*, &c. and each of these of differing proprieties, both as to penetrations, Quantities and Gravity, Congruity, and the like; and that That part of it which is next the Earth might be a compound of the Fluids *A*, *B*, *C*, *D*, and *G*, *H*, extending to a certain number of Yards above the level of the Sea, the next part of the Atmosphere immediately above it may consist of *B*, *C*, *D*, *E*, and *G*, *H*, and have nothing of *A*, or *F*. The third Region may consist of *C*, *D*, *E*, *F*, *G*, *H*, and have nothing of *A*, or *B*: And this seems probable, First, because we find that there are several distinct Surfaces of the Air, upon which the several Regions of the Clouds seem to swim like Froth upon the Surface of Water; for 'tis obvious to any that shall observe it, to see the under Surface of the Clouds smooth and level, and the upper in confus'd heaps, and further, that all the under Surfaces of Clouds appearing at the same time lye as near as one can judge by the Eye in the very same Level. Next that the make of the Clouds in a higher Region are quite differing. Thirdly, that the parts of the Air in several heights from the Earth, have differing proprieties, as it hath been found in very deep Wells, that the lower twenty Fathoms were all possess'd by a Damp, or an Air in which no Fire would burn, or Animal live. We are inform'd also, that the Air at the top of some exceeding high Mountains is of such a Nature as will not serve for Respiration. Possibly the presence of *A*, in the lowest, may be the cause of the first Effects and the want of *B*, at the tops of Mountains may be there the cause of those other Effects.

Variety of fluids in the same Liquor.

Tab. 8. Fig. 4.

In

IN the following Lectures the Reader will find a Confirmation of the foregoing Treatise of Earthquakes and their several Effects or Consequences, as likewise of the Corrollaries raised from them, and tho' they are not all here Printed in the order of time they were read, I think that is excusable, since I thought it more proper to joyn those Tracts together that related to the same Subject than interpose others of far different Matters. In these our Author endeavours to confirm his former Hypothesis by Histories; and in the first place by two very remarkable ones, the first that related by Plato *in his* Timæus, *the other that of the Circumnavigation of* Hanno *the* Carthaginian. *The next Discourses contain the interpretation of several of the Fables of* Ovid's Metamorphosis; *how the Learned will receive them I know not, but in my Opinion they are at least very plausibly explain'd.*

R. W.

I Have indeavour'd to discover and prove the true Figure of this Body of the Earth upon which we Inhabit, and likewise to give some Conjectures concerning the *Form* and *Shape* of the *Superficial* Parts thereof. This I have done in order to comply as near as I could with a Natural Method of Natural History: This great Body being the Mother of all Terrestial Productions, which make up the greatest part of *Natural History*; and the Foundation, as it were, upon which, not only all that History, but all the other Parts and Superstructures almost do rest; for from the Productions of this we take our Principles, we raise our Axioms and Maxims, we form our Similitudes, we make our Observations, Experiments and Trials, and by Analogy from Comparison and Similitude we deduce our Conclusions. I thought it therefore not improper, since Natural History will carry us into forein Parts of the World, very far remov'd from this our Country of the Earth, to be first of all a little acquainted, at least, with what we have at home, that thereby we may the better be able to observe and judge of what those far remote Parts may present us with, whether they be like our own or not, in what they agree, and in what they differ, that these we know at home may be the Standards and Touch-stones of all the rest we meet withal Abroad.

In prosecution of this Method, I began first to shew what seem'd to me to be the most likely Figure of the whole Body, which I shew'd for several Reasons seem'd to be of a prolated Sphæroidical Figure, not of a perfectly Globular, as most Authors suppose and affirm, much less of an Oblong Oval, as the ingenious Author of the sacred Theory of the Earth, and some others, have indeavour'd to make probable. *Of the Figure of the Earth, &c.*

From this I deduc'd the prolated Sphæroidical Figure of the Waters also, and more eminently of the Air or Atmosphere, and from that deduc'd these Conclusions, That the Lines of Gravitation or Perpendicularity did not tend to one single point, as all hitherto have asserted, but to infinite points in the middle parts of the Axis.

And that a Degree, or a 360th part of the *Æquinoctial* did not agree exactly with any one Degree in a *Meridian*, and thence that the Magnitudes of the respective Parallels were not to be estimated as if the Body were truly Globular.

From this I deduc'd a necessity of a differing Gravitation of the same Body in differing parts of the Earth, and thence a necessity of a differing length of Pendulums to measure by their Vibrations the same quantity of time, by which the universal Standard of Measure, by some suppos'd from the length of a Pendulum, became questionable and dubious.

I have likewise shewn what Observations of Celestial Bodies were likely to be assistant to the perfecting and confirming of these Matters, at least of discovering the Truth whether really so or not.

I have also inquir'd concerning the fixedness and instability of the Terrestial Axis, and shewn some Arguments to induce us to believe that it may have and suffer a mutation, and not be always fixt in the same parts of the Earth, and by what methods that may be ascertain'd in a short time with more exactness than

than many Ages of Obſervations made with leſs accurateneſs would have done.

And from thence I have deduc'd what would be ſome of the neceſſary Conſequences of ſuch a mutation; ſuch as the differing Latitude of places in differing Ages. The differing Azymuth of Places as to one anothers Poſition; the differing Altitudes of Places with reſpect to the Superficies of the Sea, as the Emerging of ſome places from below that Surface and the ſinking under, and the being overwhelm'd by that Surface in others, and conſequently of changing the Nature, Soil, Climate, *&c.* of the ſuperficial Parts of the Surface; to which, as I conceiv'd, ſome alterations might be aſcribed.

But Laſtly, I ſhew'd that the ruggedneſs and inequalities of Hills and Dales, Mountains and Lakes, and alſo the alterations of theſe ſuperficial Parts of the Earth, as to the ſeeming Irregularities thereof at preſent, ſeem'd to me to be moſt probably aſcribable to another Cauſe, which was Earthquakes and Subterraneous Eruptions of Fire. That there had been many ſuch alterations I indeavour'd to prove from the almoſt univerſal Diſpoſition of thoſe curious Medals of former Ages now found in the petrify'd Monuments of the parts of ſeveral both Terreſtial and Aquatick Animals and Vegetables, but eſpecially by thoſe Productions of the watery Element found in places now far remov'd from the Sea, and far above its Level; of which I have produc'd ſeveral Inſtances, ſome of which, and thoſe very conſiderable, were procur'd by the inqniſitiveneſs of a Perſon here preſent.

I have made ſome Excurſions out of this Method; as Firſt, in order to anſwer the Doubts and Scruples of ſome, and the Obloquies of ſome other Perſons, who, I hope, are now, or will be ſomewhat better ſatisfy'd, which I wiſh all might be, for I have no deſire to impoſe Conjectures and Inquiries as Demonſtrations, but only to ſhew what Arguments have inclin'd me to be of theſe Opinions, which, whether ſufficient, I muſt leave to their better Judgments and Examinations, hoping at leaſt that no prepoſeſſion will hinder them from examining them with Candor and Indifference, as I indeavour to do in all my Inquiries. Next by ſome Experiments made for the clearing ſome accidental Diſcourſes at the meeting, as thoſe about the beſt ways of communicating force at a diſtance, and of making a Pendulum to obſerve by Trials the Velocities of the parts of Pendulous Vibration, and to make a Pendulum that ſhall, without Clock-work, continue moving twelve Hours or longer. And Thirdly, By accidental Obſervations made of the growth of Trees and ſome others; nor will it, I hope, be taken amiſs that I indeavour to produce ſuch Arguments as occur to me, that ſeem to favour theſe Conjectures, tho' poſſibly much better may be ſhewn by others eithers for or againſt them; however give me leave to alledge what I can to anſwer ſuch as I conceive are not ſufficiently cogent Arguments againſt what I have ſuppoſed.

One of the moſt conſiderable Objections I have yet heard, is, that Hiſtory has not furniſh'd us with Relations of any ſuch conſiderable changes as I ſuppos'd to have happen'd in former Ages of the World; I do confeſs our Natural Hiſtory as to theſe and many other matters of the firſt Ages is very thin and barren, but yet I conceive not wholly devoyd of Inſtances, nay, poſſibly if they be look'd into with a little more attention than hitherto has been uſed, they may be found to contain many more than has of late Ages been imagin'd. Some things of this kind, I fancy I have detected, of which I ſhall produce ſome, together with ſome Remarks upon them, which I have added, they are, I conceive, related as true Hiſtories; but whether ſo or not I muſt leave others to judge who are better Antiquaries and Criticks.

An Account of the Atlantis out of Plato's *Timæus.*

What Learning and Accounts of Ancient Times the *Ægyptians* might have in their Hiſtories, who are ſaid by *Plato* in his *Timæus*, to have had accounts of great alterations in the World for nine thouſand Years before *Solon*, which is now above two thouſand Years ſince, it is very hard to gueſs from that ſhort account that is there given of it; yet ſince of all the Records that are to be met within the Ancient Hiſtorians to this purpoſe, this is the moſt conſiderable, I thought it would not be improper to relate it on this occaſion, by reaſon that tho' it ſhould be accounted *fabulous*, as ſome have thought, and to

to be only a Fiction in *Plato* in order to lay a Scene for his Republick; yet there is so much of Probability in it (bating only his number of Years) and so much of Reason and Agreement with the State of things, that if it be not a true History, it will at least shew that *Plato* himself had, at that time, some such Notion or Imagination of the *Preceding State of the Earth*, and that he saw, or found at least, some very good Arguments for his being so; *Plato* then in his Dialogue maketh *Critias* thus speak, 'Hear, O *Socrates*, a wonderful indeed, but yet a true History, which *Solon*, the wisest of the seven Wise Men, related to my Grandfather *Critias*, as the old Man hath since told me; among other things he told me of the memorable Actions of this City (*Athens*) by length of Time, and Death of many, quite obliterated. But among the rest he related one remarkable Passage, which I think now proper to acquaint you with, and it was an old History, which he being then about ninty Years old, told to me when I was about Ten, upon a solemn Day, when I, with divers other Boys, as the Custom was, were wont to recite divers Verses by Heart to see which could excel, among which were divers Verses of *Solon*: And I remember I heard my Grandfather then say, that if *Solon* had but committed to Verse, not what he did for refreshing of his Mind, but seriously, and like other Poets, the History, which he, returning out of *Egypt*, resolv'd to have written (from which, by disturbances which he met with at home, he was interrupted in perfecting) neither *Homer*, *Hesiod*, nor any other Poet, would have been comparable to him. This was of the greatest Affair that had been transacted by this City, of which we have no remains at present, by reason of the length and injury of Time. The summ of what I remember was, That *Solon* going into *Egypt* to *Saim*, at the Mouth of the *Nile*, when *Amasis* was King, was there receiv'd honourably. There he inquiring of those Priests which were most skilful in those Matters concerning the Memorials of great Antiquity, found, as he related, that neither himself nor any other Greek knew any thing of Antiquity; and when he to provoke the Priests to tell him some of their Knowledge, had, in there presence, spoken concerning the most antient Actions of the *Athenians* of *Phoroneus* and *Niobe*, and of *Pyrrha* and *Deucalion*, after the inundation of the World, and of the times when those had happen'd; one of the Seniors of the Priests cried, O *Solon*, *Solon*, you Greeks are all Boys, not one Old Man among you. *Solon* asking him why so? The Priest answer'd, beeause you have young Heads always that contain nothing of ancient History, of ancient Opinion, or of Old Mens Science, which has happen'd to you by reason that there have been already, and shall be many and various Destructions of Men: But the greatest of all will be caus'd necessarily, either by a Conflagation of Fire, or an Inundation of Water; but the lesser by innumerable other Calamities: For what you tell of *Phaeton*, the Son of the Sun to have got into his Father's Chariot, and not knowing how to Drive like his Father, had fired the Earth, and with that Flame had almost set Fire to the Heavens, tho' it may seem fabulous, yet 'tis not without its truth in some sense. For in long process of time there is a certain *permutation of the Celestial Motions which a vast Inflammation must necessarily follow.* Whence such as inhabit high and dry Places will suffer more than such as are nearer the Sea and Rivers. Now our *Nile*, as it is in most other things very wholesome for us, so will it preserve us from such a Destruction. But when the Gods of the Waters shall wash away the Filth of the Earth by a Flood, those which feed Sheep and other Cattle at the tops of the Mountains will scape the danger; but your Cities that are situated in the Plains, by the impetuosity of such Floods will be swept into the Sea. But in our Region we have no Water descends from above, but all ours springs out of the very Bowels of the Earth; which is the reason that with us the Records and Monuments of the most antient things are safely preserved. Whence it comes to pass, that where neither too great a Storm of Rain nor any extraordinary Fire happens, tho' sometimes more, sometimes fewer, yet still some Men always escape. Now whatever we hear that is worthy notice, either acted by our selves, you, or any other Nation we keep described in our Temples: With you indeed, and other Nations things lately

'done have been committed to Writing, and preserved by other Monu-
'ments. . But in certain periods of Time there come from the Heavens cer-
'tainDestructions which depopulate all; whence the followingGenerations are
'depriv'd both of Letters and Learning. Whence you are all again made
'Boys, rude, and altogether ignorant of preceding Matters. Hence 'tis that
'what but now you speak of, O *Solon*, differs very little from Childish Fa-
'bles. First, In that you make mention but of one Inundation, whereas
'many have preceeded. Next, That the stock of your Ancestors which was
'most Eminent, and of the best, you know nothing of; whence both thy self
'and the other *Atheneans* had your Birth, which was a small Remnant that
'scaped the publick Destruction: Which becomes unknown to you; for that
'this Remnant and their Posterity for many Years wanted the use of Let-
'ters; whereas your City before that had excelled both in the Arts of War
'and Peace, of which we had a full account. [So he proceeds to tell how they had Records of their own City for nine Thousand Years, and of the Laws, *&c.* as also, of long times for *Athens*, which I pass over, and only mention what seems to relate to Natural History.] He proceeds then,
'Many wonderful Actions of your City are preserved in our Monuments;
'but one above the rest for Greatness and Virtue exceeds; for 'tis said, that
'your City resisted a numberless company of Enemies, which coming out of
'the Country where the *Atlantick-Sea* now is, had conquer'd almost all *Eu-*
'*rope* and *Asia*; for at that time was that navigable Streight which is call'd
'that of *Hercules Pillers* which had near the Mouth, and as it were in the
'very entrance of it, an Island then said to be bigger than *Lybia* and *Asia*,
'through which was a Passage to other Neighbouring Islands, and from the
'Islands was a prospect to the main Lands lying near the Shoar, but the
'Mouth of the Streights was very narrow. This Sea was truly the Ocean,
'and the Land was truly a Continent. In this *Atlantick Island* was a most
'great and wonderful Power of Kings, who Rul'd over, not only that whole
'Isle and many others, but over the greatest part of the Continent, and e-
'ven over those which were near us, for they Reigned over a third part of the
'World, which is call'd *Lybia* even unto *Ægypt*, and over *Europe* even to the
'*Tyrrhene* Sea; the whole power of these collected together, invaded both
'ours and your Country, and even all the Lands within the *Herculean*
'Streights, but both your and our Country repell'd them; the manner I o-
'mit. Afterwards by a prodigious Earthquake and Inundation which hap-
'pened in a Day and a Night, the Earth cleaving swallow'd up all those War-
'like Men, and this Island of *Atlantis* was drown'd by a vast Inundation of
'the Sea, by which means that Sea became unnavigable, by reason of the Mud
'of that sunken Island which was left. the rest I omit.' Now,

Whether this Relation be a Fiction or Romance invented by *Plato*, or a true History, I shall not now dispute, only by all the Circumstances of *Plato*'s relating of it, I conceive he design'd to have it to be reputed a true History and not a Romance, for that his design for laying a Scheme for his imaginary Government, needed no such Fiction, and accordingly he made very little, if any, use of the Circumstances of it that relate to Natural History. However, be it what it will, it evidently shews that *Plato* did suppose and believe that there had been in many preceding Ages of the World, very great changes of the superficial Parts of the Earth by Floods, Deluges, Earthquakes, *&c.* for as much as he could suppose a Continent or Island as big as the third part of the known Earth, to be by one Earthquake sunk into the Sea and overwhelmed by it.

I think therefore I may at least conclude, that divers of the Antients, and particularly *Plato*, had some knowledge of past Catastrophys of some parts of the World. And those to have been caus'd by Earthquakes and fiery Eruptions, such as had sunk some places into the Sea and rais'd other places out of it, of great Floods also and Inundations by Rains and Eruptions of the Sea: And that some of those had happened in *Greece*, others without the Streights Mouth, and others elsewhere, and at another opportunity I shall produce a Cloud of Witnesses to this effect, which, I conceive, will put it past dispute. but because this Relation has been possibly too long, I shall only add one Re-

lation

lation more, because it seems to relate to the remainders of the Island of *Atlantis*, and it seems to be of a later date much than the *Egyptian* Stories.

That which I mean is the History of the *Periplus* of *Hanno* the *Carthaginian*. When it was writ I know not, but sure it was very ancient, 'tis lately in the Year 1674, Publish'd by *Abrahamus Berkelius*, with some fragments of *Stephanus Byzantinus*, with the Commentaries of *Gesnerus* and *Bochart*, being but short I have put it into English.

The History of Hanno's Circumnavigation

It pleas'd the *Carthaginians* that *Hanno* should sail beyond the Columns of *Hercules* and build *Lybyphenician* Cities, he went then with sixty sail of Ships each rowed with fifty Oars, in these were transported to the number of 30 Thousand Men and Women with necessary Provision and Stores. After we had sailed two Days without the Columns; the first City we built we call'd *Thymiaterium*; under this lay a large Plain, thence carried Westward we made *Solunte* a Cape of *Lybia* cover'd with Wood, where having built a Fane to *Neptune*, we tacked about and sailed πρὸς ἥλιον towards the South, half a Days sail into a Lake not far from the Sea, filled with many and large Canes, where were fed Elephants and various other wild Beasts; having passed this Lake in one Days sail, we built those Maritime Cities, *viz. Caricus*, *Gytte*, *Acra*, *Melissa* and *Aranibys*; sailing thence we arriv'd at the great River *Lixus* which falls out of *Libya*. Near this the *Nomades* (a sort of Grasiers or Cattle-herds) and *Lixitæ* feed their Cattle, with these having made Friendship we stay'd sometime. Beyond this the savage *Æthiopians* live, whose Country is full of wild Beasts, and intercepted with great Mountains from which the *Lixus* flows. Those Mountains the *Troglditæ* inhabit a strong sort of People swifter in Running than Horses, as the *Lixitæ* told us. From hence we coasted two Days Southwards, and then one Day more πρὸς ἥλιον and in a Bay found a small Island five Stadia in Compass, where we left some Planters and called it *Cerne*; this, by the Journal of our Voyage, we judged to be in the same parallel with *Carthage*, and as far without the Columns as *Carthage* was within. Hence we enter'd a great Lake, through which past a great River, which we called *Chreses*. There we found three Islands bigger than *Cerne*. From these in a Days Voyage we reach'd the inermost parts of the Lake: It was incompassed with vast Mountains, inhabited by Savages, who threw Stones at us. Thence sailing we past a large River full of Crocodiles and Hippopotams, and return'd to *Cerne*. From hence we past twelve Days by the Coast towards the South, all inhabited by *Æthiopians*, much afraid of us, and not understood by our Interpreters; the last day we discover'd great Mountains covered with Woods, which were of various Kinds and Odoriferous. Coasting round these Mountains we found an immense opening of the Sea, that side which was next the Continent was a plain Country, from whence by Night we perceived Fires from all places, some greater some lesser Watering here we Coasted along for five Days till we came to a great Bay, which they called Εσπέρου κέρας Here we found Lakes and Islands, where landing we found nothing by Day but Woods, but in the Night we saw many Fires, and heard an innumerable noise of Drums, Trumpets, Cymbals, and the like; wherefore being afrighted, and our South-sayers commanding us also to leave it, we Coasted χωρὰν διάπυρον θυμιαμάτων the burning Coast of stinking Vulcano's, from whence there run out into the Sea Rivers of Fire, and the Earth was so burning hot that our Feet could not indure it. Hence therefore we hasted and for a Days sail we saw all the Land full of Fires in the Night; but in the middle of these was one vastly bigger than the rest, so that it seem'd to touch the Stars; this, in the Daytime, we found to be a prodigious high Mountain call'd θεῶν ὄχημα or the Chariot of the Gods, in three Days sail more we past all the fiery Rivers, *&c.*

The reason why I have been so particular in translating the whole Story, is because I conceive it is an instance in History so considerable, especially as to the preceding Relation of *Plato*, that I can hardly believe there is a better Instance to be found. *Plato* tells us of the Island of the *Atlantis* that it was by an Earthquake some Thousands of Years before him sunk into the Sea, but yet so that it left many Lakes and unnavigable Places. This gives us a

Re-

Relation of a Navigation (over the very place where the *Atlantis* was placed and sunk by the former Relation) in the times of *Philip* of *Macedon*, or sooner, as some suppose; these Navigators find the Coast of *Africa* without the Mouth of the Streights to trend Westward almost πρὸς ἑσπέραν *ad Occasum*. *Gesner*, in his Notes upon this place, seems a little startled, and says, *At qui mihi videtur ambientibus Africam omnis post columnas Navigatio converti vel ad Meridiem vel ad Orientem & postremo ad aquilonem*; not thinking, I suppose, of this Supposition. He seems also to be as much to seek about the situation of *Cerne*, but at last he thinks it may be the *Maderas* (p. 85.) which I conceive to have lain North-westward from it, but with divers Gulphs and Bays in which were divers great Lakes and Islands, divers Mountains likewise and some Rivers. But which is most considerable, a great part of this Island to the South was then all on Fire. Now comparing this Relation to the present State of those parts, we find all that Continent which they passed by between the Columns and *Cerne*, to be wanting, for 'twill be hard to reconcile the Relation with the present State of that Country, so in probability sunk and co-ver'd with the Sea; for *Cerne* by this Description, lying in the same Latitude with *Carthage*, and as far from the Pillars without as *Carthage* was within, it must have lain to the North or North-west of the *Maderas*, from which place the Coast of the main Land seemed then to trend South for twelve Days Voyage as far as the *Canary Islands* are now found, or somewhat farther, from whence it turned away to the Eastward. About these Islands, I conceive, was the Land that was all on Fire, multitudes of which they saw in the Night, and heard the noise of the Vulcanes, and Rivers of Fire running into the Sea, and in some places found the Earth so hot as to burn their Feet. That which directs me the better in this Conjecture, is the prodigious *Vulcano* mention'd, called θεῶν ὄχημα the Chariot of the Gods, by reason of its prodigious height, seeming to touch the Stars. This, in all probability, seems to have been the same with the present *Pike* of *Tenarif*, which tho' it burns not now, yet, yet there are present Evidences enough, as I have been told by those who have been at the top of it, to prove it to have formerly been a *Vulcano*. And if they had now been wanting, yet no longer since than *Sebastian Munster*'s time it was known to be so, and in his Geography he has so described it. Besides, this by late Example, as in 1639, and by a latter in *Ferro*, which I have Printed, it appears, that those Vulcanoes are not Strangers to those Parts even in this Age: But I have detained you too long with those Conjectures, yet if all Circustances be examined in the Relation of *Plato*'s *Atlantis*, and in that of *Hanno*'s *Periplus* and compar'd with the present Condition of those Parts, I conceive there will appear many Reasons to make us conclude that there have been in those parts prodigious alterations somewhat like those I have supposed in my Hypothesis, which may serve as an instance of History for such Mutations. The next opportunity I shall produce many other, which, I conceive, will as plainly speak the same thing, according to the Mind and Intention of most of the Ancients, and this is to take off the odium of Novelty.

After the foregoing Passages quoted out of *Plato*'s *Timæus* and the *Periplus* of *Hanno*, I shall adventure to present this illustrious Assembly with some of my Conjectures at the meaning of the Fables of the Poets, but first to say something as to that of *Plato* and of the *Periplus*, which last is suppos'd by several Authors to be very Ancient. From both those Relations compar'd together, there seems at least to result a probability, that there has been some great changes of the superficial Parts of the Earth, where the now *Atlantick* Ocean without the Streights of *Gibraltar*, as they are now call'd, is; and then we have certain Histories now to prove that the main of *Africa* or *Libya* hath extended Westward beyond the *Maderas*, and Southward as far as somewhat farther than the *Canaries*. I have given the Reasons why I entertain'd those Conjectures, which I submit to the Judgment of such as are more knowing and better read in Historical Matters.

Varro

Varro has distributed the Ages of the World into three, *viz.* the ἄδηλον, μυθικον, and ἱςορικὸν of the ἄδηλὸν we know nothing from Heathen Writers; of the μυθικὸν we must look for an account from the Fables of the Poets, *Homer*, *Hesiod*, *Ovid*, &c. *Ovid*, to pass by *Hesiod* and *Homer*, is said to have imitated the Greek Poet *Parthenius*, and has left us a very large History of the changes that had anciently happened in the World, his whole Metamorphosis, being, as I take it, written for that purpose: We are extreamly obliged to *Pliny* and some few others, as all well know, for what they had collected out of others, or wrote from their own Observation and Knowledge.

Now, that *Ovid*'s Metamorphosis was penned for this end we may find by the 4 first Verses.

In nova fert animus mutatas dicere formas
Corpora, Dii cœptis (nam vos mutastis & illas)
Aspirate meis, primaq; ab origine mundi
In mea perpetuum deducite tempora carmen.

I sing of Beings in new shapes array'd,
Assist ye Gods (for you the Changes made,)
That from the Worlds Beginning to these Times
I may comprize their Series in my Rimes.

That is the time of *Augustus Cæsar* in which he Lived.

The Hypothesis in *Ovid* (for I conceive it only an Hypothesis in him) is this, that the præ-existent Matter of the World was first, a quantity of Matter without any particular form, *Rudis indigestaq; moles*, a rude disorder'd Mass, and yet it had the property in it which (when directed afterwards to some Center) was weight, which as yet he calls *Pondus iners* unactive weight. Secondly, It had in it the seminal Principles, which were afterwards to effect the Productions, these he calls *discordia semina rerum*, the jarring Seeds of things, as being then *non bene junctarum*, not well conjoined, no not to form the Sun, Moon, or the Earth, the primary or secundary Planets, *Nec circumfuso pendebat in aere Tellus, ponderibus librata suis*, nor did the self-poiz'd Earth encompast round hang in soft Air; these Verses do seem to glance at an *Hypothesis* I have formerly acquainted this Society with, somewhat of which Mr. *Newton* hath Printed. *Tellus*, *Pontus & Aer*, Earth, Water, and Air were yet all confounded with each other, like Mortar or Mud. *Instabilis Tellus innabilis unda.* The Earth unstable, Waves for Keels unfit, which it comes to attain afterwards, and remains so for sometime, till by degrees again it lost it when *Astræa* left it, which was just before the Gygantomachia; for *Astræa*, as I shall by and by make appear, is the Virgin and primitive Smoothness and Stability of the superficial Parts of the Earth, from (α) the first or Primitive, as (α and ω) *Alpha* and *Omega*, and σὲρνα stability, *Et Virgo cæde madentes ultima Cælicolum terras Astræa reliquit.* The last of Deities from Blood polluted Earth *Astræa* flies; for like moist Pap or Mud, by degrees the watery and Aerial exhaleing, it settled into a smooth, tender, and uniform Substance, like the Youthful and Virgine Constitution, but a farther separation of the Fluid Parts makes the Earthy, Dry, Rough, Rincled and Chopt; inclining to the Countenance and Constitution of Age, and the Virgin Beauty is fled: For a while there was a jumble, *Corpore in uno, frigida pugnabant Calidis, humentia siccis, mollia cum duris*, the Cold, the Hot; the Moist, the Dry ones fight; the Soft, the Hard, all incorporated strove together, *Sine pondere habentia pondus* with weight, yet weightless, that is, they all being Bodies had a capacity of being weighty, but a gravitating or attracting Center not yet being existent, they had no actual Gravity any way; but so soon as *hanc Deus & melior litem Natura diremit*, God and the better Nature ends this War; that is, God and Nature had made the gravitating Center, presently the heavier descend towards it, the lighter rise from it

Et Cœlo tærras & terris abscidit Undas
Et liquidum sprisso secrevit ab aere cælum.

From Sky the Earth, thence Floods divided were,
And liquid Æther from the thicker Air.

The Atmosphere inclosed the Ball, and was distinct from the Æther; 'tis remarkable that he makes the Water the lowest in this and the following Account.

Ignea convexi vis & sine pondere Cœli
Emicuit.

Of the convex and weightless Heav'n the bright
And fiery Power shin'd forth.

He seems to make it by the word *Emicuit* to be at the first encompassed with a shining Fire like a Star or Sun, for its place was *in arce*, above all; within this was Air.

Proximus est aer illi levitate locoque.

The next to this in weight and place is Air.

The Earth is assigned next.

Densior his Tellus Elementaq; grandia traxit,
Et pressa est gravitate sui.

Prest by its weight Earth sinks, to which repair
The heavier Elements.

And the Water lowest.

———Circumfluus humor
Ultima possedit solidumq; coercuit orbem.
The Floods at last sink in
From every side, yet leave a spherick Skin.

So that it seems there was a notion that the middle part of the Ball of the Earth was filled with Water as well as the outside covered with it: To which also agrees *Des Cartes* Theory and that of the ingenious Dr. *Burnet* in his *Theoria Sacra.* Thus far, I suppose, it will easily be granted that the Poet gives us a short History of the formation of the Earth, and 'tis as plain that the twenty eight Verses following are to the same effect, wherein he describes the cutting and forming the Face of the Earth into Lakes, Seas, Rivers, Hills, Dales, *&c.* the dividing the whole into Zones, and assigning the use of Air, for Clouds, Rain, *&c.* nor has he yet Personated or Mithologized any thing, but in the twenty ninth Verse following, *viz.* The sixtieth Verse of this first Book he begins calling the Winds Brothers, *Tanta est discordia fratrum*, &c. the Sense of all the rest is plain till the eighty second Verse, where he begins again to personate Actions Mythologically; for speaking of the formation of Man,

———Natus homo est, &c.
Sive recens tellus seductaq; nuper ab alto
Æthere cognati retinebat semina Cœli;
Quam satus Japeto, mistam fluvialibus undis,
Finxit in effigiem moderantum cuncta Deorum.

Man's

Man's Born, *&c.*

--------Or th' Earth new gain'd
From nobler Æther, some Seeds still retain'd
To Heav'n ally'd, which Earth Prometheus *took*
And mixt with Waters of a living Brook
Made Man like th' all-commanding Deities.

From this place onwards he seems to Mythologize the most part of his History, of which he gives notice in the eighty sixth and eighty seventh Verses.

Sic modò quæ fuerat rudis & sine imagine Tellus
Induit ignotas hominum conversa Figuras.

So what was rude and shapeless Earth, puts on
When chang'd, the unknown Character of Man.

Hitherto he had spoken of things as Dead and Unactive Earth, but from hence forth he will describe the Earth as changed and clothed with the various shapes of Men and Persons, and so having described the Formation or first Generation of all things Physically and plainly, he comes next to tell the Age or Ages of the World, and what Periods of Life or Being it hath had, and the States it hath been in during those several Periods.

The first Age or Chilhood of the World he calls the Golden Age: Gold is soft, flexible the most ductile of Metals, it has the best Lustre, and has always had the greatest Esteem. This state of the Earth he represents to be like that of Childhood, wherein all things are gay and pleasant, all things flow plentifully and smoothly; the Skin or Shell is yet smooth, succulent and soft, moisture and heat abound; so that things sprouted forth and flourish: There is a continued Spring, all things are Budding, Blossoming, and bearing Fruit at the same time, no need of Art as yet to help the progress of Nature forwards; or to regulate it, no one part of Nature intrenched, invaded, or hindred the free progress of another; there was plenty and enough, for all Rivers flowed with Milk and Nectar, and Honey drop'd from the Leaves of Trees.

All these Poetical Expressions, which the Author seemeth to speak, as of Men, and their Actions, and Enjoyments, I take to be significative of all acting Powers of the Earth whether Vegetative or Animal, *Per se dabat omnia tellus, Ver erat æternum. Sponte sua sine lege fidem Rectumq; colebant.* The Earth gave all things of itself, Spring was Eternal, and Justice observ'd without Law, *&c.*

Now, tho' all that happened in those times of the World, fell within the Age which *Varro* calls the *Adelon Tempus*; that is unknown as to the Heathen Writers, yet I look upon this Account almost as considerable, if not more, than those things which fall within the Mythologick; for I take this to be the Summe and Epitomy of the Thoughts and Theories of the most ancient and most knowing Philosophers among the *Ægyptians* and *Greeks*; and howmuchsoever there may be some who slight and neglect and villify the Knowledge, Doctrines and Theories of the Ancients, which Humor I am apt to think proceeds from their ignorance of what they were, and the difficulty of attaining the knowledge of them: Yet certainly former times wanted not for Men altogether as eminent for Knowledge, Invention, and Reasoning as any this present Age affords, if not far before them; for if we do believe a time of the Creation or Production of this Earth (as we have somewhat more of Argument to persuade us than possibly the Heathens had from the History thereof written by *Moses*) then 'tis very rational to conclude, that in the more Youthful Ages of the World, there was a much greater Perfection of the Productions of it, and that before those many and great Alterations and Catastrophies that have since happened, and before the senile Iron and decaying Ages of the same, wherein every thing by degrees grew more Stiff,

Rocky,

Rocky, Unactive and Barren, and so a degeneration of the Productions thereby seems a necessary Consequent. In the times, I say, that preceded all or many of these, it seems very rational to conclude, that it might produce Men of much longer Life, bigger Stature, and with greater accomplishments of Mind (of all which we have very good Testimonies without the Argumentations, Histories, Traditions or Theories of the Heathen Writers) upon which account tho' this Description of the Genesis of the Earth, and the first Age of the World should be supposed to be but the Theory or Philosophy of some of the most eminent Men, as *Orpheus*, *Pythagoras*, &c. in Ages so much nearer to those more active Ages of the Earth, yet, upon that account, they may, I conceive, be well worth our inquiring into, to see, at least, how Consonant those things are which they thought Reason, to that of ours at this present. Some possibly may be of *Aristotle*'s Opinion that the Earth was eternal: But I am apt to think that such as are so, have not so fully consulted their own Reason and Experience, nor much troubled themselves with that Speculation. We found that the *Ægyptian* Priests by that Passage I quoted out of *Plato*, had the notion of the *Genesis* Mutations, Catastrophies, by Fire and Water, and the like of the Earth, if we will not allow them to have the History of them, or the Accounts of so many 1000 Years as *Plato* mentions. But it will by some be required perhaps, by what means can we judge of any such preceding Age? I answer, That possibly the petrified Shells that lye in the Repository, and the prodigious Bones and Teeth that have been found buried in the Earth, of which the Repository affords some instances, and more might be fetched elsewhere: These, I say, might to some unprejudiced Men prove Arguments, but for others 'tis best to let them enjoy their own Thoughts. But to return to the Subject I was indeavouring to prove, namely, That the Metamorphosis of *Ovid* was a continued account of the Ages and Times of the duration of the Earth. I say, so far as I have gone, namely, to the end of the Golden Age, none will doubt but that this was the design of it, to relate what were the most celebrated Opinions concerning its Formation and first Ages, and as I conceive more particularly that of *Pythagaros*, who had spread and left his Doctrines in *Italy* long before *Ovid*'s time.

We come next to the 313 Verse where he begins to give an account, tho' very short, of the Youthful time of the Earth, which he calls the Silver Age. *Postquam Saturno tenebrosa in Tartara misso, Sub Jove Mundus erat, Subiitq; argentea proles.* After a long time was past and buried in Obscurity, the World had got a new Face and was under the Regiment of *Jupiter*, which signified the *Æther* and *Celestial Fire*; before this 'tis said in the Golden or Infant Age of the World, *Ver erat æternum; placidiq; repentibus auris, mulcebant Zephiri natos sine semine flores.* The Air and Earth was moist and tepid, which made a continual Spring, but now that moisture is dried up, and fervour, heat and drineſs is got into the Air. *Subiit argentea proles*, now *Jupiter antiqui contraxit tempora veris, perq; hiemes æstusq; & inæquales Autumnos, & brene Ver, Spatiis exegit quatuor annum.* This ingress of *Jupiter* caused those strange changes in the Air, that we in part now feel; for 'tis not immediately the heat of the Sun that makes that difference in the heat of the Air, tho' that be also a Cause. But as I shall have occasion to treat in an other place 'tis the Constitution of the Air, nor is it the oblique Radiation (as all which one consent affirme) nor the nearness to, or distance from the Sun, but it is the ingress of *Jupiter* that makes the Air susceptible of these Mutations. *Tunc primum siccis aer fervoribus ustus canduit*, &c. then entered Lightening and extraordinary Heats; and so he proceeds in the description of the other Seasons and Constitutions of Air, *Semina tum primnm longis cereolia Sulcis, obrnta sunt*, &c. The Earth being now dried having lost much of its Infant softness and moisture, needed some helps to make the Seeds grow. After this iuvenile Age was past over, then *Tertia post illem successit a henea proles, Sævior Ingenio & ad horrida prompior arma, non Seclerata tamen.* All the aforesaid Qualities increased, the Earth growing drier and drier, and the Air more intmperate, but yet it produced no direful Effects of terraneous or aerial Catastrophies. But *De Duro est ultima ferro.* Now the Shell of the Earth is Petrified, and the Iron Constitution

ſtitution is introduced, all its Rocks and Iron Mines. *Protinus Erupit venæ pejoris in ævum omne Nefas.* Then followed all the diſmal effects of Subterraneous and Superterraneous Diſſentions, Conflagrations, Floods, Earthquakes, the Sea overwhelming the Lands, and the Lands getting out from under the Seas, here Iſlands, there Lakes, here Mountains, there Voragoes and Abyſſes, and multitudes of other Confuſions which raſed and mangled the ſuperficial Parts of the Earth, ſo that no place was free from the effects of theſe diſcordant Principles. *Aſtrea*, as I ſaid before, which ſignified the Virgin, *Juvenile* ſmooth, ſoft, and even Face and Conſtitution of the Earth which it firſt received from the gentle Influence of the Heavens, and preſerved in the Infant, *Juvenile* and pretty well in the Virile or brazen Ages. Now, that the Earth was arrived to its old Age, Wrinkles, Chops, Furrows, Scarrs, and the like, had not left one ſpot of *Aſtrea* unblemiſh'd, then ſhe is ſaid to have left it. This is a ſhort account of this Iron or old Age of the World, of which I ſuppoſe the whole following Metamorphoſis is written; this in good part falling within the Mythologick Hiſtory of the Poets, but the Geneſis and three preceding Ages, I look upon to belong to *Varroe's* Ἀδήλου *tempus*, and to be the Epitome of the Theories of the moſt antient and moſt approv'd Philoſophers. This I could in part prove, as I could alſo many other Paſſages of this Diſcourſe, by Quotations out of other Authors among the Antient, and alſo by the conſent of many more Modern Writers. But that poſſibly might ſeem too tedious, and I doubt not but there are others who having more applied their Studies that way will do it more fully. The firſt of the memorable events of the Iron or old Age of the World is deſcribed in the next following Verſes.

Neve foret terris ſecurior arduus Æther,
Affectaſſe ferunt Regnum cæleſte Gigantes
Altaq; congeſtos ſtruxiſſe ad ſydera montes.

But leaſt high Heav'n ſhould unattempted reſt,
Aſpiring Thoughts the Giants Minds poſſeſt,
Mountains they rais'd 'gainſt the ætherial Throne.

Now the diſmal effects of the old Age of the Earth appear, the outward Shell of the Earth being now hardned and petrified, and the Pores of Emanation ſtoped ſo that the fiery and watery Vapours and Rarefactions below the ſame, could not now find their uſual tranſits; theſe are ſaid to conſpire againſt Heaven to break out of that Priſon of *Tartarus*, where *Jupiter* had lately thruſt down and incloſed *Saturn*, *Saturno tenebroſa in tartara miſſo*, and to force their Paſſage into the open Heaven, where *Jupiter* now prevails; theſe therefore fermenting together had raiſed the ſubterraneous Parts into many Cavities and *Cryptæ*, and therefore were ſaid to have a thouſand Hands, being ſo many Caverns and far extending *Cryptæ*, wherein theſe ſubterraneous Sprits convened, in which lay their ſtrength; and becauſe ſuch *Cryptæ* are winding and not ſtreight, they were called *Anguipedes* like Snakes; theſe at laſt break forth and make Mountains, lay *Pelion* upon *Oſſa*, *Altaq; congeſtos ſtruxere ad ſidera montes.* Then *Jupiter* is ſaid to have rent the Heavens with his Lightning and to have buried them at laſt with Mountains heaped on them; that is, theſe Vapours having made Eruptions and thereby carried the Earth up with them, ſo as to make Mountains one of the top of the other, the Vapour got into the Air where it produced hideous Lightning and ſo ſpent it ſelf in the Air, and the Mountains being left, and the Vapours that raiſed them ſpent, *Jupiter* is ſaid to have deſtroyed them and buried them under thoſe Mountains: One of theſe is ſaid to be buried under *Sicily*, and to breath through the Mountain *Ætna*. But I muſt not ſtay too long upon the particular Explication of every thing concerning it, it may be ſufficient for me at preſent to hint the meaning in general; only 'tis to be noted, that the Blood of theſe produced a generation that was of the ſame kind; that is, that the remainders in the Earth were of the ſame kind.

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These remainders of the first Effects were so prodigious that they made *Jupiter* groan and grow white hot with Anger, that is, made Thunder and Lightning, and call a Council of the Gods,

Terrificam Capitis concussit terq; quaterq;
Cæsariem, cum qua terram, Mare, sydera movit,
Talibus inde modis, ora indignantia solvit.
Non Ego, pro mundi Regno magis anxius illa
Tempestate fui, qua centum quisq parabat
Injicere anguipedum captivo brachia Cælo.

The Thund'rer oft this dreadful Tresses shakes,
At which the Heaven, the Earth, and Ocean quakes,
And thus he his affronted Mind exprest.
Not a more anxious thought my Mind possest
For the Worlds Empire, when the captive Skies
With hundred Hands the Snake-feet did surprize.

It seems this was as great a Conflagration, or Collection of subterraneous Spirits, and like to be as dreadful as the preceding, nay greater, for that was but one single Enemy, but one small part to be destroyed; but now there is an universal defection, all must be destroy'd; for speaking of the last Eruption,

Nam quanquam ferus hostis erat, tamen illud ab uno
Corpore, & ex una pendebat Origine Bellum.
Nunc mihi, qua totum Nereus circumsonat orbem,
Perdendum est mortale genus, &c.

For tho' the first was a fierce raging Foe,
From one Original the whole did flow,
And all the War depended on one Head.
Now where so'ere the silver Waves are spread,
I must destroy Mankind.

The Fable of the Lycaon *explain'd.*

And why must all this be? Why *Jupiter* being informed of this designed Conspiracy, coming down found *Lycaon* had laid a design to destroy not only the *Semidei*, *Fauni*, *Nymphæ*, *Satyri*, and *Sylvni*, that were the terrestrial Deities of the Plains, Rivers, Woods and Hills; but even *Jupiter* himself, who ruled the celestial Deities, the Æther, Air and Meteors, all which he had call'd together, who

Confremuere omnes studiis ardentibus.
A Murmur rais'd with an inflam'd desire.

But who is this *Lycaon*? Λυκάων, as the Word signifies, is Dissolution, the general Congregation of the Sulphureous, Subterraneous Vapours being every where pent in, threaten'd a general Dissolution and Catastrophy of the whole World at once, and so would not only overturn Hills, Plains, Rivers and Woods, but set on Fire and destroy the Air; for, as in another place he expresses it,

Vis fera Ventorum cæcis inclusa cavernis
Expirare aliqua cupiens, luctataq; frustra
Liberiore frui Cælo, cum Carcere Rima.
Nulla foret toto, nec pervia flatibus esset,
Extentam tumefcit humum: Seu Spiritus oris
Tendere Vesicam solet.-----

Winds

Winds raging force within close Caverns pent
Desirous to break out at any Vent,
Long strives in vain t'injoy a freer Field
Of Air, the well-clos'd Pris'ns no Crannys yield;
At last it stretches out Earths hide-bound Shell,
As with strong Breath blown up tight Bladders swell.

The whole Earth was big with these collected, subterraneous, fiery Spirits and watery Exhalations.

--------Partim ferventibus artus
Mollit aquis, partim subjecto torruit igne.

-------Part soft with the boyling Waters, part
He roasts with Flames beneath.

Jupiter therefore descending destroys him *vindice flamma*, that is, fires into Lightning such as had broken out,

Territus ipse fugit, nactusq; silentia Ruris
Exululat.

Frighted, to dark and silent Groves he flies
In these he howles aloud.

This made the subterraneous Vapours fly to other places and make a noise under Ground, and in some places where it broak out, it had

-------Veteris vestigia formæ:
Canities eadem est, eademviolentia vultus,
Iidem Oculi lucent, eadem feritatis Imago

He still the marks of his old Form retains:
The same gray Hair, the same stern Look remains,
The same Eyes stare with wildness still the same.

The same white tops of Mountains, the same gaping devouring Mouth, the same flaming Eyes, the *Caldera* at the top yielding Fire, the same frightful and terrible Aspect, like that of a devouring Wolf; and that this is the meaning of the shape of a Wolf which *Lycaon* is said to be transformed into, is more plain by what is said in the eleventh Book, Verse 365, of *Psamathes* being turned into a Wolf, where *Antenor* is introduced telling a story to *Peleus* of a devouring Wolf destroying Men and Cattle which had come out of the Sea: It will be plain to any that shall read it, that an Earthquake is there meant by the description of the Wolf, but I must not now insist upon it.

But to proceed, there was yet but a stop put to some small *Vulcano* or Eruption which had destroyed but some small Country *de Gente Molossa*, some of which it had overflowed with Water, and destroy'd some other parts with Fire.

---------Sed non Domus una perire
Digna fuit, qua terra patet fera regnat Erynnis.
In facinus jurasse putes.

Thus one House perish'd by revenging Flame
Deserv'd by all, the Furies all possess;
You'd think the World conspir'd in Wickedness.

But this was not sufficient to vent these subterraneous imprison'd Spirits; but an universal Catastrophy was necessary, because *Erynnis* ruled over the whole Globe; *Jupiter* therefore is said to have considered which way to effect it, whether by an universal Conflagration by fiery Eruptions

Jamq;

Jamq; erat in totas sparsurus fulmina terras,
Sed timuit ne forte sacer tot ab ignibus Æther
Conciperet flammas, totusq; ardesceret Axis.

And now he just was ready to let fly
His Light'ning, but he fear'd the sacred Sky
Should catch the Flame, and Heav'ns whole Axis blaze.

He concludes at last to do it by an Inundation.

But I must not dwell too long upon the Explication, which with this notion will plainly appear to him that reads the Poet's Description. Next this follows the Story of *Python*, which is nothing but the Corruption and ill effects of it from the Mud and Stagnations left by the Flood, which the Sun by its Rays by degrees destroys, drying it up. And the next of *Daphne* turned into a Laurel by *Apollo*, is nothing but the pleasant verdures the Sun produced upon the Earth, inriched by the Inundation after it was dried. I could proceed, but I fear I have already wearied you with this Recital, which was only designed as a Specimen to shew what I hinted the last Day, namely, That this Mythologick History was a History of the Production, Ages, States and Changes that have formerly happened to the Earth, partly from the Theory of the best Philosophy; partly from Tradition, whether Oral or Written, and partly from undoubted History, for towards the latter end we find accounts of many things our Histories reach, as *Orpheus*, the *Trojan* War, *Pythagoras*, *Romulus*, *Rome*, *Numa*, and it comes down even to the Death of *Julius Cæsar*, and the Reign of *Augustus*, under whom he lived.

IN Confirmation of what is said in the foregoing Page concerning the Giants, *I shall here insert a loose Paper, as I found it among Dr.* Hook's *Manuscripts, inscribed, A Copy of Dr.* Thomas Gale's *Paper concerning* Giants.

R. W.

SIR,

IN Answer to your Question about the word Rephaim *and* Gigantes, *I make this short return.*

1. *There is no rudical word in the Hebrew Language whose signification doth at all lead us to understand* Gigantes *by the word* Rephaim, *so that the Radix of* Rephaim *is either lost as to the present Hebrew Language (as many others are) or else that word* Rephaim *is a foreign word to that Language, as many more such are now found in the Bible.*

2. *The Septuagint Translators do often render Hebrew words not according to their Natural Sense, but with respect to some History or Tradition, or general belief prevailing at that time: The reason was because those Translators lived among Greeks at* Alexandria: *And they were desirous to shew that the Bible was not unacquainted with the Greek Stories, where the thing could be done without injury to their Books.*

3. *In their rendring of the word* Rephaim *by* Gigantes *and* Mortui, *and the Verb——————they plainly point at the Story of the* Titanes, *who in the Greek Mythologies are said* Ταρτηρωθῆναι. *St.* Jude *uses the same word when he speaketh of the Hellish Angels*, ἐταρτηρώθησαν. *Another Greek Translator rendereth the same word* Rephaim *by* Titanes.

4. *As to the suspicion that the* Gigantomachia *was an Earthquake, or perhaps several Earthquakes, but by the Poets put altogether, the true notation of the word* Gigas *seems to make for you. In Hebrew the* Radix Gagash, *is* terra commota fuit. *And the Substantive* Gigas, *tho' commonly taken for a Greek word, is indeed of Hebrew or Phænician Original. In that place of* Isaiah *where the 70 use* Gigantes, Symmachus *uses* θεομάχοι, *both alluding to the Poetical Fable, but the 70 do it more warily,* Symmachus *more plainly.*

But

But to me I confess it seems rather to allude to the fourth Verse of the sixth Chapter of *Genesis*, where it is said, that there were Giants in the Earth in those Days, because the word γιγαντες is made use of by the Septuagint οἱ δὲ γιγαντες ἦσαν ἐπὶ τῆς γῆς ἐν ταῖς ἡμέραις ἐκείναις, and it seems to be a full Period, besides we find that God immediately after this Passage, is said to be very highly displeased with the wickedness of Mankind at that time upon the Earth, and to resolve their Destruction and Extirpation, which shews that there is a great agreement of the Poets Mythology with this History of *Moses*: For *Ovid* makes this *Gigantomachia* to precede the Flood of *Deucalion*, as the Scripture doth make this to precede that of *Noah*. And besides joins the Fable of *Lycaon* to that of his Giants, which seems plainly to allude to the wickedness of Men mentioned by *Moses* upon this occasion. Further, I do not know whether the word may not sometime have been used to denominate Earthquakes, or subterraneous Powers; for in the ninth Verse of the fourteenth of *Isaiah* where the same word is used by the seventy. It seems plainly to signify some such thing; but this is besides my Province, and I shall rather leave it to the Divines to determine: For *Gigas* is the same word with the Greek word γιγας, which *Eustachius* derives from γῆ and γαω that is an Off-spring or Progeny of the Earth, *i. e.* somewhat generated in the Bowels or Womb of the Earth and thence Born, brought forth or protruded, which is a very proper Appellation and Description of that production of Nature, wherewith the Earth seems to be first impregnated and made tame, then to be in great Agony and Pangs, and to have many pangs and throws before it is delivered of it; and last of all to produce Islands, Mountains, or the like Monsters, which seem to threaten or aspire at the Celestial Mansions.

When I gave an account the preceding Meeting, *July* the thirteenth, of what I conceived the Poets meant by the Mythology of the Giants warring with the Gods, some of the Society then present were very Inquisitive to be informed what should be meant by the History of *Python* which was destroy'd by *Apollo*, of which though I had made some mention in a former Discourse concerning the Mythology mention'd by *Ovid*, yet being then only mention'd *in transitu*, I have now somewhat more particularly drawn up my Sentiment concerning it. I mention'd before then *Ovid* by this Mythology (as I conceived) did design to describe the state of the Earth from its first beginning and formation out of a *Chaos*, through all the various Alterations, Changes and Metamorphoses it had undergon even to that time in which he lived. And therein to comprise the Traditions and Opinions of the Antients, and possibly also some of the Moderns of his Times, and some also of his own, thereby to give some Account and some Reasons of the then present Phænomena of the World. I need not repeat what I have formerly instanced in, about the *Chaos* and the Ages succeeding, nor what I said concerning the Fable of the *Giants*: But to make the probability of my Conjectures the more manifest, I would observe to you the Co-hærence and Connexion of the Mythologies, as they are ranged in this first Book. After the War of the *Giants* which had raised up Mountains that seemed to threaten the very Heavens by their height, and the disturbances that had thereby been caused in the Air by Lightning and Storms which he makes to be the means by which the Gods destroy'd their fury, he comes to consider the Face of the Earth as it was left, which he Mythologizes by the Story of *Lycaon*, whereby he describes the confusion there was left by the subversion, sinking, overwhelming and destructions that had been made, the *Rustica Numina* as the *Fauri*, *Nymphæ*, *Satyri*, and the *Sylvani* of the Mountains, were all likely to be destroyed for the future; that is, the fine Plains, the Woods, the Rivers and Rivulets, the Woods on the Hills were all deformed, confounded, and put into confusion, and not only so but the Air itself was from the Clefts and Chasms poisoned and continually filled with noxious Expirations out of the Earth, the People remaining were distracted and grown barbarous, preying upon and destroying one another; it was thought therefore by *Jupiter*, i. e. Divine Power, necessary, that all must be set to rights again by a general Deluge, whereupon the Poet brings in *Jupiter* Swearing,

Nunc mihi qua totum Nereus circumsonat orbem
Perdendum est mortale Genus: Per flumina juro
Infera, subterras Stygio labentia Luco.
Cuncta prius tentanda, sed immedicabile Vulnus
Ense recidendum est, ne pars sincera trahatur.

Now wherso'ere resounding Waves are spread,
All mortal Beings must die; by Streams that run
Beneath, I swear, Streams that ne'er see the Sun.
All ways first try; But th' incurable Wound
Must be cut off, lest it infect the Sound.

The Fable of Deucalion *and the Flood explained.*

The Flood then follows that was to reduce this torn aud confounded Face of things into some better Form and Order, by which the Caverns left should be filled, the ruggednesses plain'd, the superficial Parts, now Rocks and Stones, and the Recrements of the Eruptions should be cover'd by a more soft, and fine, and fatter Skin of Earth, which should be fit to produce and nourish Vegetables and Animals as before. The Poet then describes the Flood, and thereby makes all Men and other Creatures to perish by it, except only *Deucalion* and *Pyrrha*, who were to be the restorers of Mankind, whom he supposed to have somewhat more Divine than all the rest of the Creatures, which he conceived to be generable out of Corruption, as you will see by and by; but Man only by propagation, yet his method of Propagation looks at first glance but very extravagant, namely, from Stones cast behind them by *Deucalion*, and *Pyrrha*, *Deucalion*'s being generated into Men, and *Pyrrha*'s transformed to Women *(quis hoc credat nisi sit pro teste Vetustas)* says *Ovid*; and I am very apt to think that *Ovid* himself was one of the Unbelievers, notwithstanding the Testimony of the old Traditions, that is, that he did not take it to be a truth in the plain Sense of the Words, tho' he seems to draw a Consequence from them. [*Inde genus durum sumus experiensq; Laborum.*] But that he understood what was meant or intended to be signified by this MythologickDescription [*Et Documenta damus qua sumus origine nati.*] But to proceed. After he has told us how Mankind was preserved and propagated after the Deluge, he next comes to the other Creatures.

Cætera diversis, Tellus animalia, formis
Sponte sua peperit; postquam vetus humor ab igne
Percaluit Solis, Cænumque udæq, Paludes
Intumuere æstu, fœcundaq semina rerum
Vivaci nutrita solo, seu Matris in alvo
Creverunt, faciem aliquam cepere morando.

All other Creatures took their numerous Birth
And Figures voluntary, from the Earth,
When slimy Marshes from the Suns vast heat,
And with his Power impregnated grow great
With Child, and Seeds, as from the Mothers Womb,
By Steps and Time both Growth and Shape assume.

And here he is for *Æquivocal* Generation to the height, if you understand him literally, or according to the words, *Quippe ubi temperiem Sumpsere Humorq; calorq; concipiunt & ab his oriuntur cuncta duobus.* All came from two Principles; for he seems to make all things to arise or be generated out of a temperature of Heat and Moisture, and by that means the Earth, when left by the Deluge, abounding with muddy and boggy Places the heat of the Sun working thereupon produced, according to him, not only all the several Creatures anew which had been lost and destroyed by the Deluge, but divers others of strange, and before unknown, and monstrous Forms, which were terrible and destructive to Mankind, and amongst the rest he mentions a strange, venomous and prodigious *Serpent*, which he calls *Python*, which he relates

The Fables of Python *explained.*

relates to be killed or destroyed by the Darts of *Apollo*. By which I conceive no more is meant, but that those boggy Places after a time corrupted and produced pestilential, dark, Clouds and Vapours, which frighted and was noxious both to Men and Beasts.

But that in some time after the Rays of the Sun and Lightning having prevailed, did thereby burn off and discharge the poisonous Exhalations, and put an end to that monstrous off-spring, nor need we be much concerned for what the *Dæmonologers* had thereupon superstructed for the promoting and carrying on of their *Theourgy*. After this drying of the boggy places of the Earth by the Sun; we have the account of the production of Woods and Trees by the Power of the Sun in the Story of *Daphne:* And then the description of the Rain, Dew and the Foggs that moistened the Air, and made Rivulets and Streams producing Grass in the Fields, and greenness on Trees and Plants by *Io* then *Juno*, the Air finding these Vapours to be drawn up into her Bed or Residence by the *Sun* or *Jupiter*, is said out of jealousy to set *Argus*, that is, the Stars to watch it by Night and cause it to fall: But *Mercury*, or the light of the Morning cuts off the head of *Argus*, that is, makes the Stars disappear and the Sun return to raise them, and *Io* is then restored to her former Shape, or the Dew or Moisture on the Ground is raised into Vapours. By the bye he inserts the Generation of Water, and River-plants by *Syrinx*, and the production of the *Rain-bow* by the Head of *Argus*, placed by *Juno* or the power of the Air in the Feathers of *Juno*'s Bird, which are the Clouds of the Air. By these Mythologies having described the postdiluvian state of the Waters, and the Air and watery Meteors, he ends the Book with the Pedigree of *Phaeton* which he compleats in the beginning of the next, of which hereafter.

Daphne. *Io* *Argus.* *Syrinx.*

But as to *Python*, which gave the occasion of my present Discourse, 'tis plain that its Name signifies Corruption, and by the manner of its Generation, 'tis evident that he supposes this Corruption to be caused by the Bogginess or Floods that remained in the Plains, Lakes, or Holes, lower Grounds or Vales incompassed with higher Grounds that the Water could not run off: From the fermentation of the softned Earth he supposes the Animals to be formed that were of the same form with the *Antediluvian*; but from a longer stay of the Waters this fermentation turned to Corruption, and then produced not only Monstrous Creatures, but noxious and dreadful Exhalations, whence proceeded Distempers and Diseases, because these Waters by several Streams moved (as most commonly they do) to lower Places and Cavities and there made a great Body which possessed a considerable part of the incompassing Hills or Mountains: *Apollo* or *Jupiter*, that is, the Sun by many Days and Years irradiating with its Darts, Rays or Beams, doth partly dry by Exhalations, partly by flashes of Lightning, dissipate, and dispel, and last of all it causeth Clefts and openings of the Earth which swallow it up, and leave those Cavities like the black Wounds which the Poet affirms to remain for a witness to Posterity.

Python.

--------Sed te quoq; maxime Python
Tum genuit : Populisq; novis, incognite serpens
Terror eras ; tantum spatii de monte tenebas.
Hunc Deus arcitenens, & nunquam talibus armis
Ante, nisi in damis Caprisq; fugacibus usus,
Mille gravem telis, exhausta pene Pharetra
Perditit effuso per vulnera nigra veneno.
Neve operis famam posset delere vetustas,
Instituit sacros celebri certamine Ludos,
Pythia perdomiti serpentis nomine dictos.

Hug.

Huge Python *th' Earth against her will then bred,*
A serpent whom the new-born People dread:
Whose bulk o're so much of the Mountain spread.
The dazling God that bears the silver Bow,
(Inured before to strike the flying Doe)
That Terror with a thousand Arrows slew,
His Quiver empty'd, and the Poison drew
Thro' the black Wounds: Then least the Memory
Of such a work in after times should die,
He instituted celebrated Games
Which from this Serpent he the Pythian *names.*

The Earth produced various Creatures some monstrously shaped, these were *invita terra* contrary to its proper teeming Vertue brought forth: Of these one was more corrupt than the rest, and more contrary to Nature; this possessing so much room of the Mountains, wrigling on all sides by the Rills that ran into its vast Body or Lake, by its Poison became dreadful to the new produced Creatures: This Celestial Power that kept the Tower of Heaven (so I English *Arcitenens*) that is, the Sun, Fire, or Heat, by its Rays and by thousands of flashes of Lightnings (insomuch that one would have thought they had been all spent and the whold stock fired off and whereas those Rays before had been only used to dispel and scatter small Clouds or Foggs) did hereby at last destroy or disperse this stagnant and corrupted Body of Water, by causing it to rise into Thunder Clouds discharging by Lightning its poisonous Vapours with which it swelled; besides the heat of the Sun and the Lightning also kindling the Subterraneous Spirits, caused Clefts and Chasms in the Earth, which swallowed up most of the remaining stagnant Waters, and so destroy'd the Cause or Original of those Evils, leaving in several places divers of those Chasms or black Wounds which the Poet describes.

To this purpose there is a notable Passage in *Lucian*, which, among others, to another intent, is quoted by Dr. *Burnet*, *Theor. Sacr.* Part 2. Chap. 4. 'These 'are the Matters (says *Lucian*) which the Greeks have related concerning 'the Flood of *Deucalion*. But among the things that have happened soon after it, there is a certain relation of the Inhabitants of *Hierapolis*, which is 'justly looked upon with great admiration, namely, that in their Country 'there had happened to be made a great Chasme in the Earth, which had 'swallowed up all the remaining Waters; whereupon *Deucalion* had built Altars and a Temple dedicated to *Juno* over the same. Now for a sign that 'this Relation is so, they do thus twice every Year, Water is brought from the 'Sea to this Temple, and not only the Priests bring it, but all *Syria* and *Arabia*, and many which dwell beyond the *Euphrates*, go to the Sea and fetching the Water from thence bring it to this place: And first indeed they 'pour it out into the Temple, and then it runs into the Chasm, and tho' 'this Chasm be but small, yet it swallows an immense quantity of Water. 'When they perform this Ceremony, they say that *Deucalion* instituted this 'Rite and Law of this Temple, that it might be a Memorial as well of the 'Destruction by as of the Deliverance and Safety procured against the Flood. 'This (says *Lucian*) is the old Story concerning this Temple. This Tradition, 'tis very probable, *Ovid* was not ignorant of and might therefore add to his Relation *Fuso per vulnera nigra veneno. Neve operis famam posset delere vetustas.* And 'tis very probable also that the Mythology of *Argus* has a respect to the Generation of the Rainbow soon after the Flood as it is mentioned by *Moses*. For 'tis plain that their Signs or Hieroglyphical Representations and Notions, were many of them abundantly more incongruous with the things signified than this is; for Clouds may by an easy Figure be fancied the Fowls or Birds of the Air, as we usually say when great flakes of Snow fall, the Winter is plucking its Geese or Fowls: And which among all Fowls, or indeed Creatures, does better represent the Rainbow then the Peacock when it spreads its Tail, whereby it represents such a glorious Arching of a most stupendious Variety

riety of Colours as numerous and as resplendent as the very Rainbow. And to make the coherence the greater those Rings being made up of a Circular Order of beautiful Spots, what could he better Metamorphose it from than from a Head adorned with abundance of Eyes, which he makes to be of one *Argus?* I suppose for want of Microscopes he knew not that the Eyes of Flies were planted in so curious an order, otherwise possibly that might have served for a Hieroglyphick for the Star-light-Night as well as *Argus.*

The occasion of this Lecture.

I have formerly discoursed concerning the great and strange Effects that have been produced on the superficial Parts of the Earth by means of Earthquakes, the raising of Hills, the sinking of Vallies and Lakes, the swallowing and new producing of Rivers, the raising and sinking of Islands, the cleaving of Hills and Rocks, and the tumbling and disordering of the superficial Parts of the Earth, by which means have been produced the Veins and various mixtures in Marbles and other kinds of Stone, and most of the petrifactive Productions, besides the Production of Mines and Metalline Bodies, as well as of other Saline, Sulphureous and divers other mineral Substances. And in short I conceive that the whole Surface of the Earth, as it is at present, has been some ways or other influenced and shaped by them: I have on several occasions alledged several Arguments and Observations to make these Conceptions probable, and have produced several Histories that seem to be that way conducing. But most of the greatest Mutations having in probability been performed in the Ἄδηλον or μυθικὸν the uncertain or fabulous Times, as they are termed by *Varro*, there is not to be found in the Historical time very many that do make much for it; the greatest Instance I conceive to be had of it, is the History of *Phaeton*, which, tho' among the Greeks it be included within the fabulous times, yet it seems by that Passage of *Plato* which he relates concerning what *Solon* had learned from the *Ægyptian Preist* that the *Ægyptians* had Records thereof in their History, as in probability they had of many others, of which the *Grecians* were wholly ignorant, as may in part appear by the Relation of the *Atlantis*; for the *Greeks* had nothing of History elder than the Flood of *Oygges*, which, as *Eusebius* says, happened about the times of *Jacob*, which was long after that of *Noah*, and long before that of *Deucalion*, which was about the latter end of *Moses*'s Life. All which time according to *Varro*, and many hundred Years after even to the beginning of the *Olympiads* (which was but 776 Years before Christ) was included in the Fabulous Age, which was likewise 776 Years after *Moses* his Death, he dying in the 1552 Year before Christ's Nativity; within which space of time the Catastrophy Mythologised by the Story of *Phaeton* seems to have happened; for *Orosius* relates it to have been much about the time of the *Israelites* departure out of *Ægypt*; as he doth also assert that of *Deucalion*'s Flood, in which the greatest part of the People of *Thessaly* were lost, only some few escaping who fled to the Mountains, especially *Parnassus*, near the Foot of which *Deucalion* then reigned. Now if we consider the Story as it is related by *Ovid* in the second Book of his *Metamorphosis*, making allowance for what is Poetically spoken, one may plainly enough from the whole drift of the Fable conjecture at the History or Tradition that is couched under it, as well as somewhat also of the Philosophy; as for the morality thereof enough have taken notice of and writ concerning it. As for the time of it, *Ovid* places it soon after the Fable of *Deucalion* which is the seventh Fable of his first Book, and the eighth, ninth, tenth, eleventh, twelvth, are of Matters consequential of that Flood which must have followed it in a very short time (as I may on some other occasion make more probable) or rather prævious to this, as being indeed part of it. But to let that pass for the present, I shall only take notice now of the Physical or Philosophical part thereof, which to me seems to contain a Description of some very great Earthquake or fiery Eruption which affected a great part of the World then known.

That the Egyptians had Records of Phaeton in their Histories.

At what time that happened.

An Explication of the Fable of Phaeton.

First then we find *Phaeton* to be termed a Son or production of the Sun, which is the biggest and most powerful Fire of the World, that we who live upon the Earth do know, but by the Mothers Side, to be the Son of *Clymene* which is an epithite of *Pluto* and denotes *Phaeton*, or this aspiring Fire to be generated by the Sun in the Bowels of the Earth; all the proeme of the

Story is Poetical and of a moral Signification to denote a Genius aspiring and undertaking more than what it was able or fit to perform and manage, yet it is so ordered as to comprise the main Design and Physical meaning of the Poet, *viz.* that by some extraordinary or universal influence of the Suns Beams the Subterraneous Vapours had been kindled, and that a fore-runner of this was Lightning and Thunderings in the Air, which seems to be expressed by the description of the Horses that drew the Chariot of the Sun.

Interea volucres Pyroeis, Eous & Æthon
Solis equi, quartusq; Phlegon, hinnitibus auras
Flammiferis implent, pedibusq; repagula pulsant.

Mean while the Suns swift Horses, hot Pyroeis,
Light Æthon, *fiery* Phlegon, *bright Eous,*
Neighing aloud inflame the Air with heat,
And with their Thundring Hoofs the Barriers beat.
Metam. Lib. 2. v. 153, *&c.*

The Managery and Course of the Horses and Chariots through the Heavens is all poetical, accommodated to shew the Constellations of *Aratus*, and to the Cosmography of the Poets, to signify the concurrence of the other Celestial Bodies and Powers: But the effects it produced on the Earth as the flaming and burning of Mountains, the cleaving and chopping of the Earth, the swallowing up of Rivers, the rising of Lands out of the Sea, as especially that about *Ægypt*, and the Sandy Deserts on the West side of it, seem to be Historical as well as Poetical.

But I confess the whole is so Poetical that much certainty of History cannot be fetched out of it; yet for the present let me add thus much that I conceive may be deduced therefrom, and that is this, That there was an ancient Tradition among the *Greeks*, and that there was an ancient History among the *Ægyytians* of some very great and almost general Conflagration or Eruption of fiery Streams which made very great Devastations on the Earth, especially of those parts mentioned by the Poet in this Relation; such as *Athos*, *Ida*, *Oete*, *Tmolus*, *Taurus*, *Helicon*, *Æmus*, *Ætna*, *Parnassus*, *Othrys*, *Cynthus*, *Erix*, *Mimas*, *Rhodope*, *Dindyma*, *Caucasus*, *Mycale*, *Cytheron*, *Pindus* and *Ossa*, *Olympus*, the *Alpes* and *Appenine*, all which Mountains are said to have been on Fire, and to have cast up Smoak, Ashes, and burning Coles, and to have thickned and darkned the Air.

Tum facta est Libye raptis humoribus æstu
Arida, tum Nymphæ passis, fontesq; lacusque
Deflevere comis, &c. *v.* 237.

Then a dry Desert Libya *became,*
Her full Veins empty'd by the thirsty Flame;
With their scorcht Hair the Nymphs the dry'd up Streams
And Lakes, their ancient seats, bewail.

Then were cast up the *Libyan* Desarts and many Lakes and Rivers swallowed up and perverted, the names of which the Poet mentions, which are too many now to repeat; then the other parts of the Earth were cleft and tumbled to and fro.

Dissilit omne Solum penetratq; in Tartara Rimis
Lumen & Infernum terret cum Conjuge Regem.
Et mare Contrahitur Siccæq; est Campus arenæ,
Quod modo pontus erat; quosq; altum texerat æquor
Existunt montes, & Sparsas Cycladas augent. V. 260.

Earth

Earth cracks, to Hell the hated Light descends
And frighted Pluto *with his Queen offends;*
The Ocean shrinks and leaves a Field of Sand;
Where new discovered Rocks and Mountains stand,
Which multiply the scatter'd Cyclades.

Then was the Sea contracted into a narrower but deeper Cestern, the Hills and Lands on each side of it raised from under the former Sea and made dry Lands and Mountains, the Islands that are now dispersed in it were thrust up out of its bottom, and stand in that Position to this time: In short not to detain you at present too long upon this Mythologick Story, I conceive it to contain the History or *Cabala* of the Production or Birth of the present *Mediterranean*, *Ægean* and *Euxine* Seas, and of all the bordering Shores and Countries near adjacent to them, together with all the Islands, Peninsula's, Cliffs, Promontories, Mountains, Hills, Lakes, Rivers and Countries which had been before that time all covered with the Sea, but by a prodigious Catastrophy which Divine Providence then caused to be effected, the former Face of those Parts was transformed and metamorphosed into much what it is now found, in General, tho' not in all Particulars; for that there may have since been by the same Divine Providence produced other particular Catastrophies and Mutations, of which there are many Instances mythologically Recorded in this our Author, some of which I have already mentioned, and divers others which I may have occasion to mention some other time, besides divers others of which we have plain and not hitherto doubted or disputed Histories. Now, tho' I confess what I have here asserted to be seemingly very Extravagant and Heterodox from the general Conceptions of most that have had occasion to mention this Fable; and tho' it had been less improbable, I should not have expected any Concurrence of Opinion: Yet possibly when the Matter has beeen more sedately and without prejudice thought of and examined, it may, as well as some of my former Extravagancies, receive at least a more mild Censure, tho' it should not be wholly accommodated to the Gusto of every such Examinant. In these Matters Geometrical Cogency has not yet been applied, and where that is wanting, Opinion, which is always various and unstable, prevails. However, I may on some other occasion shew that there is to be found in Physick, as well as Geometry, unanswerable Probation.

And when the Extravagancy and Novelty of the Doctrine has run the Gauntlet of Censures, I shall indeavour to add somewhat to cover and cure its Scars.

I did the last day indeavour to shew what I conceived was veiled by the Poet under the Story of *Phaeton*, and that was this, That by this Mythology the *Grecian* and *Latin* Poets did preserve the memory of some extraordinary great Catastrophy, which all the parts of the Earth or Countries not far removed from the *Mediterranean*, *Ægean*, *Euxine*, and *Caspian* Seas had suffered by fiery Eruptions or Meteors, effecting Earthquakes.

This to me seems probable from the Order and from the Manner of the whole Relation.

For the Order of it; we find it placed by *Ovid* soon after the Flood of *Deucalion*, and so we find it is related by *Paulus Orosius* (which I hinted the last day) for in the ninth and tenth Chap. of his first Book of Historys he makes the Flood of *Deucalion* to have happened much about the time of the Plagues of *Ægypt*, and the Passage of the *Israelites* through the Red Sea, by which Flood the greatest part of the People of *Thessaly* were destroyed. *Quo* (says *Orosius*, speaking of that Flood) *Major pars populorum Thessaliæ absumpta est, paucis perfugio Montium Liberatis. Maxime in monte Parnasso, in Cujus Circuitu Deucalion tunc Regnabat; qui ad se confugientes Ratibus Suscepit & per gemina*

Parnassi

Parnassi Juga fovit aluitq; ob idq; locum fecit Fabulæ ut ab eo Reparatum Genus humanum diceretur. His *etiam temporibus adeo jugis & gravis æstus incanduit ut Sol per Devia transvectus, universum orbem non calore affecisse, sed igne torruisse Dicatur. Impressnmq; Fervorem & Æthiops plus Solito, & insolitum Scytha non tulerit. Ex quo etiam quidam, dum non concedunt Deo ineffabilem potentiam suam, Inanes Ratiunculas conquirentes Ridiculam Phaetontis Fabulam texuerunt.* Thus far he, by which it seems that *Orosius* did, in the Stories of *Deucalion* and *Phaeton* for the main, believe the Matters of Fact to be true, but he was not for giving a Philosophical Conjecture at the Causes of it, or the ascribing them to the Pagan Deities, but for ascribing it immediately to the ineffable Power of God.

Now I do not conceive it doth any ways detract from the Omnipotency and Power of God, to explain the Causes that he was pleased to make prævious to those Effects: For the Power of God is not less wonderful, in producing and disposing the Causes of things, than in producing the things more immediately. But such a Story as this Fable of *Phaeton* is, and to give such an account of its Causes, as the Poets have there given, if understood literally, seems sufficiently ridiculous, and impious. But it is easy enough to be seen that those who made this Fable knew better things, and only made use of Mythology to conceale their knowledge from the Vulgar, and yet communicate it to such as had the Key to unfold the Mystery contained therein.

And this appears plain enough from the whole series also of the History; for as I noted before, *Phaeton* is said to be produced or generated by the Sun in the Womb of *Clymene*, an Epithite of *Pluto*, that is, in the Subterraneous Regions; and that it is so understood, appears plainly by the behaviour of *Clymene*, who is said, after the Death of her Son, to have been *Lugubris & amens, & Laniata Sinus totum percensuit orbem, exaniniesq; Artus primo, mox ossa requirens.* Which seems to denote the murmuring and tumbling in the Earth that continued after the Conflagration was over, and the Story of the Sisters of *Phaeton* seems very consonant also thereunto if I had time now to consider them.

Phaeton being grown to maturity, is said to have a great desire to know his Father, whom *Clymene* directs to go to the Palace of the Sun; that is, the Vapours being copiously generated in the Earth are expelled into the Air ascending towards the Sun. *Phaeton* is said to have come at length to the Palace of the Sun, and there to have been much pleased with the glorious work thereof, and more especially with the Workmanship of *Vulcan* in the Gates. *Nam Mulciber illic Æquora cœlarat medias cingentia terras, terrarumq; orbem Cælumq; quod imminet orbi. Cæruleos habet unda Deos, Tritona Canorum, Proteaq; ambiguum Balenarumq; prementem, Ægeona Suis immania terga lacertis,* &c. *Terra Viros, Urbesq; Gerit, Sylvasq; Ferasq; Fluminaq; & Nymphas & Cætera numina Ruris. Hæc Super imposita est Cœli fulgentis Imago Signaq; sex foribus dextris totidemq; sinistris,* &c. Then approaching the Sun-----. *Sedebat, in Solio Phœbus claris Lucente Smaragdis, a Dextra Lævaq; Dies & Mensis & Annus, Sæculaq; & positæ Spatiis æqualibus Horæ. Verq; Novum Stabat Cinctum florente Corona: Stabat nuda Æstas & Spicea certa gerebat. Stabat, & Autumnus calcatis sordidus uvis, Et Glacialis Hyems Canos hirsuta Capillos.* The meaning of all which seems to be this, That the state of the World before this Catastrophy was much the same *(facies non omnibus una, nec diversa tamen)* with the State of it afterwards; that is, the Course of the Sun was through the twelve Signs; there was a Spring, Summer, Autumn, and Winter, as there has been since; no alteration of the Axis or obliquity of the Ecliptick: But there were Ages, and Years, and Months, and Days, and Hours as now; and *Phœbus* describing the way to drive his Chariot through, doth name the same Constellations: So that the Philosophers who made the Theory, or the Poets that made the Fable, did not understand or suppose the obliquity of the Ecliptick to be made by that Deviation of the Chariot, or that this Catastrophy had altered the Axis of the Earth, with respect to the Heavens. But neither did they design to signify, even by this Story, the Deviation of the Sun it self at that time, as if that had descended and fired the Earth: For *Phœbus* did not accompany the Chariot, *Occupat ille levem juvenili corpore currum,* v. 150. But

they

they rather seem to make *Phaeton* a fiery Meteor proceeding from the East, and moving Westward by another way and course than the Sun usually took, and differing from the Direction that *Phæbus* had given to *Phaeton* to observe: But his Horses now mounted upwards towards the fixt Stars, now downwards towards the Earth, now far to the North, then as much to the South; and last of all he was broak all to peices by Lightning, and fell down like a Meteor upon the Earth, and like some such Meteors as have of late Years been observed, but much greater. *At Phaeton, Rutilos flamma populante capillos, volvitur in præceps, Longoq; per aera tractu Fertur, ut interdum de cælo Stella Sereno, quæ si non cecidit potuit cecidisse videri.* Whether there might ever have been any such Comet as in its Course might come so near the Earth as to set the superficial part on Fire, and to kindle or excite the Subterraneous, Sulphureous and Nitrous Minerals, or whether it were some Exhalation collected into a great Body in the upper Regions of the Air, and being kindled might seem to pass near those Constellations, through which *Phaeton* is said to be hurried and to come so near the Mediterranean parts as to burn the superficial Parts, and to inkindle the Subterraneous Mines of combustible and inflammable Substances; or whether it were some prodigious quantity of inflammable Steams collected in the Air, and so burnt off by continual Lightning, it is hard positively to determine, because that part of the Story I conceive to be Hypothetical, and Conjectural, or Philosophical, and not meerly Historical. But the Effects produced, those I conceive to be Historical; that is, that there were divers parts, which were before covered by the Sea, that by this Eruption, were raised from under it and left dry. *Tum facta est Libye, raptis humoribus, æstu arida: Tum Nymphæ passis fontesq; lacusq; Deflevere comis.* 237, 238. *Et Mare contrahitur, Siccæq; est campus arenæ, quod modo pontus erat.* 262 263. Then also were raised from under the Sea both Islands and Mountains. *Quosq; altum texerat æquor Existunt montes, & Sparsas Cycladas augent.* 263, 264. Then also did other parts sink under the Water. *Ipsum quoq; Nerea fama est, Doridaq; & Natas, tepedis latuisse sub undis.* Other parts were overflowed by the Sea and again deserted. *Ter Neptunus aquis cum torvo brachia Vultu, Exerere ausus erat, ter non tulit aeris ignes.* 272. Then were also caused great Earthquakes, and overturning and tumblings of the Earth. *Alma tamen Tellus, ut erat circumdata ponto, inter aquas Pelagi, contractosq; undiq; fontes, Qui se condiderant in opacæ viscera Matris, Sustulit Omniferos Collo tenus arida Vultus: Opposuitq; manum fronti,* Magnoq; tremore omnia Concutiens *paulum Subsedit; & infra, quam Solet esse fuit.* Then also was the Air filled with Fumes and Smokes, and the Surface of the Earth covered with Ashes and Cinders. 231, 232. *Et neque jam Cineres ejectamq; favillam ferre potest, calido involvitur undiq; fumo.* And again, 283, 284, speaking of the Earth, *(Presserat ora vapor) tostos en aspice crines, inq; oculis fumum; volitant Super ora favillæ.* The superficial parts of the Earth, Vegetable and Animal, were destroyed. 210, *&c. Corripitur flammis quæq; altissima tellus, fissaq; agit Rimas, & Succis aret ademptis, pabula canescunt; tum frondibus uritur arbor, Materiamq; Suo præbet Seges arida Damno: Flumineæ volucres medio caluere Caystro.* The Earth was rent and cleft, and all the high Hills on Fire like *Ætna* or *Vesuvius*: Those I named the last day. By this means many Rivers were swallowed up into the Earth; others dried up by evaporation and boyling Heat. *Mediis Tanais fumavit in undis.* 243, &c. *Nili Ostia septem Pulverulenta vacant, Septem sine flumine Valles.* And, to be short, all the effects that have ever been observed in Earthquakes, are here eminently expressed. So that there can be no manner of doubt of the design of the Story, *viz.* That it was designed to denote or describe a Catastrophy of the Mediterranean parts of the Earth by Earthquakes; since all things are so properly delineated and represented for that end, as if the Poet or Maker thereof had been spectator or Eyewitness of it, or at least a Contemporary with it. And we may here find the whole Progress or Phænomena of an Earthquake from its very first beginning to its very last end, and the effects also that precede it, and those that are subsequent to it, as I could plainly shew if it were not too much for this present Discourse, by explaining the Mythologick Histories immediately prefixt and following it. Nay, there has not been in this late Earthquake in *Sicily* (which

which seems to be the greatest mentioned in History) any one Phænomenon which cannot be shewn in this of *Phaeton*, and indeed most of the Phænomena mentioned in this of *Phaeton* have been exhibited or exemplified in this last of *Sicily*; which I could easily manifest by comparing *Ovid*'s Description with that of the *Italian* Frier; but I shall pass it by for the present.

Part of another Lecture to the same purpose.

I have, in some of my former Discourses, indeavoured to shew some Probabilities, that the Mythologick Stories of the Poets did couch under those monstrous and seemingly impossible representations of Actions performed by humane Powers, some real and actual Catastrophies that had been caused by the Body or Face of the Earth by other Natural Powers, of which the *Ægyptians*, *Chaldeans*, *Greeks*, or some other learned Nations had preserved some Histories or Traditions among the more learned part of them; which, that they might the better conceale their Knowledge, and keep it to themselves, and abscond it from the Vulgar, and such as were not initiated and admitted into their Fraternities, they had contrived and digested into fabulous Stories, which, as they might serve to amuse and awe the Vulgar by the Dæmonology they had thereupon superstructed, so they might serve to instruct and inform the Adepti, or such as were admitted to the true interpretation and understanding of what they knew, of the real History that was concealed thereby, as also of their Philosophical or Physical Hypothesis for the Explication and Solution thereof. I think it cannot be doubted that the Theogonia of *Hesiod* was of this nature, which if it was *Hesiod*'s (of which, yet I confess their are some Moderns make a doubt) it seems to have been some of the first Notions which the *Greeks* had obtained of these Matters from the *Ægyptians* or *Phænicians*, or some other of the Eastern Nations; except we suppose that *Orpheus*, who preceded both *Hesiod* and *Homer* near five 100 Years, might in those times have known and communicated some what of what they had by the same Methods procured. The Histories of those times are very dark and uncertain, and nothing convincing can be built upon them. It will be therefore but lost Labour to indeavour to prove my Conjectures from Histories, or hints to be sought among those few Fragments which are now to be met withal among the Relicks of written Antiquities. Those, if such there were, (as being committed to small and perishable Substances) have been more easily drowned and swallowed by time, or buried and overwhelmed with the Dust of Oblivion: And the Copy or Counterfeits of some of them, which have been made by some of those we now call the Ancients (though with respect to them they are to be accounted Modern) seem to have been but very imperfect, and to have been like Structures made up and peiced of the Rubbish, Ruins and Fragments of those Antiquities which they in those times could rake together; so that though some great Buildings have been by these secundary Ancients erected; yet being made up of such Fragments or Parts of those more ancient sacred Piles by the new Disposition and Order of them they now appear a preposterous *Moles*, yet we cannot but conceive that they had some better and more certain informations of those more ancient Histories or Traditions than what we now can find; and we cannot think so mean of them as not to believe they did in some measure comprehend the Intention, Meaning, and Drift, or Design of those that preceded them; and tho' they wanted a compleat knowledge, yet from the knowledge they had of the then Ruins, they were better inabled to Judge and Conjecture concerning them, than we now can. And tho' their Conjectures might not be all right, yet we cannot but think they might be tollerably near the matter, and that they did acquaint Posterity by their Writings what those their Conjectures were. And of this Nature I take the Metamorphosis of *Ovid* to be, who, I conceive, had made it his study to inform himself as fully as he was able of what was then to be found concerning that knowledge, and out of those informations he compiled that Book which was to comprise all the Records of Antiquity concerning the Changes and Catastrophies that had happened to the Earth from the Creation unto his own time, which his four first prefactory Verses do plainly enough declare. *In Nova fert animus mutatas dicere formas, Corpora dii cœptis nam vos mutasti & illas, Aspirate meis, Primaq; ab Origine mundi, In mea perpetuum deducite tempora Carmen.* Which is as much as to say, My design in this

this Book is to speak concerning the various alterations and transformations which the Bodies or superficial Parts of the Earth have, by the Divine Powers, undergone; for to those he doth ascribe them, *Nam vos mutastis & illas*, and therein to comprize all the knowledge I have been able to procure from the very first Creation or Original of it, even to these very times in which I live. And accordingly we find him to begin this his History, even with the beginning of the Creation of the Earth itself, and therein to have followed the Traditions, Opinions, and Doctrines of the most Ancient Sages concerning its manner of Formation out of a preceeding Chaos; which Doctrine that it was very ancient, and indeed the most ancient of all others concerning the Origination of it, I think the Learned and Ingenious Dr. *Burnet* in his *Archæologia* has sufficiently proved, and therefore I shall not need to say any thing concerning it; only I would make this one occasional Remark, That how ancient soever it was, it did not savour of an unlearned or ignorant Age or of a first beginning of real Knowledge, for that we find by *Ovid*'s Copy of it, that it contained a more refined Conception concerning the Figure, and Shape, and Properties of the Earth, than many of the Greek Philosophers (who in probability were many hundreds of Years after those first Sages) had concerning it. Some of those Greek Philosophers making the Earth to be of the form of a Drum or Cylinder, others of an infinite Column, others of a Skiff or Boat, or of a floating Island in the midst of an infinitely extended plain Ocean, and others of other extravagant Shapes; whereas we find that the Doctrine of the Chaos made it to be of a Sphærical Form, *Solidumq; coercuit orbem*, to consist of Land and Water, to have a proper Gravity that kept all its parts in that shape, or his *Tellus* (*Elementaq; grandia traxit & pressa est gravitate sua*) to be Involved with the Air, and that again with the Æther. *Hæc Super imposuit liquidum & gravitate carentem Æthera nec quicquam terrænæ fœcis habentem*, to be suspended in the Air, or Æther, or space of Heaven without being supported by any imaginary Foundation, as those Greeks fancied. *Circumfuso pendebat in aere tellus, Ponderibus librata suis.* Nay, and by several other Passages and Expressions of this Book, it is clear, that in those very ancient times, whenever they were, for 'tis hard certainly to limit them; the Learned Men that then lived, had arrived to a very great height of Natural Knowledge, especially of that part which concerned the Cosmography or Constitution of the Universe; and by that Expression, *Ignea convexi vis & sine pondere Cæli emicuit, summaq; Locum sibi legit in Arce.* It seems plain that they placed the Sun in the Center of the universe, and made the Earth to move about it. *Principio terram, ne non æqualis ab omni Parte foret, magni Speciem glomeravit in orbis.* But this only by the bye; for I know the common interpretation of these places, is altogether differing from what I now give, yet were it now my business, I think I can shew sufficient Reasons to persuade any unprejudiced Person that what I have given is the designed meaning of them; but I proceed to shew the general design of *Ovid* in this Book. After the Description of the formation of the Earth, he comes to describe the first times of its continuance; that is, the ἄδηλον, or unknown Ages of the World, of which he makes four, the Golden, Silver, Brazen and Iron, in the last of which comes in the Mythologick and Historick, for that he himself hath Mythologized also some of the Historical Times and Events. What space of Time he allows to each of these Ages it doth not so readily appear, but it is certain that the *Chaldeans*, *Ægyptians*, *Brachmans*, and some Heathen Historians have assigned spaces large enough and even beyond belief almost; and Mr. *Graves* tells us, that the Chinese do make the World 88640000 Years old. He begins the Mythologick Times with the Gygantomachia, which to me seems to be nothing else but a Description of some prodigious Earthquakes or Eruptions. And that by the Giants he plainly means nothing else but the Subterraneous Fires or Accensions which break out, and throwing up before them the Earth, seemed to threaten the very Heavens by piling Mountain upon Mountain (*Affectasse ferunt Regnum Cæleste Gygantes Altaq; congestos Struxisse ad Sidera montes*) I shewed before in the interpretation of the Rape of *Proserpine*, where it plainly appears what was meant by *Typheus* one of those Giants, who is said to lie buried under the Island of *Sicily*,

cily, and therefore shall not need to say more upon that Subject. After the breaking forth of these Subterraneous Streams and Flames, we find *Ovid* describing them to be burnt off with Lightning. *Tum Pater omnipotens misso perfregit Olympum Fulmine & excussit Subjectam Pelion Ossa. Obruta mole Sua cum corpora dira jacerent, perfusam multo Natorum Sanguine terram immaduisse ferunt, Calidumq; animasse cruorem.* This we find to be a general Concomitant or Subsequent of such Eruptions, and it were easy to produce many Examples of it in our late Eruptions; and 'tis also as usual for many of those places that have been thrown or raised up into Hills to be sunk or tumbled down again, *Excussit subjectam Pelion Ossa.* So we are told of a Hill that lately rose up by *Catanea*, which soon sunk again. [*Obruta*] by this, I think, is plainly signified the Eruption of fiery Streams or Rivers of melted Minerals out of those Orifices or fiery Vents, such as in the two last Earthquakes in *Sicily* have broke out of *Ætna*, and overflowed and burnt up and destroyed several Towns, Villages, Fields, *&c.* for what can better express the moving, raging and devouring Qualities of such a stream of Liquid Fire, than to call it an animated, or living scalding Gore from its red and fiery Colour, its scalding and burning Heat, its fluidity and rapid Motion, and its devouring and consuming Power; but it would be too tedious to insist on all the remarkable Circumstances and Expressions, which, I conceive, makes it plainly enough appear what was the Design and Scope of the Story; nor need I mention the Description of it by other Mythologers, as *Claudian*, *Hygynus*, *Antoninus*, *Liberalis*. Nor will it, I hope, be needful to answer any thing to those who would interpret it another way: Some making it to be only a Description of a Rebellion; others a disguising of the History of the Tower *Babylon*. I shall rather leave it to the Judgment of every one to make choice of which interpretation he shall, upon duly considering the relation, think to be most aggreeable to the whole drift of the Book. And what I now deliver I would not have to be taken otherwise than only as my Reasonings and Conjectures upon the like Considerations: For as I observed before, the Poet has so couched all his Relations and Expressions as to comprize a Physical, a Moral, and an Historical Meaning in them. And it may be so interpreted as if it were designed to describe some particular Earthquakes, or some particular Rebellion, or the general Rebellion of wicked Men against Heaven, and the Divine Powers, or the attempt of those at *Babel*, and at the same time it may also be found designedly to contain in brief the Theory of Opinions of the most antient Physiologers which they held concerning the Causes and Effects of Earthquakes upon the uper Face of the Earth; which to me, I confess, seems to be the principal aim and design of this Story of *Ovid*, as well as of the most part of the rest of the Book, which I design, God willing, to prove more expresly and particularly in a Treatise upon this Subject, so soon as I have settled some Affairs, which have hitherto hindred me from perfecting that and many other Subjects.

I shall not need here to say any thing concerning the Custom of the *Greeks* in those former Ages of turning all their Histories into Mythologick Poetry; 'tis plainly enough proved by that Relation I read the last day out of *Plato*'s *Timæus*; and it was not only used by them but by divers other Nations, as the *English* and *Germans*, as you will know. I suppose the reason was for the better fixing it into the Minds of the Youth by a kind of indelible Character, as *Plato* expresses it: Which could not be forgotten; for extravagant Marks we know are the great helps of Artificial Memory, for that they raise extraordinary Attention; and that extraordinary Attention and Wonder does stigmatise or burn in as twere indelible Ideas in the Memory. Pleasure also is another help to fix Ideas, and that Poetry and Songs contribute to, and the activity of the Spirits in Youth work the Effects more powerfully, and make them more durable. These, I imagine were the Reasons why the *Ægyptians*, *Greeks* and other Nations converted their true Histories into these Romantick Fables: Not that I do here undertake for the truth of History in every Fable, for I conceive that there are as various kinds of Fables as there are of Histories. Some are repeated and believed Fables which are true Histories, others are believed true, but are really Fables: Some are believed Fables

and

and are really so, and others are believed true and really are so. But of this fourth Head I fear is the smallest number; but we must take the best Evidence we can to confirm our Belief of those that are generally so reputed: Among which none has been more looked after of late than Medalls, Inscriptions, and real Monuments, yet remaining of the preceding Persons and Actions, these are by all looked upon as a most undeniable Proof to confirm a written History, and yet we know that many things of this kind have been counterfeited, yet that cannot be said of all: Now, if these that may be counterfeited be yet looked upon as more Authentick than Written History, then certainly these Medals, Inscriptions, or Monuments of Natures own stamping, (which I alledged to prove an Hypothesis) which 'tis impossible for Art to counterfeit, might in reason be looked upon as Proof sufficient tho' no History could be produced. If I saw a perfect Medal, tho' I could not be assertained whether it were Antique or Counterfeit, yet I could certainly conclude it had been made by Art from the sensible Characteristicks of it; now it seems very strange to me that so many evident Characteristicks as may be plainly discovered in those figured Bodies should not force an assent; but truth will in time prevail; but to give as much satisfaction as I can to all Doubts, I will pitch upon one or two of the Fables of the Metamorphosis for instances, to shew that they were designed to convey a certain History very much differing from the first appearance of the Fable. I will begin with those of *Perseus*, *Atlas*, *Andromeda* and *Medusa*, because, as I conceive, they have relation to the *Herculean Columns*, and to the *Atlantis*, or those parts of *Libya* which were near it; they are somewhat long, however I must beg your Patience to explain them a little more fully, and I will be shorter in the rest.

Perseus from περιζέω *circumferveo*, I take to signifie hot inflamed Air or Lightning which is the Earthy Exhalations set on fire by the Air dissolving them; he is said to be the Son of *Jove*, that is of Ætherial or Elementary Fire begotten in a shower of Gold or Fire from Heaven, that is Lightning. He carries with him the *Gorgons* Head haired with Vipers, the Picture of Lightning. *of* Perseus.

Viperei referens spolium mirabile Monstri
Aera carpebat tenerum stridentibus alis.

Bearing the spoil adorn'd with snakey Hair
With clashing Wings he rends the yielding Air.

This I take a proper Description of Thunder and Lightning, fiery Serpents representing the Emanations of Lightning, or the wrigling flashes of it darting out sometimes: 'Tis represented as held in the Hand of *Jupiter*, sometimes in the Mouth, sometimes in the Claws of his Eagle, and we shall find afterwards in the Fable, that the Actions of *Perseus* against the Sea Monster or the Flood are compared to those of *Jupiter*'s Eagle.

Cumq; super Libycas Victor penderet arenas
Gorgonei capitis, guttæ cæcidere cruentæ,
Quas humus acceptas varios animavit in angues.

And while the Victor hover'd in the Air,
The drops that fell from Gorgon'*s Bloody Hair,*
By Earth receiv'd, were turn'd to various Snakes.

These are the effects of Heat in those sandy, hot, burning Countries, and I conceive this alludes to the Snake-Stones, or Thunder-bolt-stones, as well as the living Serpents; for the vertue of the *Gorgon*'s Head, which is Subterraneous Eructations or Damps, was the petrifying Quality converting all things to Stone.

Inde per immensum ventis discordibus actus,
Nunc huc, nunc illuc, exemplo Nubis aquosæ
Fertur, & ex alto, seductas æthere longe
Despectat Terras, totumq; supervolat Orbem:
Ter gelidos Arctos, ter Cancri brachia vidit,
Sæpe sub Occasus, sæpe est sublatus in Ortus.

Thence carry'd by discordant Winds he's hurl'd,
As watery Clouds through the expanded World;
Now here, now there, on the far distant Plains
He casts a glance, then Heav'nly Arches gains;
Thrice the cold Bear, thrice the hot Crab his Eyes
Survey, as oft to West or East he flies.

This I conceive very properly apply'd to Lightning, which is now here, now there, all over the World.

Jamq; cadente die veritus se credere Nocti,
Constitit Hesperio, regnis Atlantis in Orbe
Exiguamq; petit requiem, dum Lucifer ignes
Evocet Auroræ, Cursusq; Aurora diurnos.

And now not trusting to approaching Night,
Doth on th' Hesperian Realms of Atlas Light,
And craves some Rest, 'till Lucifer displays
Auroras blush, and she Apollo's *Rays.*

This describes the settling of this fiery Vapour about the Westermost parts of *Africa*; where

Hominum cunctis ingenti corpore præstans
Japitionides Atlas fuit: Ultima Tellus
Rege sub hoc & Pontus erat, qui solis anhelis
Æquora subdit equis, & fessos excipit axes.

Gigantick Atlas Empire here possest
O're Lands extended to the fartheſt West;
Where Titans *panting steeds his Chariot steep,*
And bath their fiery Fet-locks in the Deep.

It was a Country that lay fartheſt Westward where the Sun seemed to set in the Sea.

Mille greges illi, totidemq; armenta per herbas
Errabant-------

A thousand Flocks, a thousand Herds there Graz'd
On verdant plains------.

It was a delicate Country for Pasture and Cattle.

Et Humum vicinia nulla premebat.

No Neighbouring Lands offended this.

It was an Island not joined to any Continent.

Arboreæ

Arboreæ frondes auro Radiante nitentes
Ex auro Ramos, ex auro poma ferebant.

The dazling Trees there glitter in the Air,
Which golden Fruit and gilded Branches bear.

Its Rivers and Rivulets all abounded with Gold or golden Sand.

Rivers are very properly Mythologised by Trees, the greater Body of Water resembling the Trunk, the lesser Rivers the Branches, the Rivulets, Fountains, Springs and Sources, the Twigs and Leaves; and the Hills and Mountains the Fruit: For as I have already, upon another occasion, hinted, Trees receive the greatest part of the Sap from the Air and little from the Earth: And they distribute more moisture to the Earth from their Bodies by their descending Sap than they draw from it by their Vessels, and as the Sea Returns the Water it receives out of the Rivers into the Air, whence it circulates again into the Fountains and Rivulets by condensation and Rain, so doth the process of Nature also operate in the manner of returning the moisture into the Leaves, as I shall upon another occasion more particularly explain, having mentioned it only upon this occasion to shew how properly the Rivers are Mythologised by the Trees, Branches, Leaves and Fruit.

The next Verses expressing *Perseus*'s Addresses to *Atlas* is Poetical, as also of *Atlas*'s Resentiment, upon remembrance of an old Prophesy that *Parnassian Themis*; or all knowing Predestination had fore-shewn, *viz.* That time should come when an Off-spring of Celestial Fire should destroy that golden Country; for fear of which it is said,

Id Mentvens solidis Pomaria clauserat Atlas
Mænibus, & vasto dedit servanda Draconi,
Arcebatq; suis externos finibus------.

This fearing, he his Orchard had inclos'd
With solid Cliffs: A Dragon too oppos'd
All Entrance------,

This *Hesperian* Garden was incircled with high Cliffs and encompassed round by the Sea.

Huic quoq; vade procul, ne longe gloria rerum
Quas mentiris, ait, longe tibi Jupiter absit
Vimq; minis addit, manibusq; expellere tentat
Cunctantem, & placidis miscentem fortia dictis.

Begon, said he, for fear thy Glories prove
But Counterfeit, and thou no Son of Jove.
Then adds uncivil Violence to Threats;
With strength the other seconds his intreats.

This Island had not been troubled with Thunder, Lightning, Earthquakes, or Eruptions, poetically thus described; and how these came on by degrees, and Barrenness with Drouth increased, and how the Inhabitants endeavoured to prevent it by their Labours; but at last because they strove against the Course of Nature, the Poet makes *Perseus* say,

Accipe Munus, ait, Lævaq; a parte Medusæ
Ipse retro versus squallentia protulit ora.

Take then, said he, thy due Reward, to's view
Shewing Medusa's *Head, his own withdrew.*

That

That is, the subterraneous Eruption, and therewith the petrifactive quality exerted itself, upon that Country, and as a Consequence thereof,

Quantus erat; Mons factus erat nam barba comæque
In Sylvas abeunt, juga sunt humeriq; manusq;
Quod caput ante fuit, summo est in monte Cacumen:
Ossa Lapis fiunt, tum partes Atlas in omnes
Crevit in immensum-----.

Atlas *to a Mountain, equal to the Man,*
Was turn'd, where Hair and Beard was, Trees began
To grow, his Shoulders into ridges spread,
And what was his, is now the Mountains Head:
Bones turn to Stones, and vastly all increase-----.

A prodigious Mountain is raised, and the *Hesperian* Garden or Country lost, this Mountain being the only remains thereof. Now before this Metamorphosis of the Country of *Atlas* into that Mountain, *Perseus* had destroyed the *Gorgons*, and cut off the head of *Medusa*. These *Gorgons* were said to inhabit certain Islands lying near *Atlas*, they were called the *Phorcidæ*, of which there were two which were said to have but one Eye between them; possibly a *Vulcano*.

-----Gelido sub Atlante jacentem
Esse locum solida tutum molimine molis,
Cujus in introitu, geminas habitasse sorores
Phorcidas, unius sortitas Luminis usum.

-----Under frosty Atlas *side*
There lay a Plain with Mountains fortify'd,
In whose access the Phorcidæ *did lye*
Two Sisters, both of them had but one Eye.

This he takes with him; that is, I suppose there began the Earthquake or the Subterraneous Vapour kindled, and thence extended to the farthest extreamity of those Islands, possibly the *Atlantick*.

Id se solerti, furtim dum traditur, astu
Supposita cepisse manu; perq; abdita longe,
Deviaq; & Sylvis horrentia fana fragosis
Gorgoneas tetigisse domos, passimq; per agros
Perq; vias vidisse hominum simulacra ferarumq;
In silicem ex ipsis, visa conversa medusa.

How cunningly thereon his Hands he laid,
As they from one another it convey'd;
Then thro' blind Wasts and rocky Forrests came
To Gorgon's *House; the way unto the same*
Beset with forms of Men and Beasts, alone
By seeing of Medusa, *turn'd to stone.*

By which it seems to have extended a great way and to have been very Rocky, Cragged and Uninhabitable, where Men and other things had been before that time petrified. Being there arrived, he finds *Medusa* asleep; that is, I suppose, the *Vulcano* not burning: But by this new Eruption the Head of *Medusa* is taken off, and the Vapour or Eructation riseth into the Air, partly in Flames and Lightning and fiery Vapours, which is *Perseus*; partly in watery Vapours and Wind, which is,

Dumq;

Dumq; gravis somnus Colubros ipsamq; tenebat
Eripuisse Caput collo; pennisq; fugacem
Pegason & fratrem, matris de sanguine natos.

And how her Head he from her Shoulders took,
E're heavy sleep her Snakes and her forsook;
Then told of Pegasus, *and of his Brother,*
Sprung from the Blood of their new slaughter'd Mother.

This may represent the mounting of fiery Eruptions, which rise as swift as *Pegasus*, and shine like his Brother, who was supposed to brandish a golden flaming Sword. But I must hasten, *Perseus* having performed those Exploits of sinking the *Atlankick*, and raising Mount *Atlas*.

------Pennis ligat ille resumptis,
Parte ab utraq; pedes, teloq; accingitur unco,
Et liquidum motis talaribus aera findit:
Gentibus innumeris circumq; infraq; relictis
Æthiopum propulos Cephæaq; conspicit arva.

His Wings at's Feet, his Faulcion at his Side
He sprung in th' Air: Below, on either Hand,
Innumerable Nations left, the Land
Of Æthiope, *and the* Cephean *Fields survey'd.*

The fiery Vapours flies over several Countries till it comes to the Country of the *Æthiopians*, and the Plains of *Cepheus* or the *Drones*. Here he finds *Andromeda* chained to a Rock expecting to be devoured by a Sea Monster. *Andromeda*'s Name and Description agrees with that of an half drowned and Rocky Country, by turns overflowed with the Sea at High Water and covered with Sand (*Jusserat Ammon*) and seems to be that part of *Africa* where *Jupiter Ammon*'s Temple was built; which since raised, is all Sandy, and therefore is called *Ammon* or Sandy. *Perseus*, its said would have thought her Marble, but that he saw the waving of her Hair by the Wind, which may signifie that some Reeds, or such Water-plants, might grow among the Sand and Rocks sometimes overflowed by the Sea. Here (to make it short) *Perseus*, or the fiery Eruption, raiseth the frontier Parts to the Sea, and repelleth the Tide of Flood from overflowing and drowning the Land. And so *Andromeda* becomes Ἀνδρόμη, raised and freed from the Inundation; this is so very plainly specified in the Description, that bating a little poetical Expression about Love; which *Ovid* had well studied, having a gust for it. It seems plainly to design the History of such a Metamorphosis, and very probably of that very Country I before-mentioned; and were it worth while, I am apt to believe, that the Histories designed by all the other Fables may be discovered; for that they have all such Histories couched under them, I do no ways doubt; not only for the Arguments I at first mentioned, but for several others. Moreover I do conceive, that there is a Chronologoe of the preceding times to be discovered out of them, and that they are written, not fortuitously, but with great Care, and according to the due Order in which they happened. And tho' possibly this do not at first view so plainly appear, nor can be so undeniably demonstrated without a more perfect knowledge of the *Hieroglyphick* and *Mythologick* Characters, yet I am almost certain that some such Chronogick Account is couched in the Fable, and may, if well examined, be detected; and to conclude, I am apt to believe, that in this Mythology is contained the greatest part of the *Ægyptian* and *Grecian* History of the preceding Ages of the World; the truth of which I do not undertake to defend, we must take that as we do all other Histories, upon trust till we can have better

The Fable of Andromeda

Proof either for or against them. And if these be so admitted, this Book will furnish a sufficient number of such Catastrophies that have happened in former Ages to make the Hypothesis, I have indeavoured to explain, to seem at least probable, if not necessary, and neither so absurd or impossible as some have asserted.

The Fable of the Rape of Proserpina.

Read *March* 8, 169⅔. I have some Years since propounded in this place my Conjectures for the explication of the Mythology delivered by *Ovid* in his *Metamorphosis*, namely, That he thereby designed to comprise a History of the changes which had happened to the World from the beginning thereof to the times wherein he lived, which he signifies Ænigmatically by the first four Verses. The method of which is by personating Things and Powers: The one by Mortals, namely, material Things, the other by Immortals, namely, Powers, or Energies and comprising therein a three fold *Cabala* or Tradition, namely, A *Physical*, comprehending the Causes, Effects and Reasons; an *Historical*, comprehending the Times, Ages, Persons and Places, And a *Moral*, to make them Instructive and Useful for the Regiment, and moralising the more vulgar part of Mankind. In which he has indeavoured to follow the method of the Greek Poets, who, as I have formerly exemplified in *Homer*, *Hesiod*, and the rest of the Mythologers, did prosecute the same design. By the interpretation of which Mythology, if we could discover and find out the true Key, I conceive it would open and make manifest much of the History of the Catastrophies that have happened in the World, and of the places and Ages wherein they were produced.

That which makes me repeat this Notion at this time, is the dreadful Effects of the late Earthquake in *Sicily*, which put me in mind of what I had here formerly instanced, on the Story as it is delivered by *Ovid* in his fifth Book concerning the Rape of *Proserpina* by *Pluto*, which I then conceived and am still of the same Opinion (however others were of a contrary) was designed by the Poet to represent some dreadful Earthquake that had formerly happened in *Sicily*, not far, nor much differing from the Place and Effects of this late dreadful Catastrophy: Save only that we do not yet hear of the swallowing up, or the sinking down into, or under the Water of any considerable Country or Town, which I conceive is plainly specified by the Poet to have been effected by that which he designs to delineate: For *Proserpina* or *Abrepta*, as the Name signifies, is plainly described to have been seated in that place of the Island where the Lake *Pergusa* was in *Ovid*'s Time, and where it remains, I suppose, to this Day: It is described to be the Daughter or Off-spring of *Ceres*, that is, a City or Place flourishing in a much civilised and well cultivated Country; for that *Ceres* doth plainly denote, and is so signified by the Poet.

Prima Ceres Unco Glebam Dimovit aratro,
Prima dedit Fruges alimentaq; mitia terris;
Prima dedit Leges: Cereris sunt Omnia Munus.

Ceres *with crooked Plough Gleabes first did turn,*
And first taught Men to feed on Fruits and Corn:
She first gave Laws Ceres *did all adorn.*

This Place or Country was also very pleasant and flourishing with Fruits, Flowers, Fountains, especially Woods, in which *Proserpina* is said to be disporting and innocently gathering Flowers, when *Pluto* suddainly seised her and carried her into the Earth; that is, whatever the place were, whether Town, Village or City before the Rape, it seems to have the same fate with St. *Euphemia* mentioned by *Kircher* in his *Mundus Subterraneus*; that is, to have been by an Earthquake swallowed up into the Earth, and to have sunk so low, as to have left a Bason for a Lake for after Ages to this Day. Now, that this is plainly the Physical meaning of the Poet will appear plain if the whole Story be taken in. First, The Poet tells you the place to be *Trinacria* or *Sicily*. This Country, tho' most Delicious, Pleasant, rich in Soil, well Cultivated and Tilled, and very

very much Civilised and Governed by good Laws, as is figured by *Ceres*, as I have mentioned, was yet seated on a Sulphureous, and Fiery, Cavernous Foundation, subject to Heavings, Tremblings and Earthquakes, expressed by the Giant *Typhæus*, who had endeavour'd to invade Heaven, that is, to belch up Flames, and throw Stones and Rocks against it, but at length came to be covered with this Island. Verse 346, to 356. Hereupon *Dis* or *Pluto*, that is, the Spirit of the Earth is fained by the Poet to be roused up to see least the Vault of the Earth over his place of Residence, should be broken by the fury of the Giant *Typhæus*; that is, by the working of the Sulphureous Vapours and Fulminations, Ver. 356----*Et Rex pavet ipse silentum*, Ver. 362. That is, the Earth rose and swelled, and there were Eruptions of Smoke signified by the Black Horses his Chariot was drawn by, and there was a general Earthquake over all the Island, but the great Eruption was at the place where the Lake *Pargusa* is. Here the Poet fains that *Pluto*, or the Subterraneous Powers were in Love with the Beauty of this Goodly Place personated by *Proserpina*. *Venus*, or Youthful Beauty or Thoughts doth excite *Cupid* or Love and Desire in this Terrestrial or Subterraneal Power to take away this pleasant Place, *Proserpina* from its curious Situation, and swallow it up, or hurry it away on a sudden into his own, or the Subterraneous Regions. Ver. 363, to 385. All Poetical to express how *Dis* was thus enamored of *Proserpina*, from 385, to 395. The pleasant Situation of *Proserpina* is described. from 395, to 408. The Catastophy is described, which manifests, that this terrible Earthquake extended from the place where the Lake *Pergusa* now is to the Place where the City of *Syracuse* stood, now called *Saragosa*, where the River *Anapis* runs into the Sea: By this the Lake *Anapis* was broken open and made a Bay to the Sea, and no remainder of *Cyane*, but some small Brooks that run into that Bay. This I take to be the meaning of the Poet from 409, to the end of 437. The remaining part of the Story seems to be a description of the Devastations made in the Country, being made unfit for Tillage, and therefore *Ceres* is said to seek her Daughter *Proserpina* all over the World, the remaining Husbandman seeking for other places fit for Tillage, but returns to *Sicily*, at Verse 463.

It would be too long to interpret all which I think I could easily do, and shew plainly the meaning of the Physical *Cabala*. But I designed to mention this only at present as an example pertinent to this present time, when we yet have the noise of the *Sicilian* Earthquake, and some others, yet sounding in our Ears: As to the Moral *Cabala* many have handled it; and for the Historical, I shall take some other time to Discourse of it, and to give my Conjectures.

A Lecture read Feb. 15, 168$\frac{7}{8}$. *confirming what the Author had before said as to Earthquakes and their Effects.*

I need not repeat what I have formerly said as to the several curiously figured Stones found in many parts, nay, I may say, all parts of the Earth, that they are really the several Bodies they represent, or the mouldings of them Petrified, and not, as some have imagined, *a Lusus Naturæ* sporting her self in the needless formation of uselefs Beings.

I shall only add some Confirmations of the Conclusions I then deduced from an *Hypothesis*, which I took the liberty to propose. And First,

As to the Sphæriodical Figure of the Earth, and thence of the Decrease of Gravity towards the Æquator instead of the Increase, as most of the followers of *Des Cartes*, Mr. *Hobbs*, and divers others of the Modern Naturalists assert; tho' it were at first much opposed, yet I find that it is now by divers not thought so improbable but that it may be supposed; and tho' I find the consequent Supposition as yet opposed, yet I question not but in time to make that appear to be necessary also; but every thing must have its time. As to that also which I have Published, how unlikely soever it may appear, I hope

also

also to be able to produce very good Arguments for it, and that it was not an Hypothesis proposed at random, as some may imagine.

But because these in themselves, tho' fully proved, were not sufficient to solve all the *Phænomena* of Nature as to the Disposition of those figured Bodies, whether Shells or other Substances; therefore in the fourth place I laid down as a Supposition, that the superficial Parts of the Earth had been very much altered by *Subterraneous Eruptions*, whereby divers Parts that had before such Eruptions or Earthquakes been under the Sea, had been raised out of it and been made Islands; and that other parts that had been dry Land had been sunk into and covered by the Sea; that Vallies had been turned to Cliffs, and Hills to Vallies or Lakes, and the like.

This was likewise opposed and thought very improbable, because for so long time as our History will reach backwards, it was affirmed there had happened no such change; and therefore, because it was supposed no such History could be produced, this also was to be rejected, and we must again have recourse to the *Lusus Naturæ* as the only expedient to give satisfaction; only some kind of Subterraneous Passages were thought of, by which Oysters and other Fish might be conveyed to the middle of the *Alps*, going along with the Stream of the Water from the Sea to supply the Springs and Fountains at the top of the Hills.

Confirmation of the Atlantis.

I confess it seemed to me a little hard, because I could not give the Pedigree of the Fish, therefore I should not be allowed to believe it a Fish, when I saw all the sensible marks of a Fish; and that, because I could not tell who it was, or upon what occasion that caused the Stones on *Salisbury* Plain to be dispersed in that irregular Regularity, that therefore I must allow them to be a *Lusus Naturæ*, or placed there by *Merlin* or, some such unknown way, and not by the Hands, Labour or Workmanship of some such Men as are now living. Nevertheless that I might, as far as I was able, satisfy these Objections also, I produced the History of *Plato* as brought out of *Ægypt* by *Solon*, concerning the Island of the *Atlantis*. But this tho' related by *Plato*, with all the Circumstances, as if he believed it a true History, was yet supposed to be only a Fiction of *Plato* to lay the Scene of his Common-wealth, or at best a Fable of the *Ægyptian* Priest to magnify the knowledge of the *Ægyptians* as to the History of preceding Ages. I confess the account of the nine thousand Years is Argument enough to make the whole History to be suspected as a Fiction; but yet till we are certain what space of Time is there signified by a Year it will be a little hard to reject the whole for that Circumstance, since most of the other Circumstances of it are more probable.

And that they were thought so by divers of the Ancients, is plain from several Testimonies that might be alledged; I shall only mention what *Strabo* says of it in his second Book, where examining whether *Eratosthenes* had duly amended the τῆς οἰκουμένης πίνακα of the Antients he adds, that τὸ δὲ εξαίρεσθαι τὴν γῆν ποτὲ, &c. *Eratosthenes* (says he) has done well in expounding the manner how the Surface of the Earth may be changed, by relating how the same may sometimes be raised, and sometimes be sunk by Earthquakes, and various otherways changed, as we also have in many particulars Enumerated, by which also he hath properly shown how the History, which *Plato* relates concerning the Island of *Atlantis*, as it was brought out of *Ægypt* from the Priests there, by *Solon*, may be well believed not to be a Fiction, but a true History. From which Passage it is plain, that both *Strabo* and *Eratosthenes* did look upon this History of *Plato*, or rather of the *Ægyptians*, as very probable; *Pliny* also was of the like Opinion, as appears, not only by his mentioning the History of *Plato*, but by the several other Mutations, which he relates to have been made by the means of Earthquakes.

But because the Scene of this Tragedy of *Atlantis* was placed very far backwards in times remote, and that we have no other History of this change but what *Plato* is pleased to relate, I did therefore indeavour to produce some History concerning the changes that had happened since that time, namely, within the reach of the Greek Histories, in the same place where this *Atlantis*

was

was said to be sunk down into the Sea. For this I produced the History of the *Periplus* of *Hanno*, the *Carthaginian*, as it is set forth by *Berkelius*; from which I collected that at the time when this Expedition was made, the place where the *Atlantis* was said to be sunk, was found to be partly Sea and partly Islands, and that the same extended, as I conceive, as far to the Westwards almost as the *Madera* Island, about which place was then found a small Island called *Cerne*; from which Coasting Southwards for twelve Days, they found the Land all on Fire, and one prodigious high Mountain flaming out at the top, called *Theon Ochema*, or the Chariot of the Gods; which, by all Circumstances, I conceived to be the same with the now Pike of *Teneriff*. Supposing which Relation true, I deduced thence that there must needs have happened great changes in those Parts between the time of this Expedition and the present; for that all those places which seem to be described by that History are not now to be found in the places where they are by that Relation placed. But this Relation was also looked upon as fabulous, because I produced no other Authority for it besides the Relation itself and the Testimony of *Pliny*. But those who are better read in Ancient History, may find that it was by most of the Ancients supposed real; and all agree that the *Phænicians*, of whom the *Carthaginians* were a Colony, were very skillful in Astronomy, Navigation, Arithmetick aud Traffick, and that they were the first introducers of these among the Greeks, together with the Knowledge and Use of Letters. And from those Particulars I noted in the said Relation, it seems to me very evident, that they understood what Longitude and Latitude was, and knew how to keep account of their Course and Distance; and tho' the Interpretation thereof which I produced, be differing from all the other I have yet known: Some supposing it to relate wholly to the Coast of *Africa* as it is shaped, at present, and others in other Situations, yet whoever (taking this Notion of their skill in Astronomy and Navigation along with them) shall strictly examine the Relation itself, he will, I conceive, be persuaded to be somewhat of my Mind. *Strabo* therefore says of them. *The* Sidonians *were reported to be good Artists in various things, as it is also manifest by their Actions; as also, good Philosophers, Astronomers and Arithmeticians, and such as well knew the secret of Numbers and of Sailing in the Night also.* From which consideration I conceive, that καὶ ἐυθυ in the Relation can signify nothing else but the same Parallel of Latitude, or the same straight Line with that from *Carthage* to the Mouth of the *Streights*.

I was not then able to quote the place in *Aristotle* which relates to this discovery of the *Carthaginians*, tho' I was well assured I had met with such a Relation; 'Tis in his Book, περὶ θαυμασίων ἀκουσμάτων, in these Words, εν τῇ θαλασσῇ τῇ εξω Ηρακλείων στηλῶν φασὶν ὑπο καρχηδονίων νῆσον ευρεθῆναι ἐρημον ἐχουσαν ὕλης τε παντοδαπῆς καὶ ποταμοὺς πλωτοὺς καὶ ἵππους λοιποῖς καρποῖς θαυμαστῶς ἀπέχουσαν ὑπ πλείονων ἡμερῶν, &c. 'In the Sea that lies without the Pillars of 'Hercules, they say, that, by the *Carthaginians*, there has been discovered an 'Island deserted, but abounding with variety of Woods, and rich Rivers fit 'for Navigation, abounding also with variety of Fruits, distant from the 'Continent several Days Sail. *Pomponius Mela* also mentions the extream *Atlantick* to be inhabited by a wild sort of People, which he calls *Ægypanes*, *Blemmeæ* and *Gamphasentes*, and a kind of *Satyrs*. And in his Third Book and tenth Chapter, he says, *Ultra hunc sinum mons altus ut Græci vocant* Θεῶν ὄχημα *vehiculum Deorum perpetuis ignibus flagrat*, &c. *Diodorus Siculus* also mentions some such Island in his Fifth Book τὴν λιβυλῶ κεῖται μὲν πελαγία νῆσος, &c. That is, 'Against *Libya* there is situated an Island in the Ocean, considerable 'for Magnitude, several Days Sail distant towards the West, *&c.* I could cite several other Authors who mention some such Place, which may have relation to the discoveries of the *Carthaginians* in *Hanno*'s Expedition; all which do plainly make it appear, that his discoveries were towards the West, and not towards the South; and therefore it seems very probable, that at that time there were Islands both greater and smaller to the Westwards of the Streights Mouth, which are not now to be found, and consequently they must have suffered a Submersion by some intervening Catastrophies, which was the thing I indeavoured to deduce from it. Nor will it seem so unlikely if we will

but consider the alterations by Eruptions out of the Sea near the Islands of the *Canarys*, and in one of the Islands also within these few Years; the former was the Eruption out of the Sea, in the Year 1639, which *Athanatius Kircher* has given a description of, and I have received a relation of it by Word of Mouth from two Persons who were both upon the *Tenariff* Island at the same time, and had each of them often observed it tho' at a considerable distance: The latter Eruption happened within a few Years since in one of the same Islands, of which I have Printed the Relation in one of my Collections.

And thus, I hope, I have given some ground to believe that the Antient Historians knew and gave some Credit also to both these Relations, namely, that of *Solon* and that of *Hanno*, which, by that Passage of *Aristotle*, appears to have been made either before or in his time.

I came in the next place to shew that the *Metamorphosis* of *Ovid* contained many Histories of great Changes and Catastrophies that had happened long before his time to the parts of the Earth; which, tho' rapped up in Mythology and Mascarade, yet those disguises being removed, it will not, I conceive, be very difficult to make appear what the true Histories are, which now pass Incognito. To this purpose I did observe that *Ovid* has in some part or other of his Fable, given Marks or Characteristicks by which it may be found what the History is which he doth there Mythologize; this he doth very often in that part which serves as a Link to join the Story into a continued Chain or in the Etymology of the Names, tho' often times also in the process of the Poem. And 'tis usual with him all along to have and mix a treble Design in each of them, namely, an Historical, a Physical, and a Moral; and this he hath done with great Judgment and Subtilty of Invention, and upon several occasions, he makes Excursions into this or that Design, and prosecuting it for a time, as if he had no respect to the other two; but yet, if well examined, it will be found, I conceive, in most that he influenceth, even there also, that design by the other two. If I had leisure to prosecute this Speculation, I conceive I could trace most of these his Designs, but it would be too long a Work; however, I hope in a short time to be able to give several Instances and Examples out of those I have more attentively examined, which may suffice to shew that there is a probability in this Conjecture how differing soever it be from other Commentators.

But those perhaps may not be thought sufficient for the present Dispute to satisfy such as demand positive and direct Histories, and undoubted Records of such Changes, as I have supposed necessary to make out the Hypothesis of the figured Bodies, which are found to be real Shells, *&c.* and to have been by them disposed and situated in the places where they are now found: For such therefore I shall prepare a Cloud of Witnesses, which, unless they will deny all History, will stand the Proof.

I confess I cannot see any Circumstance in the Story of *Hanno* that should render it suspected, since 'tis granted by all, that the *Phænicians*, of whom the *Carthaginians* were a Colony, were so early eminent in Arts, especially in that of Navigation and Traffick; so that we find *Solon* made use of them; and that *Sanchoniathon Beritius* before the time of the *Trojan* War, did write the Theology of the *Phænicians* (as *Porphyrius* relates) in the *Phænician* Language: And that the Philosophy of the Greeks was derived principally from them; as also Astronomy, and even the knowledge and use of Letters. For *Thales* was a *Phænician*, and *Pherecides* who was the Master of *Pythagoras*, and the founder of the Italick Phylosophy, and co-equal with *Thales* learned it out of the occult Books of the *Phænicians*. And from *Pythagoras* his Philosophy sprang and flowed both the *Platonick* Philosophy, and also the Philosophy of his Scholar *Aristotle*, tho' somewhat altered by the Pipes it ran through. So that tho' we have but very little of the History of those Times, yet by those few Fragments dispersed here and there, we may be sufficiently satisfied they were able, and actually did make as great Voyages and Discoveries, as that of *Hanno*; of which there are divers Relations mentioned by *Herodotus* in his second Book.

But

But tho' (notwithstanding what I have alledged) all these Histories shall be looked upon as Fictions and Romantick without any real Ground, yet what I have indeavoured to shew by Experiment and Inspection, and the deductions made therefrom, will not be found destitute of good Authority, proved from very eminent Authors both Antient and Modern, to make out the Truth and Certainty thereof. As first to prove, that those Bodies were found at the tops of Mountains, and that they were notwithstanding asserted to be Shells; we have the Testimony of *Herodotus* in his *Euterpe* or second Book, and twelveth Section, where speaking of the Country of *Ægypt*, as having been mostly raised by the Mud and Sand of the *Nile*, he says, the whole Country was of such a Soil, only the Mountain above *Memphis* was Sandy, and had *Conchilia* or Fishes Shells upon it, and abounded with Salt, so that it corrupted the *Pyramids*. Which Passage is very pertinent to my present purpose, and is also fully confirmed by *Aristotle*: For it seems all the lower *Ægypt* was a Plain, which had rose by the settlement of Mud of the *Nile*, which he says, in the space of nine hundred Years, had been raised eight Cubits, or twelve Foot; for that eight Foot rise of the *Nile*, in the time of *Myris*, overflowed all *Ægypt*, and in his time there was necessary sixteen Cubits, or twenty four Foot swelling to overflow it. So that he seems to understand, that all the lower *Ægypt* had been at first Sea, and that the *Nile*, by degrees, had filled it up to the height of the Plain, and so had covered all the bottom or Sand of the Sea, only the Mountainous part above *Memphis* was above that level, and so that kept its old bottom or covering of Sand and Shells. This seems to be the meaning of what he argues for; but yet I must needs say, that does not solve all the Difficulty; for how comes this Mountain to be so much higher than the Plain, as it was then raised by the *Nile*, and thence that Plain to be much above the Sea that was thereby excluded, unless we do suppose also that some Subterraneous Power did raise that Mountain above the level it was of when covered by the Sea, or that the Sea had sometimes been so high as to cover that Mountain, which, tho' *Herodotus* takes no notice of, yet *Aristotle* does fully solve it; but be it which way soever, 'tis Testimony enough of the matter of Fact, that *Herodotus* himself calleth them κόγχυλια, and observed the exudation of the Salt. But this Place is also observable for another Passage, and that is to confirm Conjectures I formerly acquainted the Society with, concerning the *Pyramids of Ægypt*, namely, that I conceived them to be *founded on and Ashler'd, as it weere about a Core of Rock*, and by this Discourse it is plain, that the place where they stand is so qualified; for by this Description 'tis plain, that it is described as Rocky, and covered with Sea Sand; for that *Herodotus* takes notice it had both Sea-shells, and Salt mixed with it; but this here only by the bye. Before I leave *Herodotus* his Testimony, I cannot but take notice of another Passage in the same Book, in the 74th. and 75th Paragraphs; the translate runs thus, *Circa Thebas sunt Sacri Serpentes Nihil omnino hominibus noxii, pusillo corpore, binis præditi cornibus e summo vertice enatis, quos defunctos in Jovis Æde sepeliunt, huic enim Deo Sacros illos esse prædicant*; thus far is the story he is told by the *Ægyptians*. *Est autem Arabiæ Locus, ad Butum urbem fere positus ad quem Locum ego me contuli quod audirem volucres esse Serpentes. Eo cum perveni, Ossa Serpentum aspexi & Spinas multitudine Supra fidem ad Enarrandum quarum acervi erant magni, & his alii atq; alii minores ingenti Numero. Est autem hic Locus ubi Spinæ projectæ Jacebant hujuscemodi, ex Arctis montibus exporrigitur in vastam planitiem Ægyptiæ Contiguum. Fertur ex Arabia Serpentes alatos, ineunte statim vere, in Ægyptum volare, sed eis ad ingressum planities occurrentes aves Ibides, non permittere sed ipos interimere, & ob id opus Ibin magno in honore ab Ægyptiis haberi, Arabes aiunt.*

Tho' History should fail Experiments are Cogent.

Proofs out of Herodotus.

The Pyramids *are founded on a Rock.*

Part of this story is what he was told, part what he saw; he was told of flying Serpents, which the Bird *Ibis* met over that Valley, and so devoured them leaving only the Back-bone. I have heard many stories told of our Snake-stones or *Cornua Ammonis*, and I have seen some to confirm the story with a very formal Head carved on them; I think not long since here was one shewed in this place; I am apt to think the Spines of the Serpents *Herodotus* there found in such plenty and such variety of bignesses, were no other than those *Cornua Ammonis*, and thence, I conceive, proceeded the superstitious

Custom

Custom when they found any of these Stones or Spinæ they carried and buried them in the Temple of *Jupiter Ammon*, and it seems to me a farther confirmation of what I formerly hinted concerning the Stone adorned with Jewels, and carried in processions by the Priests of that Temple, mentioned by *Pliny* and several others. But to proceed, to this Testimony and Opinion of *Herodotus*, I shall add that of *Pythagoras*, as related by *Ovid* in his 15th Book of the Metamorphosis, *ver.* 262, and so onwards. *Vidi ego quod fuerat quondam Solidissima tellus, esse fretum. Vidi factas ex æquore terras: Et procul a pelago conchæ Jacuere Marinæ. Et vetus inventa est in montibus anchora summis.* From which Testimonies 'tis plain that this Phænomenon of Shells was taken notice of by the Antient Historians and Philosophers: And I am apt to think that this might, in some measure, spread among them, the Notion of general Deluges that in preceding Ages had happened, as *Pythagoras* seems to hint in this place, by supposing them to happen after a certain long Revolution of time; and that *Thales*, and many others, supposed that the Principle, from which all things sprung, was Water: And that the Passage in the Fragment of *Sanchoniathon*, where he speaks of the first Original of all things, says, That in the *Phænician* Language it was called μὼτ, which possibly may be much of the signification of מוט in the Hebrew, which signifies Motion; that is, Fluidity, for so the interpretation of *Sanchoniathon* seems to make it τὸ τινὲς φασιν ἰλὺν οἱ δὲ ὑδατώδους μίξεως σήψιν ἣ ἐκ ταύτης ἐγένετο πᾶσα σπορά κτίσεως καὶ γένεσις ὅλων. Which some will have to be Mud, others the Corruptions of watery mixtures (as if μὼτ were derived from מות, *Mors* Death or Corruption) from which sprung the Seeds of all living Creatures, and the Generation of all things. That the *Ægyptians* threw the History of the Flood so far backwards, and make it so differing from the Chronology of the Bible, I take it to be for no other Cause but to make the World believe they were preceding to all others in Antiquity of History and Chronology: To which purpose *Herodotus* tells a pleasant Relation of *Psammiticus*, that the *Ægyptians* before his time had vaunted themselves to be the first People upon the Face of the Earth, but he having a mind to be informed of this by Experiment, caused two Children to be bred up in a Desert Place by a Shepherd, so that they should not hear any Language at all spoken, to the end to see what Language they would naturally speak of themselves; from hence he supposed they would speak the first and most Natural Language. This having been done, and the Children grown two Years old, the Shepherd opening the Door of the place where they were so kept and fed with Milk, they both reached out their Hands to him crying *Beccos*, which the Shepherd taking notice of acquainted *Psammiticus* with, who inquiring what that word might signify in any Language, was informed that *Beccos* signified Bread in the *Phrygian* Language; from which time *Herodotus* says, the *Ægyptians* lost their seniority, and granted the *Phrygians* to be the first and themselves the second People for Antiquity. So that tho' their account of Years may be hence supposed to be uncertain, yet their Learning and their lasting Monuments of their former greatness, namely, the *Pyramids*, *Obelisks*, *Colossi*, *Labyrinths*, and the like, shewed them to have been long before *Herodotus* his time very considerable for Arts and Literature. And that they had some Records of a preceding Flood, I have before mentioned, whether the same with that of *Noah*, or some more particular Flood, which those of *Deucalion* and *Ogyges* seem to have been, I leave to the learned Antiquaries to determine. I could produce several other Testimonies to shew they had the notion of a Deluge.

of Noah's *Flood.*

But it seems to me very improbable, that these Shells should have been the effect of *Noah*'s Flood by reason of its short duration; which was not long enough of continuance to produce and perfect those Creatures in so short a space to the bigness and perfection they seem to have had. It must therefore have been either some particular Floods of a longer duration; or else the places where they are found, must have been some times or other the bottom of the Sea, and afterwards raised by Subterraneous Motions, Swellings, or Eruptions: Which, whither those just immediately preceded the end of the general Deluge in the time of *Noah*, and that That part which before the Flood was Land, did sink, and became covered by the Sea, and those parts

parts which were before under the Sea, did, by degrees, towards the determination of that Catastrophy, rise and swell up into Land, Hills and Mountains, I leave to the Learned to determine. Certain it is, that there were some very great changes of the superficial Parts of the Earth at that time; since it is said, that all the Fountains of the Deep, or Abysse, were broken up; the Scripture renders ἐρράγησαν πᾶσαι αἱ πηγαὶ τῆς ἀβύσσου καὶ οἱ καταρράκται τοῦ οὐρανοῦ ἠνεῴχθησαν. There seems by the Expression to be a twofold supply of Water to cause this Flood, the one by the opening of the *Stereoma* or Firmament in the middle of the Waters, *viz.* that of the στερέωμα ἐν μέσῳ τοῦ ὕδατος, and of the στερέωμα τοῦ οὐρανοῦ, the gathering together of the Waters above the former στερέωμα; but ὑποκάτω τοῦ οὐρανοῦ, these God called the Sea, and the parts of the Earth that were uncovered thereby he called dry Land. The *Stereoma* τοῦ οὐρανοῦ is assigned for the place of the Stars, Sun and Moon, *&c.* and has always the Epithet of τοῦ οὐρανοῦ joined with it. *Ovid* likewise who seems to allude in some measure to this History of the Creation delivered by *Moses* in the first Chapter of *Genesis*, says, *Circumfluus humor ultima possedit solidumq; coercuit orbem.* I think, were it proper to the present Subject, I could give a very plausible account concerning the manner of that Deluge, as it is expressed by *Moses*; tho' it differ from all that I have yet met with, yet I can prove it warranted both by the Text and by genuine Physical Principles; but it would be too long a digression for the present Subject, and I shall shortly have a more proper opportunity to demonstrate the inner Parts and Constitution of this Globe, my present Business being to explicate the Phænomena of the outward and superficial Parts, and to prove that the Bodies, which I have asserted to be Shells, have been so reputed by the Antient as well as the Modern Historians: Next to shew that they are, or have been, found in most Parts of the World. And if those two be proved, then will necessarily follow that there must have been some time or other such Catastrophies, Metamorphoses, or Mutations as must haue caused those parts, which were once the bottom of the Sea, to be now, or at the time when they were so observed, to be dry Land.

That they were so esteemed by divers of the Antients I have in part shewn and could inlarge upon that Head, but that I would likewise shew that they have been so esteemed by the most eminent of our Modern Naturalists, and for this I could produce the Testimonies of *Georgius Agricola*, *Cardan*, *Gesner*, *Aldrovandus*, *Ferranti Imperatus*, *Wormius*, *Calceolarius*, *Bauhinus*, *Belonius*, *Fracastorius*, *Cisalpinus*, *Fabius Columba*, *Stevinus*, and a great many others yet more Modern, besides the Testimony and Opinion of divers others, who have themselves declared their Judgment by word of Mouth; but this would be too great a wasting of Time to prove that which carries in itself the true *Medium* of its Proof and Demonstration, which is by sensible examination. I shall therefore only give one Instance or two for all, and that is, First, That of *Fabius Columba*, who has writ a Treatise on purpose to evidence this Truth by many Arguments; 'tis at the end of his Treatise *De Purpura.* *Nituntur quidam* (says he) *acanis Naturæ in medium adductis, omni Responsione Seclusa, Linguas Serpentinas aut Glosso-petras; quia non Solum mari, proximis & insulis, sed etiam Longe dissitis, copiose Reperiri traduntur, ab ipsa formatrice natura, sic genitas atq; Lapideas esse: Vel qui dentes esse dicunt, non Carchariæ, Lamiæ, Malthæ aut ejusdem generis Cætaceorum, sed illis similes sponte sic ortos Quin etiam id tantum Naturam produxisse eo loci, quod ratione materiei aptum erat ad formam illam Recipiendam affirmant. Hoc Argumento in dubium Revocare videntur, an unquam Locis illis mare fuerit,* Quod probatissimi antiquiores Philosophi & Historici affirmarunt. Nos *quidem dicimus hujusmodi concretionem* non *esse* lapideam, *ex ipso* aspectu, Effigie *rei, ac* tota substantia: *Ac neminem censemus tam Crassa Minerva Natum, qui statim primo* intuitu *non affirmarit* Dentes *esse* Osseos *non lapideos, Sed præter* aspectum *omnia quæ Ligneam, osseam, & Carneam Naturam habent,* Ustione *in* Carbonem *prius abeunt, quam in Calcem, aut Cinerem. Ea vero quæ tophace vel Saxea Sunt Natura, non in Carbonem sed in Calcem abire, nisi liquuntur propter vitream ant Metallicam mixtionem. Cum igitur hi* dentes *statim* assati *transeant in* Carbonem *& tophum adhærentem minime, clarum crit osseas esse dentes non Lapilleas.* He hath many other Arguments to confirm this Truth, which

Proofs out of Modern Writers.

which would be too long to trouble you with at this time, and I only proceeded so far that I might give an occasion to have the Experiment now tried in the presence of this Society, there being several of that kind in the Repository, and the trial being very easy will not be long in making, all things being in a readiness for it. I shall only add one more Testimony, which is of *Andreas Cisalpinus* in his first Book *de Re Metallica* and second Chapter. *In fodinis metallorum seu Marmorum* (says he) *aliorumq; Saxorum Nunquam vivens Corpus Reperitur. Etsi enim aliquando in eorum Cæsura ostrearum testæ aut cætera Conchilia Reperta sunt; hæc recedente Mari & Lapidescente Solo inibi derelicta in Lapides concreverunt. Ubiq; enim vbi nunc est arida aliquando affuisse Mare testatur Aristoteles. Hoc enim modo Censere magis Consonum est rationi, quam putare vim animalem, intra Lapides, rudimenta animalium ac plantarum Gignere ut quidam putant.* He hath not told where *Aristotle* hath maintained this Doctrine; but whosoever shall examine his Writings, shall, by many Passages in them find, that he was fully of this Judgment: And more fully in the fourteenth Chapter of the first Book of *Meteors*, where also he confirms the same Sentiments of *Herodotus*, which I have newly quoted; and concurs likewise with the Doctrine of the alterations that are caused by slow degrees of Progress, which I have Hypothetically explained by the Oval Figure of the Earth, and the alteration of that shorter Axis to differing parts of the Earth: But this only by the bye to shew how much soever that Hypothesis were exploded by a learned Dr., by reason of the Consequences that would follow from it; yet *Aristotle* (though he hath not explained by what means and in what manner) hath asserted Mutations as great and much after the same method of Progression, as those which are alledged to be the *extravagant Consequences of that Hypothesis*, some of which I shall have occasion to mention at another time. So that to conclude for this time I hope I have shewn good grounds to evince. First, That these kind of Bodies are either Animal or Vegetable Substances. Secondly, That the places where these are found must have sometimes been covered with the Sea. Thirdly, That the general Deluge of *Noah* was not of duration enough to effect it, unless the manner of its effecting were after that which I proposed, by changing that part which was before dry Land into Sea, by sinking; and that which was Sea into dry Land, by rising underneath it. Fourthly, That the universality of the *Phænomena* over the whole Earth seem to argue for this manner. Fifthly, That there have been several particular Floods, as that of *Deucalion*, the *Atlantick*, &c. which being caused, for the most part, by Earthquakes, may have been the causes of divers particular *Phænomena*, such as the raising of some parts from under the Sea, and the sinking of others into it, or into Lakes.

The former Lecture was read *Feb.* 15*th.* 1688.

Feb. 29. 1688. I have, in my former Lecture, proved how early and how generally the Phænomena of Shells were taken notice of by the most antient Historians and Philosophers, and I could have given many other Instances to confirm it, if it had been thought necessary. And thence, I conceived, might be continually revived the Traditions and Theories concerning preceding Floods and other Catastrophies that had happened to the Earth in Ages long preceding. But because, among the Philosophers, I only quoted that place in *Plato* about the *Atlantis*, which was thought to be a Fiction (however that shewed he had such a notion) and the Doctrine of *Pythagoras* as reported by *Ovid*, which was thought Poetical (tho' as I conceive all those Mythologies have certain Historical and real Truths thereby represented) I shall therefore add one out of *Aristotle* which I hinted the last Day out of his first Book of Meteors. 'The same parts of the Earth (says he) are not always dry or 'moist, but they receive a change from the increase or defect of Rivers; 'therefore parts bounding Sea and Land change often, nor is the same part 'always Sea or always Land, but is changed in time, and that which was Sea 'is Land, and that which was Land is Sea; but this is in a long process: 'This arrives from interior changes of the Earth, which from a long Constitution grows old, as the Bodies of Plants and Animals, and that not singly the

Proofs out of Aristotle.

'Parts

'Parts but the whole. It may therefore for a time be moist, and by degrees 'grow dry and old: This may happen both by the decreasing of Rivers and also 'of the Sea; but these happen not, but in a long time, in comparison of our 'short Life, which is the cause they are not noted, the change being so little 'in the space of one Life, and so several Ages pass before they are finished; 'whence the memory of them is lost. (He adds much more to the same effect 'to explain his Notion) Exemplifying his Doctrine by *Ægypt*, which (says 'he) has been all made by Mud of Rivers, and is observed continually to 'grow drier, and the Lakes filling up by degrees have been inhabited, and 'length of time has obliterated the memory of such changes; for all the pre-'sent Mouths of *Nile*, except the *Canobic*, have been cut by Art; for old '*Ægypt* was that only about *Thebes*, as *Homer* testifies, who lived not long 'after these Changes; for he mentions *Thebes* only as if *Memphis* had not yet 'then been, so he proceeds in explicating, and instances again in saying, so 'marshy places grow better by draining, but dry grow worse and barren, as 'it has happened to the Country about the *Argives*, and the *Mycenæans*, and 'what has happened to these parts, the same may be conceived of the whole. 'So many parts which have been Sea have been added to the Continent; and 'the contrary, those that do *respicere ad pauca*, ascribe these changes to the 'Heavens, but they are mistaken; but they are to be ascribed to Causes that 'happen after a long process of time, as that of *Deucalion*'s Flood, which hap-'pened only to *Greece* about that part which is called old *Hellas*, which is 'that about the present *Dodon* and *Achelous*; this happened from great abun-'dance of Rains which are generated by the Mountains, which are by de-'grees changed and so produce differing effects. He exemplifies his Doctrine further by *Ægypt*, and the Country where the Oracles of *Jupiter Ammon* was, saying, ''Twas formerly Marshy, but by degrees dried and grew parched; 'so not only the present most famous Rivers will come in long process of time 'to be dried and changed, but the Sea also; and that which was Sea will be 'Land, and the Land will be Sea. I have here given the sum of his Doctrine which he doth much inlarge upon to explain it; but to save time, I have only abstracted the meaning, and given you the Epitomy of it that may easily enough be more fully explained or read at large in the fourthteenth Chapter of his first Book of *Meteors*. By the whole it plainly appears, that *Aristotle* was of the Opinion that all the dry Land of the Earth had been sometimes covered with the Sea, which he seems to be informed of by the then present *Phænomena*, as he plainly expresses in his description of *Ægypt*, and of the Country about the Oracle of *Jupiter Ammon*; and 'tis not to be doubted but one of those *Phænomena* and possibly not the least considerable was that of the Sea-sand and Shells, which I shewed the last Day *Herodotus* had taken notice of. I do therefore humbly conceive (tho' some possibly may think there is too much notice taken of such a trivial thing as a rotten Shell, yet) that Men do generally too much slight and pass over without regard these Records of Antiquity which Nature have left as Monuments and Hieroglyphick Characters of preceding Transactions in the like duration or Transactions of the Body of the Earth, which are infinitely more evident and certain tokens than any thing of Antiquity that can be fetched out of Coins or Medals, or any other way yet known, since the best of those ways may be counterfeited or made by Art and Design, as may also Books, Manuscripts and Inscriptions, as all the Learned are now sufficiently satisfied, has often been actually practised; but those Characters are not to be counterfeited by all the Craft in the World, nor can they be doubted to be, what they appear, by any one that will impartially examine the true appearances of them: And tho' it must be granted, that it is very difficult to read them, and to raise a *Chronology* out of them, and to state the intervalls of the Times wherein such, or such Catastrophies and Mutations have happened; yet 'tis not impossible, but that, by the help of those joined to other means and assistances of Information, much may be done even in that part of Information also. And tho' possibly some may say, I have turned the World upside down for the sake of a Shell, yet, as I think, there is no one has reason for any such assertion from any action I have hitherto done; yet if by means of so slight and trivial Signs and Tokens as these are, there

there can be Discoveries made and certain Conclusions drawn of infinitely more important Subjects; I hope the attempts of that kind do no ways deserve reproach, since possibly 'tis not every one that takes notice of them, nor one of a hundred that does, that will think of a reason; besides, much greater conclusions have been deduced from less evident and more inconsiderable Marks, if we respect Bulk, Magnitude, or Number, and much more weighty Consequences may, and will in time, be drawn from seemingly more trivial, and much lighter and slighter Indications, yet where the Testimonies are clear, certain and self-evident, they are not to be rejected for their bulk, tho' it be so small as no Eye or Sense can reach it unless assisted by Engines, as the Sight by a Microscope, Telescope, and the like: In how few Letters, Words, or Characters is the History of the World before *Noah*'s Flood? Is it therefore not to be believed because we have not as many Volumes of its History as there are now to be found words? In how little room will the History of the Flood be contained if *Homer*'s Iliads could be boxed in a Nutshell? But to leave every one to the freedom of his own Thoughts, I shall proceed to what I thought was further necessary to be added to what I hinted the last Day, which was concerning the Flood of *Noah*, because I find the generality of those who indeavour to give a solution of these *Phænomena*, are inclined to ascribe them to the effects of that Flood, and because what I then said was but in brief, and so possibly what I design might not be so plainly apprehended, or it may be misconstrued, I thought it might be necessary to explain it a little more fully. I said then, that I conceived that those universal *Phænomena* of the remainders of the Sea which are found in all parts almost of the present superficial Parts of the Earth, could not be caused by the general Flood of *Noah*, if the manner of performance and executing thereof were such as is for the generality supposed and explained by Commentators by reason that they make the time of the continuance of the present superficial Parts of the Earth under the Waters to be no longer than the time of the duration of the Flood, as it is recorded in Holy Writ. Supposing that the present Earth and Sea is in the same places with respect to the Body of the Earth as they were before the Flood; nor will the Hypothesis or Explication of the ingenious Author that has lately writ of that Subject, reach it, he supposing there was no apparent Sea before the Flood, but that the Sea was all covered by the Earth, if at least I do rightly comprehend his intentions; for that space of time will not be found of duration long enough to produce *de novo* such multitudes of those Creatures, and to such Magnitudes and Ages of growth as many of them seem to have had, and it will be difficult to be imagined, that such Creatures as do not swim in the Water, should, by the Effects of that Deluge, be taken from their Residences in the bottom of the Sea and carried to the top of the Mountains, or to places so far remote from those Residences. So then, if we will ascribe those Phænomena to that Flood, it will be necessary to consider which way that Catastrophy might be effected that it might be the occasion of such effects. I therefore said, that unless we supposed that there were thereby a change wrought of the superficial Parts of the Globe, and that those Parts which before the Flood were dry Land became Sea, and the Parts which were before covered by the Sea after the said Deluge, became the dry Land, it seems to me, that these appearances cannot be solved by *Noah*'s Flood.

A further explication of Noah's *Flood, and the formation of the World.*

Tho' possibly this may seem a little improbable upon the first mentioning of it, yet possibly also upon a little further examination, it may be thought to have somewhat more of liklyhood than is yet imagined, at least I hope the manner will be conceivable.

We have no other means of being informed of the true History of it, but what is to be found recorded in the sacred Writings of *Moses*; and therefore those are to be consulted, and the true meaning of them, as far as can be, must be obtained; for whatever else may be scattered here and there in other Authors that seem to relate thereunto in all probability, were some way or other fetched from his Informations.

I con-

I conceive then, that considering the Descriptions of *Moses* both of the Generation of the Earth and manner of the Flood, the History of both may be thus explained.

First, For the Fabrick of the Earth, the Description is but short in the first Chapter of *Genesis* and 2d Verse. *Et terra erat Solitudo & Inanitas, & Caligo Super facies abyssi, & Spiritus Dei manabat Super facies aquarum, & dixit Deus sit lux & fuit lux.* This doth seem to represent the order of the four Gradations, Earth in the middle, Water next, then Spiritus, then Light; the Central Earth is described only as a *Vacuum*, and called the *Abysse*, and Darkness inclosing it; that is, the Water follows next above it, which covered it all round: Above this the Air, and lastly the Fire, Æther, or Light in the fourth Verse, according to the Hebrew, *Et divisit Deus inter Lucem & inter tenebras:* The Septuagint renders it, καὶ διεχώρισεν ὁ θεὸς ἀνὰ μέσον τοῦ φωτὸς καὶ ἀνὰ μέσον τοῦ σκότους. That is, God caused a twofold Seperation, one in the middle of the Light or Æther, and another in the middle of the Darkness, which covered the Face of the Abysse or Central Earth; which covering of Darkness was the Water, which is often called the Abysse or great Deep; the former of these is afterwards always called the στέρεωμα τοῦ οὐρανοῦ, the Firmament of Heaven, to distinguish it from the latter, called the στέρεωμα ἐν μέσῳ τοῦ ὕδατος, the Firmament in the middle of the Waters; for in the sixth Verse it is so exprest, καὶ εἶπεν ὁ θεός γενηθέτω στέρεωμα ἐν μέσῳ τοῦ ὕδατος. Let there be a Firmament in the middle of the Waters, and let it be a division between the Waters and the Waters: And in the seventh Verse; and God made the Firmament, and God made a separation of the Waters that were below the Firmament, from the Waters that were above the Firmament. And in the eighth Verse, καὶ ἐκάλεσε ὁ θεὸς τὸ στέρεωμα οὐρανόν; it is generally rendered, and God called the Firmament Heaven; I conceive it may be rendered, Also God called the Heaven the Firmament, for to shew that there was also a Firmament of the Heavens; for so it is afterward every where called, στέρεωμα τοῦ οὐρανοῦ. But this I submit to Divines.

This first Firmament then, ἐν μέσῳ τοῦ ὕδατος, seems to have been a solid and hard Sphærical Shell, as it were, which incompassed the Ball of the Earth Central, not clear without the Liquid Water, as the hard Shell of the Egg is without the White, and so the Egg-shell doth inclose the whole White of the Egg, as well as the White incloseth the Yolk: But it was, as I conceive, meant, that this Firmament or Sphærical hard Shell was placed, as it were, in the middle of all the White, or of the incompassing Water; the Circumferential half of it being without the Shell, and the Central half of it within the Shell. So then at its first Creation, the order was first the Central Earth or great Abysse; this was in the middle as the Yolk of the Egg round or Sphærical; this was inclosed in Darkness by the Shell of Water underneath the Firmament, being half the whole Body of the Water which was inclosed perfectly within this Firmament, as the White of the Egg by the Egg-shell; and by that hard Shell it was perfectly seperated from the other half of the Water which was above the Firmament, and as it were a second White of the Egg without the Shell, and was the Water upon the Face of which the Spirit was said to move; so that the whole Globe, for that time, was all covered with Water. This *Ovid* seems to allude to, when he saith, *Circumfluus humor ultima possedit, Solidumq; coercuit orbem*; which I took notice of in my Lecture about the History of the World, as expressed by that ingenious Mythologick Poet; for he seems to make the Water to be both below the Shell of the Earth and to encompass it.

Plato also was of that Opinion in making *Tartarus* the place of the Waters, that is, the middle and Central parts of the Ball or Globe of the Earth; and so the hard part of the Earth to be nothing but this Shell near the Superficies, and it seems also, that *Pythagoras*, yea, and the *Ægyptians* and *Chaldeans* likewise were of the same Sentiment, and divers are of Opinion that *Moses* also understood the same by the great Abysse which he mentions in the Description of *Noah*'s Flood. But by this Description of the Creation he seems to be understood otherwise, when he says, *Et terra erat Solitudo & Inanitas & Caligo super facies Abyssi.* For by this he seems to make the form of the Terraqueous *of* Tartarus.

Globe to be no other than that of a Bubble, such as Children blow into the Air, that is, only a Sphærical Film or Orb of Water, which within it had nothing but *Solitudo & Inanitas* תהו ובהו , *Vacuum & Inane*, ἄόρατος καὶ ἀκατασκεύαστος, and only that this Film of Water was divided in the middle by the solid hard Shell of the Firmament which inclosed half the Film; that is, the inner side; and excluded the other half of the Film; that is, the outward superficial Parts: And hence 'tis possible that *Virgil* in the eighth Book of his *Æneids*, says, *Spiritus Intus alit, totamq; infusa per Artus mens agitat molem & magno se Corpore miscet. Inde hominum pecudumq; genus vitaeq; volantum & quæ marmoreo fert monstra sub æquore pontus*, &c. He seeming there to make the place for the Soul of the World; others there are who would have it to be Fire, and thence to proceed the Causes of the Vulcanos and fiery Eruption; but *Aristotle* there places the pure Element of the Earth; some of the Modern Philosophers would have it to be all one great Load-stone. I could produce various other Opinions, but they are all but Opinions; and it matters not much what the Substance be that fills it, as to the present inquiery; I shall therefore proceed.

This Firmament then in the middle of the Waters, I take to be that which in many places of the Bible is said to be the Foundation of the Earth, as in *Psal.* 24. 2. *The Earth is the Lords and the fullness thereof, for he hath founded it upon the Seas.* (Prov. 3. 19.) *The Lord by wisdom hath founded the Earth, by understanding hath he established the Heavens*, (this seems to refer to the two Firmaments) and in the following Verse, *By his knowledge the depths are broken up, and the Clouds drop down their Dew.* (This seems to refer to the Causes of the general Deluge by opening of those two Firmaments, as I shall by and by shew.) So *Job* 38. 6. *Whereupon are the Foundations of the Earth fastned?*

This Sphærical Firmament or Shell then in the middle of the Waters, we may suppose, was in some places raised or forced outwards, and some other parts were pressed downwards or inwards, and sunk lower, when in the ninth Verse, God commanded the Waters under the Heaven to be gathered together to one place, and the dry Land to appear; for by depressing in of some parts of that Sphærical Shell (to make room to receive all the Waters that had before covered the whole) other parts must be thrust out, the Contents within being the same, and so requiring equal Space or Extension; so that what went below the former Sphærical Surface, must be equalled by other parts ascending without that Surface, and so the quantities of the Waters both within it, and those without it, remained each the same, and still distinct and separated by this Firmament in the middle of the Waters, tho' altered from its Sphærical Figure; and the outward Surface of the outward Water, as well as the inward Surface of the inward Water, must remain Sphærical, because of the Power of Gravity from without a Central Earth, or Yolk within, formed of a Sphærical Figure.

In this State the Earth seems to remain till the time of the Flood, which is accounted between sixteen and seventeen Hundred Years according to the Hebrew. When *God looked upon the Earth, and behold it was corrupt, for all flesh had corrupted their way upon the Earth*, as Chap. VI. v. 12. And in the thirteenth told *Noah*, that he would destroy all living Creatures with the Flood. This Destruction began in the six Hundred Year of *Noah*'s Life, Chap. VII. v. 11. The manner of which was expressed thus in the Septugint ἐρράγησαν πᾶσαι αἱ πηγαὶ τῆς ἀβύσσου καὶ οἱ καταρράκται τοῦ οὐρανοῦ ἀνεῴχθησαν. *The fountains of the great deep were drawn up, and the windows of Heaven were opened.* This refers again to the twofold Firmament, that ἐν μέσῳ τοῦ ὕδατος, and that τοῦ οὐρανοῦ. As for that of the Heavens the effects of the opening of them was, that it Rained 40 Days and 40 Nights; but the Consequents of the other are not expressed any otherwise, but that the Flood was upon the Earth forty Days, that is, the Sea continued to flow in upon it. *And the Waters increased, and bare up the Ark, and it was lifted up above the Earth*, v. 17. *And the Waters prevailed exceedingly upon the Earth, and all the high Hills, that were under the whole Heaven, were covered*, v. 19. *Fifteen Cubits upwards did the Waters prevail, and the Mountains were covered*, v. 20. *Every living substance was destroyed which was upon the Face of the ground*, Noah *only, and those with him in the Ark, remained alive.*

live, v. 23. By which it appears, that not only all Men, Beasts, Cattle, Fowls, Insects, Worms, *&c.* perished by the Flood, but every living Substance; that is, all Vegetables also; for all Animals were enumerated before: We see therefore that here was a double Cause of the Waters. First, The Rain from above. And, Secondly, The pulling up of the Fountains of the great Deep: What I understand by the great Deep, I shewed before; that is, the sinkings inward of the Firmament in the middle of the Waters; and the forcing up of the Fountains of the great Deep, I conceive to signify the raising again of those parts that were before sunk to receive the Sea; and a Consequent of that would necessarily be a sinking of that which was the dry Land, and a Consequent of that, flowing and increasing of the Sea from out of that which was the great Deep, and a prevailing and increasing upon that which was a sinking Earth; and this motion being forty Days in progression before the rising Surface of the Sea, and the sinking Surface of the highest Land met. So long the Waters were said to be flowing and increasing before it was wholly covered; nay, the History goes on with the Journal of its progress, till the Waters were gotten fifteen Cubits above the highest Mountains; but then the account ceaseth, and adds only, that the Waters prevailed on the Earth a hundred and fifty Days, and so long the whole Firmament was covered with Water. So that in probability the progress of the alteration of the Firmament proceeded so far till it recovered its perfect Sphærical Figure truly in the middle of the Waters, as it was at its first Creation placed at about seventy five Days after the forty; but as I conceive it staid not there, but the progression of both the parts went onwards; that is, the sinking parts went as much below the Level, as before they were above, and the rising parts by degrees ascended as much above as they had been below, and that which had been the bottom of the Sea under the Water, became the dry Land, and that which had been before the dry Land, now became the bottom of the Sea, whether the Waters retreated from off these parts which were raised when the Flood was finished; for it is said in the eighth Chap. That God remembred *Noah*, and what was with him in the Ark, to prepare them another Habitation, by making dry Land for them again; and, First, The Heavens were cleared from Raining. And, Secondly, By turning of the Water that had fallen, into Vapours, and by turning all those Vapours, which such a Commotion of the Earth and Sea had caused, into Wind, and by causing the Waters to return from those parts which it had covered into the Deeps that were appointed for their Reception; so that at the end of the hundred and fifty Days the new Earth began to appear. *Ver.* 3. *And the Waters returned from off the Earth continually, and after the end of the hundred and fifty Days the Waters were abated.* And, *v.* 4. *And the Ark rested in the seventh Month, on the seventeenth day of the Month, upon the Mountains of* Ararat, which probably was the Name of the Mountain after the Flood in the time of *Moses.* Ver. 5. *And the Waters decreased continually until the tenth month, when the tops of the Mountains were seen. Forty days after this,* Noah *opened the Windows of his Ark and sent out a Raven.* So that it seems that as the old was forty Days in being covered, so the new was forty Days in being discovered; but *Noah* staid yet many Days longer before the Surface of the Ground was dried. This Explication, I think, doth fully answer to the words of the History of the Flood as they are written by *Moses*, and will likewise shew a probable Cause how those Phænomena of Sea-sand and Shells are become so universal over the Face of the whole Earth, as it is at present, which were the two things which I now indeavoured to make intelligible. I have not, I hope, given any Explication, or made any Supposition, how differing soever it be, from all the Explications I have yet met with, that will any ways distort the plain words of the Text; for I have in this, as near as may be, guided my progress by that Direction, and I hope I have hereby shewed a very plain and intelligible way how the Flood became so perfectly universal, and the Earth returned perfectly to its primitive and first Created Figure, without any extravagant supposition of new Created Waters, or bringing them down from above the highest Heavens; nor is here any great need of Calculation to know how great a quantity of Water would need to be new Created and afterwards Annihilated, or first fetcht down from the

Heavens,

Heavens, and then sent back again; nor is there any need of supposing the Earth to be broken to pieces since the Flood, and the Antediluvian World without any visible Sea. And if it were much to the purpose, I could shew how all this, that I have supposed, may be Physically explained, and the Æquilibrium maintained: And, in short, to shew how consonant this Hypothesis may be both to several Expressions in the most antient Authors, and, in a word, with the Rules of Nature itself, of which I have formerly given divers hints to this Society, and may some other time more fully explain, but I fear I have detained you too long at this time.

THE following Treatises were Lectures read at several times relating to the Authors Theory of Earthquakes, and their Effects, and contain several very remarkable Histories of the Alterations that have been caused by them in the several parts of the World; the first is an account of an Earthquake in the Leeward *Islands. These are backt by a Citation out of* Aristotle, *and several deductions from it, are made by the Author. The next is a Discourse explaining some Effects of Earthquakes by the Phænomena of Thunder and Lightning, and relates to the Causes of Earthquakes. That Nature is always changing. That Earthquakes were formerly more frequent,* &c.

R. W.

July 23. 1690. *A Discourse of Earthquakes in the* Leeward *Islands.*

THE greatest Objection that has hitherto been made against a Theory which I have several times discoursed of, to give a rational and probable account of the Reasons of the varieties observable in the present superficial Parts of the Globe of the Earth; which was, that all those inequalities of its Surface had been caused by the Power of Earthquakes, or Eruptions of fiery Conflagrations inkindled in the Subterraneous Regions, which by that means did sometimes raise Mountains, Hills, Islands, &c. and sometimes produce the quite contrary Effects, by levelling of Eminences or sinking of Places, swallowing up Rivers, and making Lakes of Land, or sinking Lands under the Sea, and the like.

The greatest Objection, I say, against this, I find hath been, that there were wanting Instances to confirm it from History. For that, all Places, Countries, Seas, Rivers, Islands, *&c.* have all continued the same for so long time as we can reach backwards with any History: All *Greece* and the *Greecian Islands*, *Italy*, *Ægypt*, &c. are all the same as they were above two Thousand Years since, and therefore they were so from the Creation, and will be so to the general Conflagration; and as to the effects of Earthquakes, First, They have happened but seldom: And, Secondly, They have not produced any notable Change, such as I have supposed them to be the Authors and Efficients of; so that it seems but a bare Conjecture and without Ground or Foundation sufficient to found and raise such a Superstructure of Conclusions as I have thereupon raised.

For Answer to which I shall not now repeat what I have formerly produced here, and alledged to that purpose, such as were the Instances that were to be met with here and there dispersed in antient Writings; since many of those Occurencies having been long since produced, and the relations of them made by such as were not Eye-witnesses, many of the particular matters of Fact have been doubted or disputed; I shall therefore take notice of some particular Instances which have happened within our own Memory, and more particularly of this late instance which hath happened in the *Antilles*, of which we have an account but this last Month in the *Gazet*, namely, in that of *June* the 30*th.*, and another in that of *June* the 16*th.* preceding; both which Relations, tho' they are but short and imperfect, as to what I could have wished and shall indeavour to obtain, yet as they are, they will be found to contain

many

many Particulars, which do very much illustrate and confirm my Conjectures. And tho' the particular effects were not so great as to equalize those which I have supposed to have been the productions of former Eruptions, such as the raising of the *Alpes*, *Pyreneans*, *Appennines*, *Andes*, and the like Mountains, or the making of new Lands, Islands, *&c.* or the sinking of Countries, and drowning of Islands as the *Platonick Atlantis* and contiguous Islands, yet if they be considered they will be found to be of the same Nature, and to differ only in Magnitude, *Secundum Magis & Minus*, but not in Essence.

Of Earthquakes in the Leeward Islands.

The first Account is dated from *Nevis*, *April* the thirtieth, in these words, ‘[On *Sunday* the sixth Instant, about five a Clock in the Evening, was, for ‘some few Minutes, heard a strange hollow noise, which was thouht to proceed from the great Mountain in the middle of this Island, to the admiration of all People; but immediately after, to their greater Amazement, began a mighty Earthquake, with that violence, that almost all the Houses ‘in *Charles* Town, that were built of Brick or Stone, were in an instance levelled with the Ground, and those built of Timber shook, that every Body ‘made what hast they could to get out of them. In the Streets the Ground ‘in several places clove about two Foot asunder, and hot stinking Water ‘spouted out of the Earth a great height. The Sea left its usual Bounds more ‘than a third of a Mile, so that very large Fish lay bare upon the Shoar, ‘but the Water presently returned again. And afterwards the same strange ‘motion happened several times, but the Water retired not so far as at first. ‘The Earth, in many places, was thrown up in great quantities, and thousands of large Trees went with it, which were buried and no more seen. ‘Tis usual almost at every House to have a large Cistern, to contain the Rain-water of above nine or ten Foot deep, and fifteen or twenty Foot Diameter, ‘several of which, with the violence of the Earthquake, threw out the Water eight or ten Foot high; and the motion of the Earth all over the Island ‘was such, that nothing could be more terrible. ‘In the Island of St. *Christophers* (as some *French* Gentlemen, who are come hither to treat about the exchange of Prisoners, do Report) there has likewise been an Earthquake, ‘the Earth opening in many places nine Foot, and burying solid Timber, Sugar-mills, *&c.* and throwing down the Jesuits Colledge, and all other Stone ‘Buildings. It was also in a manner as violent at *Antego* and *Montserrat*; ‘and they had some feeling of it at *Barbadoes*. Several small Earthquakes ‘have happened since, three or four in twenty four Hours; some of which ‘made the biggest Rocks have a great motion, but we are now in great hopes ‘there will be no more.]

This is the whole of the Relation from *Nevis*. But the other Account from *Barbadoes*, of the 23*d*. of *April*, taketh notice of other particulars than what are mentioned in this Letter; the Printed Account is this that follows. ‘[About three Weeks since there were felt most violent Earthquakes in the ‘*Leeward Islands* of *Montserrat*, *Nevis* and *Antego*; in the two first no considerable hurt was done, most of their Buldings being of Timber; but where ‘there were Stone Buildings they were generally thrown down, which fell very hard in *Antego*, most of their Houses, Sugar-mills and Wind-mills being ‘of Stone. This Earthquake was felt in some places of this Island, but did ‘no manner of hurt to Men or Cattle; nor was any lost in the *Leeward Islands*, ‘it happening in the Day-time. It is reported to have been yet more violent ‘in *Martinico*, and other *French* Islands. And several Sloops who came from ‘*Nevis* and *Antego* passing between St. *Lucia* and *Martinico* felt it at Sea: The ‘agitation of the Water being so violent, that they thought themselves on ‘Rocks and Shelves, the Vessels shaking as if they would break in pieces. ‘And others passing by a Rock and unhabited Island, called *Rodunda*, found ‘the Earthquake so violent there, that a great part of that Rocky Island split ‘and tumbled into the Sea, and was there sunk, making a noise as of many ‘Cannon, and a very great Cloud of Dust ascending into the Air at the fall.] ‘[Two very great Comets have lately appeared in these parts of the World, ‘and in an Hour and a quarters time the Sea Ebbed and Flowed to an unusual ‘degree three times.’] In these Relations are many considerable Effects produced, which will much confirm my former Doctrine about the Effects of

Observables in this Earthquake Earthquakes. And First, It is very remarkable, that this Earthquake was not confined to a small spot or place of the Earth, such as the Eruption of *Ætna* or *Vesuvius* out of one Mouth, but it extended above five Degrees, or three hundred and fifty Miles in length; namely, from *Barbadoes* to St. *Christophers*, and possibly, upon inquiry, it may be found to have gone a great deal further, and to have produced Effects in *Statia* St. *Martin*, *Anguilla*, *Porco Rico*, or some other of those Islands in the North-west of St. *Christophers*, where, by the Relation, it seems to have been the most violent: And tho' possibly there might not be opportunities of feeling or taking notice of the effects in all places of the Sea where it might have been felt; yet by those few Instances which are related, we may probably conjecture, that its effects might be very considerable, and sensible a great way in breadth under the Sea; for we find that the Strokes or Succusions thereof were felt by the Vessels sayling over some parts of the Sea so affected; and those so violent as if the Vessels had struck upon Rocks, which could be from nothing else but the suddain rising of the bottom of the Sea, which raised the Sea also with it, like Water in a Tub or Dish: And that this was of that Nature does further appear by the unusual Tides at the *Barbadoes* mentioned in the last Relation, *viz.* That in an Hour and $\frac{1}{4}$ the Sea Ebbed and Flowed three times in an unusual Degree; which, in probability, were nothing else but Waves propagated from the places where the Ground underneath, and the Sea above, had been by the Concussions of the Earthquake raised upwards. This appears also farther by the recess of the Sea from the Shore at *Nevis* $\frac{1}{3}$ of a Mile; for the whole Island being raised by the Swelling or Eruption of the Vapour or Fire underneath, made the Sea run off from the Shores, till it settled down again into its place after the Vapour had broken its way out through the Clefts that were made by those Swellings: From all which Particulars, and several others, 'tis manifest, that the space of Earth raised or struck upwards by the impetuosity of the Subterraneous Powers that caused it, was of great Extent, and might far exceed the length of the *Alps*, or the *Pyreneans*, &c. But there may be other Instances also produced of the great extent of the Powers or Effects of Earthquakes, as those I have formerly mentioned to have happened in *Norway* about thirty Years since; and those which happened in the Northern parts of *America* of a later date.

Another particular notable in this, is the Recess of the Sea from the Shore, and the leaving the Fish upon the so raised bottom; and tho' this part soon after sunk again, so that the Sea returned to its former bounds, yet if some other parts of the Subterraneous Ground had filled up the made Cavity, or that they had so tumbled as to support the so raised parts, Instances of which kinds of Accidents may be produced from other Earthquakes, then it would have left some such kind of Tract as it is now in *Virginia*, where, for many Miles in length, the Low-land is nothing but Sea-sand and Shells, which have been, in probability, so raised into the Air, and there supported and continued from sinking again and being covered with the Sea: Of Shells taken up from this Tract, there can be no doubt that they have belonged to Fish of their kind, they remaining hitherto perfect Scallop Shells; of which kind there are some in the Repository.

A Third particular Remarkable, is the overturning and burying of thousands of Trees which were no more seen, being covered by the Earth which was thrown up by the Eruption. This gives us a very plain Instance of the manner how Trees that are now found in divers parts of *England* buried under the Ground, may have come to have been there so disposed and deposited; for tho' possibly in those places there may be no such Trees now growing; and tho' we have no History when there were, or of any such Eruption that might have so overturned and buried them; yet the Records that we have of the antient or former State of those Parts, are not so full and particular, but that we may well enough suppose that such Catastrophies may have happened long since we have begun to have Writings and Records in *England*; that is, since the time that the *Romans* first conquered this Isle; and yet not find any mention thereof there made; since possibly those that might be in or near those Parts might have perish'd with it, and those which were at a distance

distance took little notice or regard of what they had little concern for: Besides, in those Days very small were the number that could Write and Read, and fewer were those that minded any thing the effects produced by Nature: What was written was either somewhat relating to Religion or Civil History, very few and rare are the Instances that can be met with of Natural History; and it has not been a Defect peculiar to these parts of the World only, but was taken notice of two Thousand Years since by *Aristotle* upon this very account, as we find in the fourteenth Chapter of his first Book of *Meteors*; 'Moreover (says he in the beginning of this Chapter) the same Parts of the 'Earth are not always dry Land, or always covered with Water, but they 'suffer a change from the rising of new Rivers, or decay and drying of old; 'therefore also in places near the Sea there are wont to happen these changes. 'So that those which are Land, or those which are Sea do not always re-'main so; but where was Land there is Sea, and where was Sea there is Land; 'and we are to conclude these changes to happen according to some order. 'Now (says he) because many of these changes happen but slowly in com-'parison to the quickness and shortness of the Life of Man, therefore they 'are hardly taken notice of, a whole Generation having passed away before 'such changes have come to perfection. Other Catastrophies that have been 'more quick, have been forgotten, by reason that such as escaped them were 'removed to some other parts, and there the Memory of them was soon lost; 'at least a longer tract of Time did quite obliterate the remembrance of 'them, and the transplanting and transmigration of People from place to 'place much contributed thereunto. This is made plain enough by the little remembrance was found in *America* of their preceding Estate, when they were first visited by the *Spaniards* and other *Europeans*.

A fourth particular Remarkable in these Relations, is the Chapping and cleaving of the Earth and Rocks, and the spouting out of them of stinking Water to a great height; as also of Smoke or Dust, which serves to explain the Reason and Causes of the Flaws and Veins in Marbles and other Stones; for by the Power and Violence of the Subterraneous Heavings or Succussions the stony Quarries become broken, flawed and cleft, and Subterraneous Mineral Waters impregnated with Saline, Metalline, Sulphureous, or other Substances are driven into them and fill them up, which having petrified Qualities in them, do, in process of time, petrify in those Clefts, and thereby form a sort of stony Veins of different Colour, Hardness, and other Qualifications, than what the parts of the broken Quarry had before, and oft time inclose divers other Substances by their petrifying Quality, which have happened to fall into those Clefts, and thence sometimes there are found Shells petrified in the middle of the Vein, as I have seen, and other Substances. These Clifts or Chaps hapening not only upon the Land, but even under the Sea; so that not only the Sea-water may descend and fill up those Clefts, but it may carry with it Sands, Shells, Mud, and divers other Substances from the bottom of the Sea, that then lay above it, there to be, in process of time, changed into Stone somewhat of the Nature of that which hath been so cleft. *Of the Veins in Marble.*

Fifthly, 'Tis worth noting, that this Earthquake happened at so great a distance from the main Land and great Continent, and that the noise of the same was first observed to begin at the great Mountain in the middle of the Island of *Nevis*, not but that it might in other parts have begun sooner or at other times; from which I draw these deductions. First, That it seems probable, that this great Mountain may have been formerly visited with Eruptions; and possibly might have been first produced by some such Power, and so have great Cavities within its Bowels produced by such a preceding Eruption, the dislocated Parts not returning each to its own place. And next, that it may hence seem probable, that some such preceding Earthquake (tho' then possibly more violent before the foment of the Fire was by inkindling exhausted) might, not only be the cause of raising this Mountain, but of lifting up from the bottom the whole Isle, nay, possibly of all the Islands of the *Antilles*, since one seems as possible as the other, and the Northern of them all seems to hint as much, if considered, in the Map; besides, there seems to be

be many Instances of a like Nature, as in the *Canaries*, *Tenariff* seems to be a most remarkable Character of such a Supposition; to this may be added *Del-Fuogo* among the *Azores* and the Island of *Madera*, *Sicily*, *Strombulo*, and *Lipary* in the *Mediterranean*, *Iseland* in the North Sea; *Mascarenos* near *Madagascar*; to this I may also add the many Islands of the *Archipelago*, which, tho' they have now no great signs of burning Mountains, yet to this Day Earthquakes are very frequent, and antient Traditions do preserve somewhat of the memory of very great alterations that have happened in those Parts by such sorts of Causes; but I will not now meddle with that kind of History, nor of Mythology, having said more concerning it in a more proper place; but I shall rather on this occasion take notice of those Islands that have *Vulcanoes* in or near them, which to me seem to proceed from the same Cause and Principle. And I do not question, but that all those Islands which lie so far in the Sea, if they were thoroughly examined, would plainly manifest whence they have proceeded by Characters of Nature's Writing, which to me seems far beyond any other Record whatsoever. Here I conceive it Lawful and Philosophical to *Jurare in Verba*, when Nature speaks or dictates; however, I shall leave it free to every one to judge, as he thinks most reasonable.

Sixthly, 'Tis very remarkable that the Isle of *Rodunda*, which it seems is all an uninhabited Rock, was split, and a part of it tumbled down and sunk into the Sea; upon which occasion it seems it made a prodigious noise as of many Cannon, and sending up at the same time a great Cloud of Dust, as they term it, which, in probability, was also mingled with Smoak. Which puts me in mind of the Phænomena I observed lately, when the Pouder-mill and Magazine at *Hackny* blew up; for besides the very great noise of the Blow which I heard, being within a Mile of it, in the Fields, I observed immediately, a great white Cloud of Smoke to rise in a Body to a great height in the Air, and to be carried by the Wind for two Miles and better without dispersing or falling down, but perfectly resembling the white Summer Clouds: But this only by the bye. From these Phænomena of the Earthquake it seems very probable, that it proceeded from such Subterraneous inkindling as resembles Gun-powder, both by the noise it yielded, and in the suddenness of its firing, and its powerful Expansion when fired; for the noise was as of many Cannon; this alone proves it to be very suddain. Next the splitting of the Rocky Island proves its Power to be very great; this is proved yet farther by the Blow and Strokes it communicated to the Sea, and so to the Ships that sailed upon it; for no slow motion whatever could have communicated such a Concussion through the Water to the Vessels upon it; but it must be as suddain as that of Pouder, otherwise the stroke of the Earth upon the incumbent Seas, would never have had the like success; for if it had been a gradual rising of the bottom, the Sea would gradually have run off from it, and upon its sinking again have gradually returned, and the Vessels on it would only have been sensible at most but of a Current or Running of the Water to or from the place sinking or rising, somewhat like the effect that happened at *Nevis*; which doth plainly shew, that, besides the suddain Strokes or Concussions, there was also a considerable rising and sinking of the whole Island as to the level of the Sea. But that which I principally note under this Head is, that a good part of the said Island tumbled down and was sunk into the Sea, which gives an account how many parts of the Earth come to be buried under Ground and displaced from their former Situations, and thence how Ships, Ankers, Bones, Teeth, *&c.* that have sometimes been digged up from great depths, may have come to be there buried.

Seventhly, 'Tis remarkable also, that this Eruption sent up into the Air great Clouds of Dust and Smoke, which for the most part must soon fall down again into the Sea, or contiguous parts of the Island. This will give a probable account how the Layers of the Superficial Parts of the Earth may come to be made; for the bigger part of this Dust must come down to the bottom first and settle to a certain thickness and make a Bed of Gravel, then will follow Beds of coarse Sand, then Beds of finer and finer Sand, and last of Clays or Moulds of several sorts; again much of that which fell upon the

higher

higher parts of the Island, will, by the Rivers, be washed down into the Vales, and there produce the like Beds or Layers of several kinds, and so bury many of the parts that were before on the Surface. Thus Plants and Vegetable Substances may come to be buried, and the Bones and Teeth of the Carcasses of Dead Animals: These may also sometimes be buried under Beds or Crusts of Stone, when the parts that thus make the Layers chance to be mixed with such Subterraneous Substances as carry with them a petrifying Quality. But I shall not detain you any longer with farther Deductions from these few Remarks we find in these two casual Relations of this Earthquake; I shall only add, that I could heartily wish that some care were taken that a more particular account might be procured of it whilst the effects thereof are fresh in Memory, that they might be Recorded and added to the Collections of Natural History. And for the same end it were desireable to know what former Earthquakes have been taken notice of in these, or any other of these Islands, as *Jamaica*, *Cuba*, *Hispaniola*, *Porto Rico*, &c. for that the Memory of such Accidents, if they be not Collected and Recorded whilst the Spectators are in being, are soon forgotten and lost or not regarded by the succeding Generations, as *Aristotle* has taken notice of also in the Chapter I before quoted.

Why Islands & Sea-Coasts are most subject to Earthquakes.

What is most remarkable in these Earthquakes in the *Leeward* Islands, is, that they have all happened to places not far distant from the Sea, or even under the Sea itself, though the Eruptions have been, for the most part on the Land. So that there doth seem to be somewhat of Reason to Conjecture as *Signior Bottoni* in his *Pyrologia Topographica*, that the saline Quality of the Sea-water may conduce to the producing of the Subterraneous Fermentation with the Sulphureous Minerals there placed, which the Experiment lately here exhibited at a Meeting of this Society, does yet make more probable; for by that it was evident, that the mixing of Spirit of Salt with Iron, did produce such a Fermentation as did produce a Vapour or Steem, which by an actual Flame was immediately fired like Gun-pouder, and if inclosed, would, in all probability, have had a like effect of raising and dispersing of those parts that bounded and imprisoned it. Now, 'tis evident that the melted Matter which was vomited out of *Ætna* in the Year sixty nine (of which we have a part now in the Repository) was very much like to melted or cast Iron, and I doubt not but that there may be much of that mineral in it; besides, the Foot of that Mountain does extend even to the very Sea, and in all probability may have Caverns under the Sea itself, which is argued also from the Concurrency of the Conflagration of *Strombolo* and *Lipary*, Islands considerably distant from it by Sea, at the same time, where it is generally believed that there may be Subterraneous Cavernous Passages between them, by which they communicate to one another; so that sometimes it begins in *Ætna*, and is communicated to *Strombolo*, and reciprocally communicated to *Mongibel*.

This possibly may afford a probable Reason why Islands are now more subject to Earthquakes than Continents and inland Parts; and indeed how so many Islands came to be dispersed up and down in the Sea, namely, for that these Fermentations may have been caused in the parts of the Earth subjacent to the Sea, which being brought to a Head of Ripeness, may have taken Fire, and so have had force enough to raise a sufficient quantity of the Earth above it, to make its way through the Sea, and there make itself a vent, as that of the *Canaries* did in the Year 39, which, if sufficiently copious, may produce an Island as that did also for a time, though it hath since that time again sunk under the Surface of the Sea. But the Island of *Ascension*, which, by all appearances, doth seem to have been the same way produced, doth still remain as a witness to prove this Hypothesis. A like Testimony to this, of the Cause and Manner of their Production, I take the Island and Pike of *Tenariff* to be, so *Hecla* of *Iceland*, so *Bearenberg* of *John Mayens* or *Trinity Island*, so *del Fuego* of the Icelnds of *Cape Verd*, so *Ternate* of the *Moluccas*, and the Island of *Mascarenas*, of the Islands about *Madagascar* among the *Antillas* or *Caribes*, all which do seem to me to be remaining Testimonies how, and in what manner, and by what means those other Islands which have now worn out the marks of their first Origination, were at first

produced. And tho' the Fires be extinct in many of the other Islands, yet 'tis observable, that the prodigious high Mountains or Sugar-loafe Pikes or Hills do yet remain as marks of what they had been heretofore; so the Pike of *Fayal* among the *Terceras*, and the whole Island of St. *Helena*, and several others of those about *Madagascar* and of the *East-Indies*, and of those of the *Antilles*, and that of St. *Martha* mentioned by *Dampire*, do seem to me to be plain evidences of the former and Original Causes of them all.

Nor do I in the least doubt but that an inquisitive Person who should purposely survey all other Islands that wanted these Marks or Tokens of such Eruptions, might find enough of other Indications to manifest by what means they so came to be placed in the Sea, so far from any part of the Continents they are opposite to. Nor do I conceive they were all thus formed at once, but rather successively, some in one, some in other Ages of the World, which may probably be in some measure collected from the quantity or thickness of the Soil or Mould upon them fit for Vegetation; whence the Island of *Ascension* may be rationally concluded to have been a Production of not many Ages, and the *Bermoodas* also of not very many more, because of the thinness of such a Soil. So also the Island of *Barbadoes*, and some others, whose Mould is yet but thin in respect of what it is in some others, and especially in those of greater Magnitude and in the greater Continents.

Hereupon possibly it may be inquired why those greater Islands and Continents should be of greater Antiquity than the smaller Islands. To which I answer, that in the first Ages of the World there were much greater Magazines, or Stores of the Materials fitted for this purpose, which being first kindled threw up from under the Sea, with which they were covered, vast quantities of it all at once, and thereupon those Magazines became in a manner exhausted, yet not so totally as not to leave some smaller parcells of those Substances so disposed, as not to be ready for inkindling together with those greater; besides there remained other smaller parcels of it disposed and placed in other parts of the Globe sufficiently distant from them, not to be affected or inkindled at the same time, as those I have mentioned to have been the causes of the Islands far distant from the Continents. Nor do I conceive that all those Clusters were all thrown up at once, as the *Grecian* Islands in the *Archipelago* the *East-Indian* in that part called the *South-Sea*, the *Maldivia Islands* near the Coast of *Malabar*, the Islands scattered at the North of *Madagascar*, the Islands to the South-west of St. *Helena* in the *Atlantick* Ocean, *Finidada dos picos*, the Isles of *Cape Verd*, *Canaries*, *Terceras*, *Orcades*, &c. also the *Gallopegas* and others in the *Pacifick* Sea or *Mar del Zur*; but rather that some were made in one Age, some in other Ages of the World. And this was timed as the several Magazines came to be ripened and then fired; they only indicating, as I conceive, that in those places of the Terrestrial Globe, there were placed the proper mineral Foments or Seeds as it were of them, which, when the convenient times were come and accomplished, then they were put into Act, and then they produced their Effects, which are the Islands that now remain the lasting Monuments of them. Nor can I suppose that all the Magazines of the Earth of this kind are blown up and spent, but that there may be many other yet remaining for future Ages to be made sensible of their Effects. Nor can I be fully satisfied that all the main Continents were thrown up or made Land all at once. Nor have we any proof that the Continent of *America* was in the time of *Noah*'s Flood, nor indeed how large the habitable World then was, but certain we are, that what was then in being was all overflowed and drowned by it, and all living Creatures, except those preserved in the Ark with *Noah*, perished by it. But whether the dry Land that appeared after the Flood, were the same with that before the Flood, is a question not easily determinable; to me it seems that the preceding Earth was wholly changed and destroyed, and that there was produced a new Earth which before that had not appeared; and this Doctrine seems to be indicated by that Text in *Genesis* vi. 13. *And God said unto* Noah, *the end of all Flesh is come before me; for the Earth is filled with violence through them, and behold I will destroy them with the Earth.* And again *Chap.* viii. 21. *I will not again curse the ground any more for Man's sake.* And 2 *Pet.* iii. 5. *By the*

the word of God the Heavens were of old, and the Earth standing in the Water and out of the Water. (ver. 6.) *Whereby the world that then was, being overflowed with Water, perished.* But the clearing this Doctrine by the Expressions in Scripture I shall leave to the Divines; nor shall I in the least interfere with them: However, it seems to me, that the Expression of *Breaking up the Fountains of the great Deep*, might signify the raising up of the bottom of the Sea; and the *Water prevailing so as to cover the top of the highest Mountains*, might denote to us the sinking or subsiding of the former part of the dry Ground: So as *the former was wholly drowned and destroyed*, which was *Cursed* for Man's sake, so a new one was raised, which God promised should not *be Cursed for Man's sake*, as the former had been; but this only by the bye. Certain I am that I have never yet met with my self, or heard of any other that hath any Records of the Age of *America*, which, for any thing appears, may have been much younger than the Flood of *Noah*: Nay, I believe it will be pretty difficult to prove even these Islands of *England*, *Scotland* and *Ireland* to have been in being ever since that Flood, and much more that there were such before it. And tho' some may Conjecture that they have been so (which is the most that any one can do) yet others may Conjecture that they have not (which is every deal as valid). The same may be said of a very great part of the Earth, without any trespassing upon our Faith or Religion; nay, it was we know, not long since, that a Bishop was condemned of Heresy because he asserted Antipodes. So skillful were some of our Fore-fathers in the Geography of the Habitable Parts of the World, or of the Figure of the Earth; and I do very much question, whether any Inhabitant of *Europe*, *Asia*, or *Africa* had ever any knowledge of *America* till within these last three hundred Years. But my present subject is not so properly to search and inquire into the History, as to find out what have been the Natural or Physical Causes of their Productions, Situations and Forms, and that, I think, I have shewn to have been in probability some preceding Earthquakes, which Earthquakes may have been caused by Subterraneous Fermentations and Accensions.

But some perhaps may except against this Doctrine as supposing it Derogatory to Divine Providence to assert any other Cause but the immediate Hand of God. To which I Answer, That 'tis not denying of Providence to inquire into, or to assign the Proximate Causes of Phænomena in Physical Subjects. For that we have Instances in the sacred Scriptures of such Explications, as in the case of the *Israelites* through the Red Sea; where 'tis said, *The Lord caused an East Wind to blow, which made the Sea to go back and to leave the bottom dry Ground.* And at the Waters of *Marah* God shewed *Moses* a Tree, which, when he had cast into the Waters, the Waters were made sweet. So in the Description of the Deluge, we find that God caused it to Rain forty Days and forty Nights, and the Foundations of the great Deep to be broken up, and the Windows of Heaven to be opened; which denote by what Natural Means God was pleased to effect and Collect the great quantity of Water that was to drown and overflow the then Habitable Earth; and many other such Instances there are to be met with in Holy Writ, where the Physical Causes are explained, for it is the same Omnipotent Power which does influence the remote Causes as well as the proximate; and the universal Providence that ordereth all the effects, doth also determine and appoint all the Causes and Means conducing thereunto; nor is there a necessity of supposing new created Causes for all the effects that we are ignorant how they are brought to pass, or to believe every thing effected supernaturally, of which we cannot find out the Natural Cause; the Divine Providence is not less Conspicuous in every Production that we call Natural, and think we know the Causes of it, than in those we are less skillful and knowing in: 'Tis the Contemplation of the wonderful Order, Law and Power of that, we call Nature, that does most magnify the Beauty and Excellency of the Divine Providence, which has so disposed, ordered, adapted and impowered each part so to operate, as to produce the wonderful Effects which we see; I say wonderful, because every natural Production may be truly said to be a Wonder or Miracle, if duly considered; for who can tell the Cause of the Growth, Form, Figure, and all the Qualifications and peculiar Proprieties

of

of each, or any one Vegetable or Animal Species or individual? An observing Naturalist may perhaps tell the Steps or Degrees he has taken notice of in its Progress from the Seed to the Seed: Again, how he has observed the Seed to sprout, how that Sprout increaseth and forms itself of this or that Magnitude, Shape, Colour, *&c.* and how it produceth such a Flower, and after that Flower such other Seeds as that from which it sprung: He may also tell the Times and Seasons in which these Progresses have been or will be performed; but if it be inquired how the Progresses come to be acted, what is the moving Power, or what is the inlivening Principle that orders, disposes, governs and performs all these wonderful Effects, there he finds the *Ne plus ultra*, there is the Miracle that he may truly admire but cannot understand; however, *Est aliquid prodire tenus si non datur ultra*, let us first find the proximate Causes, and then proceed to the more remote; I think no one ought to be blamed or discouraged from searching after these Causes and Reasons of Natural Productions so far as the Powers he is endowed with will enable him; for this will more powerfully convince him of a Divine Providence that Rules and Regulates the things of this World, than all the other methods of Contemplation or Argumentation whatsoever.

July 30. 1699. *A Discourse of the Causes of Earthqnakes.*

I mentioned in some Lectures that the Earth did seem to grow old and to have lost many of those Parts, which, in the younger times of the World, it seemed to me to have more abounded with; that which I instanced in, was the Foment or Materials that serve to produce and effect Conflagrations, Eruptions, or Earthquakes. These Materials I conceive to be somewhat analogous to the Materials of Gun-pouder, not that they must be necessarily the very same, either as to the Parts or as to the Manner and Order of Composition, or as to the way of Inkindling and Accension; for that as much the same Effect may be produced by differing Agents, so the Methods and Order of proceeding may be altogether as differing: A clear Instance of this we may find in the Phænomena of Lightning, wherein we may observe, that the Effects are very like to the Effects of Gun-pouder.

Of Lightning and Thunder.

For we have first the flash of Light, which is very suddain, very bright, and of very short continuance, being almost momentaneous, at least every single flash is so, tho' the kindling of several parts at some distance from one another does sometimes continue a succession or longer duration of the Light.

Next we may observe the violence of the Crack or Noise which is likewise as momentaneous as the Fire, if it be single, but if there be many particular flashes that contribute to this effect, and those made at several distances, then the duration of the Thunder heard is longer than the duration of the flashes of Lightning, which proceeds, as I conceive, from two Causes; First, For that those flashes that are farther distant, have their Thunder a longer time in passing to the Ear, than those which are nearer, by reason, that tho' the Passage or Motion of Light be almost instantaneous, yet the progression or motion of sound is temporaneous, and requires a certain sensible time to pass a sensible space, and the times are proportionably longer as the spaces passed are greater. But a second Cause of the duration of the Thunder, I conceive, proceeds from Echoes that are rebounded both from parts of the Earth, and likewise parts of the Air, as from charged Clouds; of both which I am sensibly assured both by natural Reasoning and from sensible Observations, and I have observed much the same Effects produced by the Echoeing and Rebounding of the sound of a peice of Ordnance, from places at several distances adapted for the production of such Repercussions.

But, Thirdly, We have also the Power and Violence of the force of the Fire and Expansion, in fireing several things that are Combustible, in suddenly melting of Metals and other Materials, which are difficult and slow enough otherwise to be made to flow, in rending, taring, throwing down and destroying whatever stands in its way, and the like; and yet after all, that which

which causeth these and many other strange Effects resembling those of Gun-pouder, seems to be nothing but a Vapour or Steem mixed with the Body of the Air, which is inkindled, not by any actual Fire, but by a kind of Fermentation or inward working of the said Vapour. Again, we find that the *Pulvis Fulminans* as 'tis called, which hath some of its materials differing from that of common Pouder; as also *Aurum Fulminans*, which is yet more differing both as to its materials and as to its way of kindling, have yet most of the same effects with Gun-pouder, both as to the flashing and thundring Noise, and as to the Force or Violence. So that as these are differing in many particulars, and yet produce much the same effects; so 'tis probable, that what is the cause of Earthquakes and Subterraneous Thundring, Lightning and violent Expansion, as I may so call those Phænomena observable in those *Crises* of Nature, may be in divers particulars differing from every one of these, both as to the materials, and as to the form and manner of Accension, and yet as to the Effects they may be very Analogous and Similar. So that tho' I cannot possibly prove what the materials are, yet the Effects speak them to be somewhat Analogous to those of Gun-pouder, or *Pulvis Fulminans*, *Aurum Fulminans* or Lightning, which, tho' they seem very differing in many particulars, yet when I come to shew the Causes and Reasons of those Effects, I shall manifest, that 'tis but one Operation in Nature, and that which causes the effect in one causes the effect in all the rest, and the outward appearances of the differing materials, and the differing way of Operating, are nothing but the Habits, and Dresses, and Vizards of the Actors, and the differing Modes and Dances by which they Act their several Parts, which, when they have done, they are at an end, and have exerted their whole Power, and there must be a new set of Actors to do the same thing again; the Oil of the Lamp will be turned all into Flame, but you must have fresh Oil, if you will have the Flame continued. So the Materials that make the Subterraneous Flame or Fire, or Expansion, call it by which name you please, is consumed and converted to another Substance, not fit to produce any more the same Effect; and if the Conflagration be so great as to consume all the present Store, you might safely conclude that place would no more be troubled with such Effects; but if there be remainders left, either already fit and prepared, but sheltered from Accension by other interposing incombustible Materials; Or that there be other parts not thoroughly Ripe, and sufficiently prepared for such Accension, then a concurrence of after Causes may repeat the same Effects, and that *toties quoties* 'till all the Mine be exhausted, which I look upon as a thing not only possible, but probable, nay, necessary, for that I find it to be the general method of Nature, which is always going forward, and continually making a progress of changing all things from the State in which it finds them in at the present; all things as they proceed to their Perfection, so they proceed also to their Dissolution and Corruption, as to their preceding Estate; and where Nature repeats the process, 'tis always on a new Individual.

All things are in a perpetual change.

Now, tho' it may be Objected, of the material that produceth Lightning, tho' it seemeth to be all kindled and so burnt off by the flash, yet we find that after some time the same is again renewed, and so from time to time, and therefore as one Operation doth destroy and consume it, so another doth generate and produce it anew, and therefore it doth seem probable that the same may be done in the Subterraneous Regions, and thence, tho' there were many Accensions and Consumings of the foment of Earthquakes in former Ages, yet if Nature did thus again repair it, there would be little reason to suppose, that former Earthquakes should be greater than those which have in later, or in this present Age, been observed; to which I Answer, That tho' it seem plain, that the foment of Lightning is renewed, yet I conceive that to be only by new Emanations from the proper Minerals in the Body of the Earth, and not for that the same Substance which is burnt off in the Lightning, is again restored into its former State and made fit for a second Accension; for tho' there may be necessary a prævious Digestion of the Steams, which is performed by the Air and heat of the Weather, yet that does only prepare it with a proper fitness, but it must be some proper Mineral

ral that must furnish the Materials: And the same thing is more evident in *Vulcanoes* and burning Mountains, which are there only oberved to break forth and burn where there is plenty of Brimstone and other proper Substances for such Conflagrations; for if the same were only a continual new Generation of Combustible Materials for the Fire, then I see no Reason why those *Incendiums* should not be equally frequent and equally great in all places, as well as in those where they are now frequently observed; for why should it not as frequently happen in our Hills and Mountains, as it does in *Sicily*, or *Island*, in *Ætna*, or *Hecla*, the one being as much colder then we, as we are then the other? It follows therefore, that it must be caused, not by the Renovation of the Foment, but from the Duration of the Mines or Minerals that supply fit Materials, and consequently, that when those shall be quite consumed, then, and not 'till then will the Fire go quite out. Nay that there are some such Instances of preceding *Vulcanoes*, which have heretofore burned and are now almost quite spent, may be concluded from the *Pike* of *Tenariff*, which, by all Circumstances, seems to have been formerly a burning Mountain, but is now quite extinct, and the Island of *Ascension* seems to be another such an Instance. All which Conflagrations are the several Symptoms of the progress of Nature in the determined Course and Method, which, tho' it be differing from that of Life or Vegetation in lesser Bodies, yet it may be possibly as Natural and Necessary in the greater.

I cannot therefore see any Absurdity in thinking or asserting that this Globe of the Earth on which we inhabit is in a state of Progression from one degree of Perfection to that of an other degree, which may be termed of Perfection, for as much as it is the Progress and Operation of Nature; and at the same time it may be conceived in a progress to Corruption and Dissolution in as much as it continually changed from its preceding State, and acquires a new and differing one from what it had before, which new Estate may be upon some accounts considered as more perfect, tho' upon other accounts it may be accounted corrupting and tending to its final Dissolution; and as 'tis certain that it is continually older in respect of Time and Duration, so I conceive also that it grows older as to its Constitution and Powers, and that there have been many more Effects produced by it in its more Juvenile Estate, than it doth or it can now produce in its more Senile, as more particularly to Earthquakes and Eruptions; for to me it seems most evident and past doubting, that there have been in some preceding Ages of the World Eruptions and Conflagrations which have infinitely surpassed any that have happened of later Years, or indeed any that we have any certain account of in History. Some kind of Memory of some antient Traditions concerning a very great one that sometimes happened, seems to be preserved by the Poetical or Mythological History of *Phaeton*, of which *Plato* also tells us, that the *Ægyptians* had a more perfect knowledge and account, than ever the *Greeks* were Masters of, who, at best, as to Histories of preceding Ages, were, by the *Ægyptian* Priests, accounted but Boys and Children; however, *Ovid*, by his wording of that Fable, does seem plainly to have had some knowledge of what was meant or understood thereby; and tho' he seems to ascribe the Cause thereof to some extraordinary heat of the Sun, yet that might be nothing else but the relating the Opinion of the Antients preserved by the same Tradition, by which the Memory of the prodigious effects that had been wrought had been retained.

In which case we are to distinguish between Histories of Matters of Fact, and those of Opinion; and *Plato* takes notice of as much when he mentions the Relation. The Matters of Fact seem to have been the Conflagration of many parts of the Earth at once, and those the most eminent, such as the Mountains, which, whether they were in being before the Conflagration, or made by that Eruption, does not appear by the Story, but it seems most probable, that that was the time of their Production; and the calling of them by several Names, yet retained, does signify no more, but that those Mountains, which are now called so or so, were then on Fire and burning.

But

But having before explain'd this Fable of *Phaeton*, and several others of that ingenious Mythologick Poet *Ovid*, I shall forbear the repetition of them here, and for the present would only infer, that in former and younger Ages of the World those kind of effects, produced by Eruptions and Earthquakes, have been much more considerable than those which are now produced, or which have been produc'd since we have had any Records kept of such Events; and therefore we are not to conclude that such huge Mountains, as the *Alpes*, the *Andes*, *Caucasus*, *Atlas*, or the like, could never be produced by means of Earthquakes or Eruptions, because we do not now find Instances of Effects of the same Grandure produced in our present Age, or in the Ages of which we have some more perfect account; for that in the former Ages there have been a much greater plenty of those kinds of Minerals which have been consumed, and for that the Relicts which are now left are but very small, and in probability not so apt for Conflagration, nor so strong and efficacious in their Operations; besides many of their Substances that were left may have since been petrify'd and converted into Substances, wholly unfit for the Foment or Fuell of such kinds of Fire; for that such Mutations have been effected by length of Time, I think no one that has observ'd and consider'd the Nature of Petrifaction can at all doubt, any more than he can whether there be any such Substance as Stone; for that all Places and Quarries especially will furnish him with Evidences enough to convince any that will not be wilfully ignorant.

Earthquakes formerly more frequent, and why.

This effect of Petrifaction is a Symptom of old Age; for as plenty of *Spirituous*, *Unctuous* and Combustible or Inflammable Juices and Moisture is a sign of Youth: So the want of them, and of the Effects produced by them, is a sign of old Age, in which those unctuous Juices are consumed and the Spirituous Fluids wasted, and the Parts become dry, and hard, and Stiff, and unactive; neither fit to inkindle the active Flame or to maintain it; neither fit to make other Substances fluid, nor to be made fluid themselves; which Fluidity is an inseparable Concomitant of that we call Spirituous Substances: And 'tis the plenty of those kind of Substances that maketh the Youthful Ages both of Plants and Animals to flourish, and the Consumption and want of them, that makes both Plants and Animals to decay and grow old, as we call them, to grow stiff, and dry, and rough, and shrivelled; all which Marks or Sypmtoms may plainly be discovered also in the Body of the Earth, and I am apt to believe would be very much more if we could be truly inform'd of the former and younger Condition thereof; for I have very good Reason to believe, that there has been times of the Earth wherein it hath had a much smoother and softer, and more succous Skin than now it hath, when it more abounded with Spirituous Substances, when all its Powers were more strong and vegete, and when those Scars, Roughness and Stiffness were not in being; and tho' possibly some may think all these Conceptions to be groundless and meerly Conjectural, yet I may in good time manifest, that there are other ways of coming to the discovery of many Truths than what have been to this purpose hitherto made use of, which yet are not less capable of Proof and Confirmation, than Histories or Records are by Coins, Inscriptions or Monuments. And tho' it may seem difficult to understand or be informed of the State of the subterraneous and inaccessible Regions, and of the Ages before History, yet I do not look upon either as an impossibility, no, nor as insuperable by the Industry of a few, nay, of a single Person. And possibly I may some other time shew divers other ways of Inquiry, and other Methods of Demonstration of Causes than what have been yet applied to those purposes.

The Earth grows old and less fruitful.

Nor is this Assertion of the growing old of the Earth to be looked on as so great a Paradox, or as Heterodoxical, or Scismatical, for we find in Scripture that the Kingly Prophet *David* in the 102 *Psalm* has an Expression that doth plainly assert it, not only of the Earth but even of the Heaven. *Of old hast thou laid the foundations of the Earth, and the Heavens are the works of thy hands, they shall perish, but thou shalt indure; yea all of them shall wax old like a garment, as a vesture shalt thou change them, and they shall be changed.* Which Expression is almost verbatim repeated by the Prophet *Isaiah*, Chap. 51. v. 6. *Lift up your eyes to the heavens and look upon the earth beneath, for the heavens shall vanish*

away

away like Smoke, and the Earth shall wax old like a Garment. Nay, this Expression of the *Psalmist* is verbatim repeated by St. *Paul* in the 10. 11. and 12. Verses of the Epistle to the *Hebrews*. By all which it is evident at least, that *David*, *Isaiah* and St. *Paul* were all of that belief. I could produce many Expressions to the like purpose both in Sacred and Prophane Histories, both of Christian and Heathen Writers, but those I have quoted I suppose may be sufficient to answer Objectors of that kind.

As for any other Objections that may be brought against this Doctrine, such as the equal Stature and Ages of Men for so long time as we have had any History; from the want of Histories of such Juvenil Estates, from the Permanency and Duration of all the Species of Plants and Animals in the same Estate, from the Incorruptibity of the Heavens and Cælestial Bodies, and so of their Influences, Causations, and many other of the like Nature; I doubt not to be able to give a satisfactory Answer if any of them shall be pressed or insisted upon, tho' at the same time I cannot hope that all will be convinced, much less, that all will confess themselves to be so, tho' really they are. All I can say, is *Valeat quantum valere potest*, let every one enjoy his own freedom.

AN Extract of a Lecture read July 18. 1688. *relating to the Consequences and Concomitants of Earthquakes, and the alterations caused by them in the Constitution of the Air as to Sickness*, &c. *Next follows an account of an Earthquake in* China, *and another in* Spain.

R. W.

THE Aim of my present Discourse is rather a Progression in the Theory of the Nature of the Air, than of any of the formerly mention'd Effects of Earthquakes, and the rather by the way of Query and Inquisition, than of possitive Theory and Affirmation.

Of the Constitution of the Air after Earthquakes.

As First, Whether the late Feaverish Distemper that was here so frequent, supposed by some to be inclined to Pestilential, tho' not so Mortal, might not be caused by some Infections or poisenous Vapours cast into it by those late Eruptions in *Italy* or *America*?

Secondly, Whether the coldness, unseasonableness of the Spring, the strange Rains, Storms and Tempests, and other such unusual Accidents, that have lately happened in the Weather, may not have been caused by the same Efficients that caused the Eruptions?

Thirdly, Whether it may be reasonable to conceive, that there could be any Communication Subterraneous between these places of those Eruptions in *Naples* and *Lima*; or whether it were Superterraneous through the Air and Æther?

Fourthly, Whether it may be rationally conceived, that Steems raised into the Body of the Air in *Lima* or in *Naples* could be continued so long in it as to be conveyed from either of those places to *England*, *London*, &c.?

Fifthly, How long time may be judged necessary for such a Conveyance?

Sixthly, Whether such Distempers of the Air may be precedent to the Distempers within the Earth, and so be of the Nature of a Procatarctick cause of the Earthquakes, and if so, whether those Distempers may arise from the Nature of the Air itself, or from some external and influential Cause, either from the Æther, Comets, or some of the more Conspicuous Cælestial Bodies?

Seventhly, Whether there may be not some general, tho' yet unknown, Cause, that may produce both those effects in the Earth and those in the Air, nay, and those in the Æther also, such as Comets and some kinds of Meteors also? because of the usual Concomitance of them; as will in part appear by subsequent Relations.

These

These possibly may be looked upon as not very easily solvable, and therefore not so proper to be propounded as Queries, unless they could also be as satisfactoraly answered. I must leave every one to Censure as he thinks meet, only this I must add, that the first step towards Knowledge is Inquisition.

And that I may manifest that these Queries are not altogether at random, I shall add some Natural Histories, that may possibly give some hints of their Solution; and those shall be the Accounts of some Accidents or Effects similar to those, which have lately happened at other Times, and in other Places; from whose Congruities one would be apt to conjecture a similitude of Causes, and if not a necessary, yet somewhat more than an accidental Concurrency of Effects, and a kind of Periodick Revolution of them.

In the Year 1672, in the Islands of the *Archipelago*, that is, the Islands of *Greece*, this Winter was so Stormy and Tempestuous, that not only the Trees and Plantations, but the Houses also were destroyed by the Lightning and Hail; so that both the Towns and Villages became almost unknowable, being reduced to Ruins.

In the *Barbadoes* also was a most violent Hurricane, in which many of our Nation Perished.

Near *Ancona*, *Fauno* and *Rimini*, there were this Year, in *April*, many Houses overturned by an Earthquake; and more especially in *Romania* and St. *Marc*, there were above six hundred People killed, and above quaruple that number hurt: At *Rimini* the Cathedral Church was overthrowed, the Bells shaken out of the Tower, and many People lost their Lives. At *Fauno* twenty eight Persons were killed by the fall of a Bell. The Churches of the *Theatines*, St. *Agnie*, St. *Apollonce*, St. *Mary de la Gomia*, St. *Innocent*, St. *Bernard*, St. *Mary della Colonolla*, and all the others except only those of the *Capuchines*, and of *Maria de Mari*, were endamaged. A great number of Palaces and Houses were ruined: This happened whilst People were at Church; so that above fifteen Hundred were killed, and many more were hurt. At *Pesaro* and *Senegallo* the Walls of the City and many Chimnies were thrown down. *Ancona* and *Rimini* were abandoned by their Inhabitants, who were constrained to lie under the open Canopy of Heaven.

September the 30th., of the same Year, there was a Hurricane passed trough all *Spain*, but it was most furious about *Madrid*, insomuch that it blew down the Roofs, Chimnies, nay, and the Houses too; as also the Towers and Churches; insomuch that the Damage was exceeding great along the *Prado* and at *Buon Retiro*. But all this was nothing in comparison of what happened the same Day in almost all the Countries of *Spain*; for this furious Tempest caused such Ravages in *Andalusia*, *Gallicia*, *Castil*, *Grenada*, *Valencia* and *Biscay*, as were truly Amazing: But what was most remarkable was this, that three Days after the Gallions of the Plate-Fleet, which came from the *West-Indies*, being arrived at the Islands of *Terceras*, felt not the least of it.

In this Year were also seen two Comets,----one in *January* another in *April*.

Eight Years before this, namely, in 1664, were two Comets also; but all the other Natural Histories, or Physical Accidents of that Year I have not yet procured.----

But eight Years after this, *viz.* 1680, which is now also eight Years since; First, For the Comets they are yet in most Mens Memories, and besides there are Histories enough extant; but next for the Earthquakes: First, By a Letter from *Botavia* we have an account of a great Earthquake that happened in *China* about *Peking* the preceding *August*, viz. That the $\frac{13}{23}$ of *August* 79, about ten in the Morning, there happened a most terrible Earthquake, which overturned almost all the Houses of that great City and the parts thereabout, whereby a World of People were destroyed in a most dreadful manner, besides multitudes that were hurt, whose number we cannot yet learn to this Hour: Two Heads of certain Beasts, which were Carved and fixed over the Imperial Palace Gate, were beaten off and thrown down to the Ground by the force of the shake. All the Palaces of the *Mandarines*, and their Families, and the Courts of Justice round the Palace were tumbled down; the Emperor commanded the principle *Mandarines*, that had command over the five parts of

the City of *Peking*, to examine themselves in their proper Persons, and to give him an account of all the damages that had happened, that he might the better advise of ways to help the Poor People that had suffered. This they did, and advised, that if his Majesty would distribute to each two or three Crowns of Silver at twenty five Frecks the Crown, it might be a sufficient supply: But he thinking this was too little, commanded ten Thousand Crowns to be taken out of his Treasury and distributed for the present Necessity. The first, second, and following Days that it lasted, the Earth was shaken five, six, or seven times a Day, but not with so much violence as by the first; so that the Inhabitants were in such Consternation as to forsake their Houses; the Soldiers and their Wives were most afflicted having nothing left to subsist; by Day they were exposed to the Sun, and by Night to the cold Heaven, which much incommoded them. The Emperor also was in great Pain to know the Damages that had happened in the Neighbouring Parts by this Earthquake, and commanded one of his great *Mandarines*, named *Samolio*, to inquire and inform him of them, who returned this Report, That the $\frac{13}{23}$ of *August*, whilst the Heaven was covered all over with dark Clouds, the Earthquake shocked extraordinarily the City of *Tongfu* about a Days Journey from *Peking*, that all the Imperial Magazines there had been overturned, as likewise the old Walls of the City; so that of ten Parts of the City scarce one remained which had not been indamaged, whose pitiful Condition was deplored by every one. The Commissioners of the Magasines Emperial who had escaped, render'd themselves presently to His Imperial Majesty to give him an account of the flying of the under Officers for the Consternation, and of their fear of the Robbing of the remaining Rice and Provisions by Thieves, which caused him to send them sixteen Hundred Soldiers for their Guard. The *Primier Intendant* of the Navy was killed by the overturning of his House. The Emperor had also reported to him, how the Robbers had wasted much of his Treasury in the Magazines that had been overturned; and upon the consideration of the general Calamity, the Emperor makes a most Pious Speech to the principle *Mandarines*, which I shall not trouble you with, only my Author adds, What Christian could have spoke better? Will not such as he rise up in Judgment against many Christians? This is a short Account of what happened to two Cities of *China*: I say Cities; for tho' generally we have only an account of the Damages caused to Cities, Towns and Men, yet we are not to conceive, as if the shaking and disorders of an Earthquake were only aimed at Cities like Marks and Goales to be shot at; no, certainly, there may, in all such Concussions and Devastations have happened much greater and different Effects from those which come to our knowledge; for that the most part of the World have little concern for what may happen in the Mountains, Hills, Plains, Forrests, Seas, *&c.* which make not any great or publick Calamity to the more considerable sort of Men; wherefore questionless, tho' many strange Effects of this kind may also have happened, and may have been seen and observed by some Men, yet they are but as it were *In transitu*, and quickly forgotten, since there is none to Record them. So that many thousands of such Effects have been swallowed up by the Oblivion of Time, where one has chanced to get by some accidental hint to lie Recorded by chance among the heap of other Histories. Comets indeed, as glaring in every ones Eyes, have found, among the multitude of Observers, some that have Recorded somewhat of them to Posterity, but even among them also, I doubt we shall not find that one of ten has obtained a History. But this Earthquake in *China* was not the only Accident of this time which I would mention; for upon the Coast of *Coromandal*, the Sea so overflowed the Country, that infinities of Men and Cattle were destroyed, many Cities and Villages were drowned. This overflowing was also found at *Jafnapatnam*, where it did much mischief to the Fortification, and to the Country, and the Cattle, but not so much to the Men.

Nor were these kind of Accidents only felt in *India*, but the same Year there happened a considerable Earthquake in *Spain*, and particularly at *Malaga*.

All

All *Spain* was this Year so perished with Drouth, that not only the Pits, Fountains and Rivers were dried, but the Harvest was spoiled, and many perish'd by this means: On the other side in the *Autumn* arose such horrible Tempests and Earthquakes as were felt long after. After the beginning of *September* they had continual Thunder and Lightning, by which divers perished. The Hail fell so on *Pardo*, a Pleasure-house of the Kings of *Spain*, that it rooted up the greatest Trees, and kill'd so many Beast and Foul, that not only the Fields were almost cover'd, but the River *Mancanarez*; it much indamaged the Village *Foncarral*; the old Bridge *de Aranda de Duerro* was born down by the Waters of the River *Tagus*, which run under, and did much damage to *Aranivez*, sweeping away divers People, Cattle, Trees, Bridges, and Houses: The like Ruins were caused almost over all the Kingdom, insomuch that in one Village, only, forty People were lost. The greatest violence was at *Madrid* the twenty sixth of *September*, where the Water overflowed so as to mount into the Garden of the *Augustines* and throw down the Wall; also into the fair Parterres of the Countess *Ognate*, and run into her House, ruin'd the rich Furniture of Pictures, *&c.* of the lower Story; ruin'd the Stables and razed one House. The River also bore away fifty Foot of a strong Stone-Wall made to stop the Passage into the River *Prado*: This River one of the least in *Spain*, so swelled as to carry away almost all before it, as four Iron Gates, and the Cross of the *Via Sacra*. It beat down the Bridge before *Buon Retiro*, and broke through the middle of the Stone Bank. It rush'd into the Gardens of *Nostre Dame de Arocha* after it had beat down the Wall; it run into the general Hospital carrying with it an Arch of Stones. The twenty seventh the overflowing continued with constant Thunder and Lightning, when the River *Mancanarez* bore down the fair Bridge of *Toledo* of sixty Arches. The twenty eighth the Streams of *Prado* so swelled by the Torrents from the Mountains, that all the Champain near it was drowned, the King and Queen of *Spain* were like to be lost in their return from *Nostre Dame de Arocha*; *Malaga*, a City of the Kingdom of *Granada*, situated on the *Mediterranean*, twenty five Miles from the Streights, a Place Great, Rich and well Peopled, had, the ninth of this Month, such violent Shocks of an Earthquake, that all were frighted, the Sea was so disturbed, that the Fish leaped out of the Water, and the Ships in the Harbour were cast above twenty Foot from their places, which the Mariners believed to be sunk; the Harbours and Walls were sunk, together with the Bulwarks, Towers and Fortifications of four Parishes, of which the City consisted, having 4284 Houses, 1057 were ruined to their Foundations; 1259 so decay'd, that they must be Rebuilt to be Habitable. Divers Churches and Palaces felt the effects also; five Cloysters of Religious with the People were utterly ruined, and above all, that of St. *Francis*, where Stone was not left on Stone, where fourteen Persons Perish'd, four Hospitals, one Colledge, the Bishops Palace, the Palaces of *d Diego de Argote*, *de Jo. de Torrez*, *de Diego de Cordua*, and a fair House joining to the Cathedral was thrown down, yet the Church which had been Repairing and Beautifying ever since 1521 scaped, tho' divers times shaken. In the Suburbs *Los Perchelez* two hundred and twenty five Houses were thrown down, so that in all 1282 Houses were destroy'd. Many Houses in the Confines of *Malaga* were overturned; besides the Earth opened in divers places and disgorged Waters in great abundance, which swelled the Rivers and made them overflow. Many Houses in the Villages were destroyed, as at *Pizaria* four Miles from *Malaga*, fifteen of twenty four Houses were overturned; some Mountains were displaced, and divers Persons and Cattle lost: The Wall of *Alhaurin de la torte*, two Miles from *Malaga*, opened four Foot, but closed again: The Jasper Columns of the Church were lifted up and setled down again on their Pedestals. At *Competa*, six Leagues from the City, nothing but the Tabernacle and the Cross of the Church remained whole. At *Aloizana* forty Houses were tumbled down, as many at *Cartama*, and thereabout also at *Coin*, and a great number of People perish'd. At great *Alhaurin* two hundred and forty Houses and the Church were destroy'd, of which only fifty three were somewhat Habitable. In the City of *Minorz* five Leagues from *Malaga*, thirty seven Houses were tumbl'd down, and fifteen

teen Persons crush'd. The Church at the City *Binal-Madera* fell on a heap, and all the Houses render'd unhabitable. The Earth opened at *Veles Malaga*, and so swelled a River, which run some space from thence, that it rose ten Pikes above the tops of the Houses, which it squash'd in running. Many Houses were ruin'd at *Aloro*, others much endamag'd, with the Cloister of St. *Francis*. All the Churches of *Granada* were shaken, and a Chappel in the Church of *Mercy* ruin'd: All which were sad Spectacles.

I have given the Particulars of the whole Relation, most of which concern Buildings, Men and Cattle, those being the Particulars most People are affected with and so observe, and you find only two hints, as it were, of other Effects, the one is of the removing several Mountains, the other of the Earths opening and disgorging a Flood. But 'tis not to be thought but that an inquisitive Naturalist might have found ten times more remarkable Effects in the Country than the shaking down a few Houses in the Towns and Villages, all which, if taken notice of, are soon forgot and lost, and so have been in former Ages, and therefore no wonder if we hear nothing of them in Books: But Nature itself has preserved somewhat of the memory of them by the Medals or indelible Characters of Shells or other Petrify'd, or otherwise preserved Substances, which any, that have Senses and Understanding, may read. But this is not the aim of my present relating these Histories, but to give an example of a Contemporarinefs of Earthquakes at great distances upon the Earth, and a similitude of Effects with those we have this Year heard of from *Italy* and *America*; nay, and let me add what we have had in *London* and *England*, *viz.* a kind of Agueish Distemper, yet not Pestilential, which, 'tis well known, has been very general; for I find that in *October* Agues were as frequent this Year in *France*, as the late Cold or Distemper was here: It was then that Dr. *Tabour* cured the Prince of *Conde*, and many other Persons of great Quality, among the rest the *Dauphinefs* first, and afterwards the *Dauphin* himself, by a Medicine he had invented; tho' *Tabours* demanding five Thousand Crowns for discovering his Receipt, made the *Dauphin* first make use of other means, but without effect. (I will not like an Astrologer name to you the Occurrences that then happened at *Cologne*, nor make comparison with the present, but leave those to the Astrologians, *&c.*) The Plague also this Year 1689, was very much at *Prague*, so that some judged there died in that City thirty Thousand, at *Dresden* above four Thousand, at *Leipsick* about three Thousand; I cannot say there hath been a Comet this Year, but I have been confidently told, that there appear'd one in the Mornings about a Month since, but I could not have the luck to see it, tho' I looked for it divers Mornings after I heard of it, but 'tis more likely it may appear in *October*, or later; but that belongs to another Head, the Affected Earth and Infected Air being those I designed at present to compare; and in these we find the effects in *China* and *Coromandel* eight Years since to answer those of *America* this present Year, and that then of *Spain* to this now of *Italy*; and those then of *France* and *Germany* to the late here in *England*, tho' in all particulars those of the Year eighty seem to exceed those of the present Year. But as the Relations of that are but short and imperfect, so are those of the present as yet much more; but 'twere to be wish'd some more full might be obtained and Recorded before they be forgotten, which a little space of time will otherwise effect, and 'tis not to be doubted but we might hear of much stranger effects of the *Lima* Earthquake, than yet have arrived, if care were taken to procure a fuller account of them. And by the Yesterdays *Brussells* we are informed of a Cleft in a Mountain belonging to the *Marquis de Tarracusa*, of four Spans broad and two Miles long, of which they can find no bottom, and of a Fire shot into the Heavens like a great Beam, of which they lost the sight, not knowing whether it went.

But in the mean time possibly it may not seem altogether unreasonable to suppose, that such an Eruption may emit poisenous Vapours, as well as sometimes poisenous Waters; as appears by that of *France* which I have Printed in one of my Collections. Nor may it seem so strange to suppose its effect may operate at such distances, and not at the very place; when we consider how fiery and volatile such Steams may be, how violently shot into the Air,

and

and blow far off the Dust and Ashes of *Hecla*, *Ætna*, the *Palma*, and many others have been carried in the Air before they have fallen, of which Instances may be produced. And that, in probability, the less active or dead Earthy Materials are those, which fall near the place, whose Qualifications may be of differing Natures. Nor will any very long time be thought requisite for their transport to far distant Countries imbody'd in the Air, when I have proved the velocities of its motions. Nor will it seem strange to one that shall well consider the known Effects of the several Winds, to suppose such kind of transports: But of these Particulars I shall say more upon some other occasion.

THis Lecture was read May *the* 29th. 1689, *and Answers two Objections against the Athor's Theory of Earthquakes, particularly as to Petrifactions.*

R. W.

I Delivered in my last Lecture in this place, the Methods I had made use of for the founding and establishing the Doctrines or Conclusions I had made concerning the Causes and Reasons of the present State and Phænomena of the Surface of the Earth, which was by a methodical Induction from the Phænomena themselves of the most remote, as well as the more approximate and immediate Causes thereof. But notwithstanding all the Arguments I have alledged, and the Proofs I have produced in the delivery of this *Theory*, I still find that there remain upon the Minds of some such Doubts and contrary Persuasions, that they cannot forsake their former Opinions; and therefore (tho' I think I have already fully proved every part, so that the Confutations of such Objections would be but the necessary Corollaries from the said Doctrine, yet since I find they are still insisted on as material Objections that will need a more particular Discussion and Examination) I thought it not impertinent to examine them more strictly, to find the Power and Efficacy, or to discover the Weakness and Insufficiency of them for the purpose they are designed. That thereby the *Idola* (as my Lord *Verulam* says) which pre-possess the Minds of some Men, and molest them in the discovery and imbracing of Sciences may be detected, and, as much as may be, removed and dissolved, thereby to leave the Mind more free to Discourse and Reason aright, without the prejudices of any unsound, unaccountable and unwarrantable Doctrines formerly imbrac'd.

The Objections I shall at present examine are only two, *viz.*

First, That if these large Petrified Bodies, such as the *Ophiomorphite* Stone which I did formerly shew to this Society in the place, be supposed to have been the Production of this Shell of a certain kind of *Nautilus* of that bigness and shape, which, in preceding Ages of the World, had been produced and perfected to that Magnitude in the bottom of the Sea, which then was near the place where they are now found, as I have argued for; then it will necessarily follow, say they, that there have been, in former times, certain Species of Animals in Nature, which in succeeding and in the present Age have been and are wholly lost; for neither have we in Authors any mention made of such Creatures, nor are there any such found at present, either near the places of their position (as on the Shores or Sea about this Island) nor in any other part of the World for ought we yet know. Now, to suppose such a Doctrine as doth necessarily infer such a Consequence, is looked upon by such as absurd and extravagant; for that it would argue an imperfection of the first Creation, which should produce any one Species more than what was absolutely necessary to its present and future State, and so would be a great derogation from the Wisdom and Power of the Omnipotent Creator. *Obj. 1st. As to a Species being lost.*

To this first Objection I Answer, First, That tho' it may possibly be true, that there is at present no such *Nautili* to be found upon the Coast or Shores *1st. Answer.*

of the Lands where these sorts of figured Stones are found, yet no one is assured that there are not some of the same Species, and as big in some other parts of the World, as possibly at the bottoms of some of the great Oceans. Of such Productions and those Multifarious both Vegetable and Animal, no one can doubt that has found in soundable Depths such variety of testaceous and crustaceous Animals there residing, as in their proper and Natural Regions; which would by no means possibly be produced or kept alive in parts of the Sea where they should want their natural Accommodations; one of which may possibly be a sufficient degree of Pressure from the incumbent Column of Water, which, if such be necessary to their Life and well Being, we are no more to wonder that they should not be found in shallower Waters, than that Men should not be found inhabiting the tops of the *Andes*, of the *Atlas*, *Alps*, or *Caucasus*, which from the thinness and coldness of the Air at those heights, are no ways fit for Respiration and sustaining Life. Now, that the present Land of *England* may have in former Ages had some such Position with respect to an incumbent Sea, I could produce several Arguments were they now material to the answering the present Objection, but I will not now insist upon it.

2d. *Answer.* But in the second place I answer, That tho' possibly there may be no such *Nautilus* to be found described in any Natural Historian at this Day, yet 'tis possible there may be many of the same Species, and of as great Magnitudes in divers parts of the World, such as have been either not yet discovered by the *Europeans* or but of late, or but little frequented; and so tho' they may be there frequent and plentiful enough, yet none may have been brought thence into *Europe* as yet, or possibly so much as seen there; 'tis not to be doubted that there really are great multitudes of differing Species of Vegetables, Insects, Beasts and Fishes yet in places less frequented, of which we in *Europe* have hitherto had no knowledge or information; and tho' many strange things have been of late Years brought to our view, yet we may with Reason enough assert, there are many more yet latent, which Time may make manifest: For if we consider the small knowledge of things of this Nature that we yet have acquired, of places remote, even the most frequented, we need not much wonder at the lesser information of such, as are not known or less frequented; for not to insist upon the multitudes of Vegetables that have been newly shewn to us by the Authors of the *Hortus Malabaricus*, and by *Brennius*, and others, we are put in hope, to see the Descriptions of as many more yet by the same Authors, from the same places, which yet are but two small spots in respect of the vast Spaces, and variety of Soils and Climates yet unsurvey'd; and 'tis not to be doubted but that the Earth, and Air, and much more yet, the Seas of several Countries and Climates would afford as great varieties of Birds, Beasts, Insects and Fishes, if there were found knowing and diligent searchers and describers of them: And that this is so, I shall mention only one Instance, because 'tis pertinent to the present Subject, namely, that I have had a peculiar kind of *Nautilus* brought from the *Caribys*, where they are in great plenty, and yet I do not find any Author has taken notice of them, nor could I ever meet with more than one Man that had taken notice or knew any thing of them, tho' the Island has been long inhabited and planted by the *English*; which Shell I have formerly shewn to this Society, who were satisfy'd by the Characteristick that it is a Species of the *Nautili*.

And as we yet want a *Hortus Sinensis*, *Japonensis*, *Tartaricus*, *Canadensis*, *Virginianus*, *Brasilianus*, *Peruvianus*, *Americanus*, &c. so we want the Natural Histories of the Animals of most kinds, of those places, and even of the Fishes which are frequently enough met with by Navigators, tho' not further taken notice of than as they may be useful for their present Food, or the like. We are therefore two hasty in our Computations and summing up all we have, and concluding that must be the summe of all that can be had; for that there are yet many particulars behind, that must come into the same account before the inclosure be fully made and the Books be shut, if at least a full Account be expected. We are informed by Mr.-----*Cole*, and divers other late inquisitive Men, how many new things have been discover'd here at home, where

yet

yet there have not formerly been wanting inquisitive Men; what then may we not expect from other places where none such have ever come, at least, that we know of?

Again, how apt should we have been, if there had been found a Petrify'd *Stella arborescens Rondeletii*, before we had been certify'd of the existence of such a strange shaped Fish of the Species of the *Stellæ*, to have concluded there had never been such a Fish, because it differs so very much from the Star-fishes or five Fingers, as they term them, commonly taken on our Coasts? The like may be infer'd concerning the strange variety I have seen of the *Echini* brought from several parts; for they differ much more from one another than the Helmet Stones, which I have hitherto seen, do from several sorts of them: The like may be said of the varieties of Sharks Teeth, as to one another, and as to the *Glossopetræ* found upon the Land.

So that upon the whole we may conclude, that it does not necessarily follow, that those *Species* of *Nautili*, must be now wholly lost that produced the moulding Shells of these *Ophiomorphite* Stones, we find here in *England*, because they are not now found upon our Shores, nor because we cannot now certainly affirm where they are to be found, and therefore that the induction or inference is made from too few Particulars, and may, nay, ought to be examined a-new, when we can procure a more full Account of the Productions of the Shores and Oceans, which Time and Industry may possibly effect.

But not further to insist upon this way of Defence, we will, for the present, take this Supposition to be real and true, that there have been in former times of the Word, divers *Species* of Creatures, that are now quite lost, and no more of them surviviug upon any part of the Earth. Again, That there are now divers *Species* of Creatures which never exceed at present a certain Magnitude, which yet, in former Ages of the World, were usually of a much greater and Gygantick Standard; suppose ten times as big as at present; we will grant also a supposition that several *Species* may really not have been created of the very Shapes they now are of, but that they have changed in great part their Shape, as well as dwindled and degenerated into a dwarfish Progeny; that this may have been so considerable, as that if we could have seen both together, we should not have judged them of the same Species. We will further grant there may have been, by mixture of Creatures, produced a sort differing in Shape, both from the Created Forms of the one and other Compounders, and from the true Created Shapes of both of them. And yet I do not see how this doth in the least derogate from the Power, Wisdom and Providence of God, as is alledged, or that it doth any ways contradict any part of the Scripture, or any Conclusion of the most eminent Philosophers, or any rational Argument that may be drawn from the Phænomena of Nature; nay, I think the quite contrary Inferences may, nay, must, and ought to be made.

For first we do find that all individuals are made of such a Constitution, as that beginning from an Atom, as it were, they are for a certain period of Time increasing and growing, and from thence begin to decay, and at last Die and Corrupt. And in every part of their Life they are in a continual change or progress, from more perfect to more imperfect, there being a continual growth of Death and Decay to the final Dissolution; yet this is not Argument against the Omnipotence, Providence and Wisdom of the Creator, who thought fit so to Create them. Again, we find that the Powers and Faculties of the animated Bodies do continually exert a succession of differing Effects, and continually change the Figures and Shapes from one degree to another. As we see that there are many changings both within and without the Body, and every state produces a new appearance, why then may there not be the same progression of the Species from its first Creation to its final termination? Or why should the supposition of this be any more a derogation to the Perfection of the Creator, than the other; besides, we find nothing in Holy Writ that seems to argue such a constancy of Nature; but on the contrary many Expressions that denote a continual decay, and a tendency to a final Dissolution; and this not only of Terrestial Beings. but of Celestial, even of the Sun, Moon and Stars and of the Heavens themselves. Nor have

I hitherto

I hitherto met with any Doctrine among the Philosophers, that is repugnant to this Doctrine, but many that agree with it, and suppose the like States to happen to all the Celestial Bodies, that is, to the Stars and Planets that happen to the Individuals of any Species; and consequently if the Body of the Earth be accounted one of the number of the Planets, then that also is subject to such Changes and final Dissolution, and then at least it must be granted, that all the Species will be lost; and therefore, why not some at one time and some at another? This Objection therefore, I conceive, is of little validity against the Doctrine I have delivered, and therefore I shall proceed to the second Objection, and examine the Validity thereof.

2d. *Obj. As to figured Spars and Chrystals.*

It is Objected then in the Second place, That since it is manifest, that there are many curiously figured Bodies found in the Earth, which cannot be imagin'd to be produc'd by the Causes and Means that I have alledg'd, as the Shapes of Salts, Sparrs, Ores, Chrystals, and divers other kinds of regular mineral Bodies, also, Agates Mochuses, curiously speckled Marbles, and the like. Now, since it must be granted, that they are made by a Plastick Faculty, why may not that Faculty extend also so far as to be the cause of those other Figured Stones, which resemble Shells or other Animal or Vegetable Substances?

To this I answer, That tho' it be manifest, that Salts, Chrystals, Sparrs, *&c.* do plainly receive their regular Figures from the Texture or Nature of their own Parts, as is evident, most especially in the Chrystallization of Salts, and the Petrifactions of the like Figur'd Substances, yet the Figures, and painted and stained Shapes, as it were of *Agates*, *Mochus*'s and the like, are not to be ascribed to the Designs of Nature, but to the Productions of Chance; for instance, the Pictures that in *Mochus*'s seem to represent Trees, Hills, Houses, and other perspective Representations, they are no otherwise caused than by some Clefts, or Flaws in the said Stones, into which some colour'd Juices have insinuated themselves, and by that means formed those Representations which appear in the Body of the Stone, and that this is so, and may be Artificially produc'd by several Bodies and Liquors, which have no affinity, either with *Agate*, *Mochus*, or Marble, I can make it plainly appear by Experiment, which, if it be thought fit, I shall produce either now, or the next Meeting.

THe Experiment here mention'd, was by taking two flat Marbles or Glass-plates, and laying upon one of them several drops of a dark Oil-colour, such as Painters use, and pressing the other flat Stone or Glass upon it, by that compressure several curious Representations, like the branchings of Vegetables, and the like, were exhibited; which explain'd the Representations in Agates, *&c. a different colour'd mineral Juice insinuating itself into the Clefts or Interstices of the Stone, and afterwards petrify'd to an equal hardness with the rest of the Stone; tho' many times there is a different hardness in the Veins, or Representations from the other parts of the Stone, as is seen in Marbles and other veined Stones.*

R. W.

We have lately had an Account from Mr. *Tentzelius* Historiographer of the Duke of *Saxony*, of the Skeleton of an Elephant found buried in *Germany*, at the Foot of a Hill or Mountain at fourteen Foot deep, and cover'd with several Layers of Earth, but buried in a Sand, which the whole adjacent Mountain is found to consist of, being at a place call'd *Tonna* near *Erfond* in *Germany*. [I take notice of these Particulars, because they may be found to give some light as to the explication of an other Phænomenon which I shall by and by relate.] Now, tho' *Tentzelius* really judged and pronounced it to be the Skeleton of an Elephant, yet it was not without the Contradiction of many others of divers differing Opinions; the greatest number of which were for asserting it to be *a Lusus Naturæ*, as it seems the whole Colledge of *Gottha*, and divers other Learned Professors; but their Arguments are prov'd insignificant, and his own Doctrine sufficiently Establish'd in the Epistles which he wrote to Snr. *Magliabechi* and Publish'd in Print, and this Honourable Society

ciety were yet farther convinc'd of the certainty of it, by the Fragments and Specimens of the trials he had made of several of those Bones: But, after all, great Difficulties arose concerning the Means and Cause of the burying of it at such a place, and at such a depth and the covering of it, to be the natural Layer of the Earth, and not the Artificial filling up of a Grave or Pit dug by Art to bury it: Some attributed it to the effect of *Noah*'s Flood, as 'tis usual for most to do in the like Cases, where they can think of no other Cause; to me, I confess, it seem'd rather to be the effect of some preceding Earthquakes, as I formerly here deliver'd in a Discourse on that Subject, when I first met with a Relation of it, as I have in other Discourses also about *Lignum Fossile* or Subterraneous Trees, and other Substances found buried, and now dug out from under the Ground, not only in *Italy*, *Germany* and *France*, &c. but even in *England*, *Scotland* and *Ireland*. Now, because by our forreign Gazets, and also by our own from them of a late Phænomenon in the *East-Indies*, we have the History of a late Earthquake that happened there this present Year, whose effects do give an evident Proof of the Doctrine which I supposed, and indeavour'd to maintain, I thought it would not be improper to mention it here, and to add it as a further addition to the History of Nature. I shall indeavour to get the full Account of it Printed at *Batavia* in *Java*, an Abstract of which was Printed in the *Harlem* Currant in *October* last, and an Epitomy of that in our Weekly News-papers, which was this. Transcrib'd out of the *London* Post for *Sep.* 30. 1699. Printed for *Ben. Harris*.

'*Amsterdam October* 2. Our Letters from *Batavia* in the *East-Indies* of the '8th of *February*, say, That on the fifth of *January*, about two in the Morn-'ing, a most terrible Earthquake happen'd, which was so violent, that one 'and twenty Brick Houses, and twenty others were overturn'd, so that if it 'had lasted a little longer they must have been all thrown down. About 40 'or 50 Persons were Buried alive under the Ruins of the Houses that fell, and 'near the same number were Lamed. Some small time before the Earth-'quake, the Blew Mountain, otherwise call'd Mount *Sales*, burst with such 'a terrible Flame and Noise, that it was both seen and heard there, tho' six 'Days Journey distant. Next Morning the River which falls into the Sea 'here, and has its Rise from that Mountain, became very high and Muddy, 'and brought down abundance of Bushes and Trees half Burnt; and the 'Passage being stopt, the Water overflow'd the Country round, all the 'Gardens about the Town, and some of our Streets; so that the Fishes lay 'Dead in them: It was a whole Month before the River could be clear'd, 'altho' 3000 *Indians* were daily imploy'd to clear the same, during which 'time we were oblig'd to fetch fresh Water from *Bantam*, which is forty Miles. 'All the Fish in the River, except the Carps, were kill'd by the Mud and dirty 'Water: A great number of drown'd Buffaloes, Tigers, Rhinocero's, Deer, 'Apes, and other Wild Beasts, were brought down by the Current; and 'notwithstanding a Crocadile is Amphibious, several of them were found 'Dead among the rest.

The Phænomena of this Earthquake, tho' they afford a probable solution of the more common Phænomena of fossile Trees, Wood, Nutts, Leaves, *&c.* of Vegetables, and of the fossile parts of Animals, *&c.* such as Teeth, Hornes, Bones; yet there are some other strange Phænomena, which I conjecture to have been effected by the same efficient Cause. If it be inquir'd what those strange Phænomena are, that I may give you an Instance, I shall acquaint you with one I late met with and receiv'd from a curious Person, who made the Observations himself, of which I have since been confirm'd by another curious Person who had seen and observ'd all the same Particulars. The Relation, in short, is this.

A Description of the Ridge of Mary Burrow *in the Queens County in* Ireland.

'This Ridge runs North and South, from *Tymohoe* to *Mary-burrow*, about 'seven Miles, from thence towards *Montmelick*, four Miles further, and as 'this Author was inform'd through the King's County of *Westmeath*, towards

'*Athlone*, but in these last mention'd Countries is much lower than in the 'Queens County.

'From the said *Tymohoe* to *Montmelick*, being both in the Queens County, 'it is about fourteen or fifteen Foot high, where highest, as near as this Au-'thor can conjecture, being laid as irregular as the Sands are usually laid by 'the Waves on the Sea-shoar, with several bendings in and out, high 'and low; the Sides so steep, that in most places not easy to ride up, and in 'many places Trees growing on the Sides, and a little thin Skin of Grass, 'apt to be burnt or scorch'd with the least dry Weather.

'It is so broad on the top as to afford room enough for four Horse-men to 'ride a Breast, the Road, in many places, lying on the top thereof.

'It is compos'd altogether of small rough Pebble grayish Stones about the 'bigness of a Mans Fist, and other smaller ones mix'd with Sand or Gravel, 'but no mixture of Clay or Loam, as this Author ever observ'd, which several 'times he sought after as he travell'd that way.

'None of the Lands adjacent to this Ridge have any of the materials where-'of it is compos'd, mix'd with their Soils; in most places there are Boggs to 'within a very few Yards of its Foot, and where any Arrable lies near it, there 'is no mixture of the above Pebble or Sand therewith.

'So that it should seem probable that this Ridge of Pebble and Sand was 'brought from some remote places by some violent motion of Waters, and 'dispos'd into the form it now remains in, which induc'd the Author se-'veral times to say, he believ'd it to be the effects of *Noah*'s Flood, the Con-'sideration whereof he refers to better Judgments.

'If any farther Particulars relating to this Ridge are desir'd, and a few 'Lines sent by the Post directed to the Author at *Rathdowney* near *Burris*, in '*Ossory*, *Ireland*, they shall be carefully inquir'd into and answer'd by

Nov. the 14th 1699. *Your most humble Servant* Ric. Prior.

This Ridge is distant from the Sea about thirty Miles.

The same curious Person who is now return'd to his Estate, which lies in the Queens County not far from it, has promised me to make many other Observations about it, which I desir'd, and has promis'd to send me an account of his success, by which I hope I shall be better enabl'd to explain the Cause and Reasons thereof; 'till when I shall forbear for the present to make any further Reflections on it.

THis Lecture treats of Animal Substances found buried in the Ground in several parts of the World, and of a Ship found in Switzerland *with the Bodies of forty Men in it at a considerable depth under ground.* Secondly, *An account of a Ship found in the bottom of a Lake in* Italy, *supposed to be ever since* Tiberius's *Time, with several Deductions and Queries thereupon.*

R. W.

Of Animal Substances found buried.

MAY 26. 1697. We have lately had several Accounts of Animal Substances of various kinds, that have been found buried in the superficial Parts of the Earth, that is not very far below the present Surface; as particularly the parts of the Head of an *Hippopotamus* at *Chartham* in *Kent*, that of the Bones of the *Mammatoroykost*, or of a strange Subterraneous Animal, as the *Siberians* fancy; which is commonly dug up in *Siberia*, which Mr. *Ludolphus* judges to be the Teeth and Bones of Elephants; and indeed that peice which I saw of it was much like Ivory in its Texture, only the out side of it seem'd to have been cover'd by a kind of Skin, which I never heard of or saw any Elephants Tooth so cover'd with; then the Bones and Teeth of a large Elephant lately dug up in *Pomerania*, of which I some while since transcrib'd the Relation out of one of the late Monthly Mercuries, and read it at one of the Meetings of this

this Society; also the great Bone in the Repository presented to the Society by Sir *Tho' Brown*, which was found upon the foundering or calving of some Cliff in *Norfolk*, which seems to have been the Leg-bone of some Elephant, if it be not some Bone of the fore Fin of some Whale; 'tis equally admirable which soever it may be found to be by one skill'd in the Osteology of those Creatures; and lastly the great Hornes that have been often found and dug up in *Ireland*, of which the account is Printed in the last Transaction; all which, and divers others which I could mention, do shew that the present superficial Parts of the Earth have suffer'd very great Alterations, which I in my Lectures in 1664. indeavour'd to prove to have been the effects of some preceding Earthquakes, without which Supposition I cannot conceive any probable Cause can be assigned, much less can there be any such rational Cause assigned for the Position of many other Phænomena which have been observ'd of such like Substances found and dug up at much greater depths, that is, of more than two or three Fathoms below the present Surface, at which depth those I have mention'd are said to be found. I conceive it will be very improbable to assign the Cause to the universal Deluge of *Noah*, and much more so to ascribe it to any particular Deluge, as to that of *Deucalion*, &c. for how could the Flood bury the Shells of Fishes in the middle of some of the highest *Alps*, and cover them with a prodigious height or thickness of Rocky Mountains? Or how should the bottom of the Sea come to be raised to such a prodigious height above the present bottom of the Sea at the Shore next such places? To me, I confess, it seems a most improbable, and groundless supposition: Improbable, for that 'tis hardly conceivable how the Water should heap up these Substancess, such prodigious masses of Stony or Earthy Concretions; and groundless, for that we have no mention in Sacred or Prophane History of any such effects produced by a Flood. However, tho' we should grant that Elephants might be carry'd by the Waters of the universal Deluge from the more Southern or Æquinoctial Parts to those Northern of *Siberia* or *Pomerania*, yet how shall we conceive by what means the universal Deluge should bury a Ship and forty Men at a hundred Fathom under Ground, and that at so great a distance from the Sea, as *Switzerland* now is, of which nevertheless we have an undoubted History? I say undoubted, because I have not found any Author that has question'd the truth of this Relation. Now, tho' I confess I did not know 'till lately (upon perusing Dr. *Wagners* curious Natural History of *Switzerland*) who inform'd me who was the first Historian that had acquainted the World with this discovery; tho' I had met with the account in several other Historians, yet none of them speaking of it with any doubting Expression I conceiv'd it must be related by some Historian of good Repute. This Enquiry then Dr. *Wagner* answer'd by telling me the first relater of it, which was *Baptista Fulgosi* Duke of *Genoua*, which Author's Book I have since procur'd, and have read his Account of it, which I will presently give you as I find it express'd by *Camillus Gilnus* in Elegant Latine, being by himself, and his Father translated from the Original, Publish'd by the Author in the Year 1483, but the Book translated into Latin was Printed 1565. In this Book I find an account of the Author, and the Esteem he had, and the occasion of the writing of it, which was partly to drive away melancholy Reflections on his past Misfortunes, having lost his Dukedome, and partly for Instruction to his own Son. In which Relation 'tis remarkable, that this Ship and Men should be buried so deep in the Earth as a hundred Fathom or six hundred Foot. Next, that the Bodies of forty Men should be found in the Ship itself.. *3dly*. That this should be a Ship of the Ocean, and not of some River, because of the great distance of it from the Sea. *4thly*. That the Anchors and Sails, tho' torn, should yet remain and be plainly discoverable. *5thly*. That he did not take this Story from uncertain Report, but from divers grave Men, who had been Eye-witnesses of it, who had inform'd him themselves. *6thly*. That it was so remarkable in that time, that the Learned Men had meditated and reason'd on it to assign the Cause of it; that is, to give a rational Hypothesis, by which to shew how it might come to pass, they having it seems pitch'd upon two especially, which do both of them to me seem very insufficient, not to say very absurd. So that upon the whole Matter, there seems to me no Reason or Cause to doubt the matter of

Of a Ship found buried deep in the Ground.

Fact

Fact or the ὅτι, but all the difficulty lies in the διότι that then shall be the next thing to be examin'd, and that the rather, because this seems to be a true *Experimentum Crucis* to distinguish between my Hypothesis and those of some other Authors. As first, concerning the two Solutions specify'd by the Author, not as his own, but as of some other Philosophical Men, who then lived, and who were satisfy'd, it seems, of the truth of the discovery, and 'tis not unlikely it might be some of those. *Plurimi Graves viri qui rem perspexerunt & qui in Re presenti fuere a quibus ipse accepit.* For as for himself he ventures not at any Solution, but says only *Cæterum utcunq; res fuerit admirationis non Mediocres relinquit Causas.*

That it could not be from Noah's *time.*

First then, for the Hypothesis of *Noah*'s Flood, 'tis not said in any History, that Navigation, especially on the Ocean, was grown to such a perfection in *Noah*'s time as to make Ships of that bigness and perfection of Anchors, Sail and Rigging, as this by this short Description seems to have been; and 'tis very likely if any such Navigation had been, it would have been taken notice of in the History of the Bible; for it cannot be suppos'd that *Noah* should not be inform'd of it, if any such Art had been then practiced in any part of the World how remote soever from the place of his Abode. Next, if such should have been, it might have happen'd that some other Men or Creatures might have escap'd with Life besides those in the Ark. Next, supposing that there had been such a perfection of Navigation at the time of the Flood, I cannot conceive how a Ship of that bigness, as this seems to have been, should be carry'd down so deep under the Surface of the Earth as 600 Foot: Certainly a twelve Month soaking of the Earth, much less forty Days, could not reduce the superficial Parts to such a hasty pudding Consistence as this Phænomenon does seem to require, since I doubt whether there can be found in the World any part of the bottom of the Sea, that has been soaked for some thousands of Years, that is so softned.

Next for the second Hypothesis of a Subterraneous Navigation, to me, I confess it seems a ridiculous Supposition, tho' I know a late Author has imbrac'd such an Hypothesis to solve the Phænomena of Sea-shells, and the like Substances found in Mountains and Mines; tho' Mr. *Purchas* has Publish'd a like Story of *Andrew Knivet*, but I am apt to think that most Readers will look upon it as told by a Seaman and a Traveller.

But the Matter of Fact being so well attested, it must at least be suppos'd to be there plac'd by some Natural Cause, as must also all those other Phænomena I have ment'on'd.

Now for assigning a Cause sufficient, I conceive there cannot be a more probable one, than the effect of Earthquakes, which have, and do still produce as considerable Effects as any of these; the late Relations we have had of the effects wrought by them in *Lima*, *Jamaica*, among the *Cariby* Islands, among the *East-India* Islands, about *Vesuvius*, in *Norway*, and in the Island of *Sicily*, will furnish us with Phænomena almost as strange; besides it seems rational to believe, that Earthquakes in former Ages before we had History, were not only more frequent, but much greater and more powerful.

These, I conceive, have not only produc'd wonderful Effects in this or that part of the Earth at one time, but at many times successively, possibly at the distance of many Ages; so that at one time they may have raised the bottom of the Sea to make a dry Land, and sunk other parts so as to be overflow'd by the Sea, which were before far above the Surface of the Water, or to make Inland Seas or Lakes, as that of *Geneva* and divers others thereabouts: But by succeeding Earthquakes those effects may have been quite differing, so as to sink again those parts it had raised, and raise again and fill up with other Earthy or Stony Matter, those it had formerly sunk, and so also by various Efforts at various Times it may have overturn'd and turn'd upside down, or otherwise tumbl'd and confounded the parts of the Earth, which seems plainly to be hinted to us by the Mythologick Story of the Giants fighting with the Cælestial Powers, and heaping Mountains upon Mountains; and (I do confess) I conceive there can be nothing more reasonable and conformable to the proceeding of Nature in these Times, than to suppose there have been the like and much greater, in former Ages of the World.

I con-

I conceive then, that whenever that part of *Switzerland* was the bottom of the Sea, this Vessel (which the Author calls *Navis* or a Ship) was upon that Sea over this very place, when there happen'd an Earthquake just underneath it, which did raise the same above the level of the Water, as much as it now is; and that by this there having happen'd to be an Opening, Cleaving, or Chasm in the Ground under it which swallow'd up some of the Sea, and with it this Vessel, and afterwards closed again, and inclosed what it had swallowed; or else that this part had been some very deep Inland Lake, as that of *Geneva*, and divers others there about, that this Vessel was Navigating in this place when some Earthquake happen'd, which overthrew some Neighbouring Mountain, Hill or Lands, which, falling into this Water, did not only sink the Ship, but fill'd up and levell'd the Lake with the Contiguous Lands or Shoars of it; neither of which ways of explicating it do need any other effect, but such as we are by antient and much more later Observations ascertain'd, are the usual effects of Earthquakes.

I have consider'd the Passage mention'd by *Leo. Bapt. Alberti* in the fifth Book and Twelfth Chapter, concerning *Trajan*'s Ship found in his time in *Italy*. Now, I find that this *Alberti* was a *Florentine* Gentleman, who flourish'd about the Year 1483, and was accounted the *Vitruvius* of his Time: He being a Scholar, an excellent Painter, Sculptor and Mechanist, and an excellent Architect, he was the first that indeavour'd the Explication of *Vitruvius*, in which he made great progress, much to the improvement of that Age; in order to which he survey'd and measur'd the remainders of Antiquity; he understood Perspective also, and writ a Book on that Subject, which was not well understood by the Antients, nor much by the Moderns in his Time. But my present Inquiry is chiefly about this Passage mention'd in his Book *De Re Ædificatoria*, produc'd the last Day by Mr. *Bridgman* concerning *Trajans* Ship discover'd in *Alberti*'s Time, which had lain sunk in a Lake of *Italy*, which he calls *Nemorensis*, ever since the time of *Trajan*, which was near one hundred Years after Christ, for he died in the Year ninty eight, which is now full sixteen Hundred Years since, and so was more than thirteen Hundred in the time of *Alberti*. The Passage is as follows. *Leo Baptista Albertus De Re Ædificatoria. Parisiis*, 1512 8°. *Libro* V. *Capite* XII. *Materiam omnem reprobant quæ fissilis, fragilis, findens, putricosaque sit, clavosq; & ligulas æneas præferunt ferreis, ex Navi Trajani, per hos dies dum quæ scripsimus commentarer, ex lacu nemorensi eruta, quo loci annos plus mille trecentos demersa & destituta jacuerat, adverti pinum, materiam, & cupressum egregie durasse, in ea tabulis extrinsecus duplicem superextensam & pice atra perfusam, tela ex lino adglutinarant, supraque id chartam plumbeam claviculis æneis coadfirmarant. (Lacus Nemorensis) a dix huit Milles de Rome vers l'Orient, il s'appelle aujourd' huy Lago di Nemi.* What this Ship was, and the History of it, I have not met with, nor can I find any such Lake as is call'd *Lacus Nemorensis*, or *Nenorensi Lago*, as *Petrus Laurus*, in his Translation of this Book into the Vulgar *Italian* renders it. *Bartoli*, who Translated this Book into *Italian* after *Caius* renders it *Lago della Riccia*. *Pliny* indeed mentions a Ship of *Layus*, which was purposely sunk at *Ostia* to found the Mole upon; but he could not say any thing of this, he dying almost 20 Years before *Trajans* time; nor do I treat upon what occasion it was that caus'd them to dig it out, nor at what depth it was found, nor whether it were buried in the Ground, or were only sunk into the Mud: If any have met with any further information concerning it in their Reading, I should be glad to be inform'd concerning it. *Fulgosus* having writ his Book much about the same time that *Alberti* writ this, I thought I might have met with some account of it in him, it being somewhat Analogous with his Relation of the Ship found in *Switzerland*, about the same time; but I do not find he hath any mention of it. It seems pretty strange how either of these Ships should come to be transported into the places where they are said to be found; but 'till we know the History we can at best but conjecture concerning them. There are many other particulars I should have desir'd information of besides those which he has mention'd, and 'tis very likely some of them may have been taken notice of in the Relation of its discovery, which I am inclin'd to believe must be somewhat more at large and more fully related than we find it here, which only hints two Remarkables

proper to the purpose, for which it is mention'd, *viz.* About the durableness of Timber fit for building of Ships in its own Nature: And, Secondly, Of the way of securing it against the Corrosion of Worms, which it seems was so long since taken notice of and provided against by the Shipwhrites of *Trajan*'s Time; which they perform'd by a double Sheathing; the first, next the double Planking, *(Tabulis extrinsecus duplicem Superextensam & pice atra perfusam tela ex lino adglutinarant)* was a kind of Tarpollin, they covering the Planks with Pitch, and that Pitch with Linnen-cloth sticking to it; the second was a thin sheet of Lead fastn'd by Brass Nails to the Plank; that it was very thin, I think is denoted by *Charta Plumbea*, that is, such kind of thin Lead as they formerly us'd for Writing on, much like the thinnest sort of Mill'd-Lead now made by the new Engine; which how they made is not known, nor do we certainly know how they make the like Sheets of Lead in *China*, of which kind I have seen a great variety, and all of it very even and regular: The Plumber will tell you 'tis done by Casting the Lead on Ticking, but that I conceive will not make it so thin and even as I have seen it; we have a way of beating it after the manner of Gold-beating, which doth foliate it very thin and even, 'tis commonly call'd *Tin Foile*, and 'tis us'd for foiling Looking-glasses; 'tis a mixture of Lead and Tin, as is also the *Tootenag* of *China*, and possibly theirs may be done the same way; but the Rowlers in the Mill I take to be much the better way; 'tis by somesuch Engine they foliate Brass and Copper in *Germany*, tho' they do some sorts also with the Hammer, as Kettles, and the thin Iron Plates for Latton by beating many of them together at once, as they do also Leaf-gold, Silver and Brass; but Asidue somewhat thicker, is done by an Engine with Rowlers, as they flatten Wire for Threads; and so also is a sort of Sheet Brass somewhat thicker: Possibly both ways may be known and made use of in *China*, where they have many other curious Inventions which we have not yet attain'd, and 'tis not unlikely but that the Antient *Romans* might for this foliating of Lead, have somewhat the same.

Sheathing Ships with Lead known to the Romans.

Now as to the use of it for Sheathing of Ships, I find the *Spaniards* make use of it at this time, and have done so for a long time. This I find Sir *Rich. Hawkins* takes notice of in the account of his Voyage to the South Sea, Page 87, which see.

Here we have an account of all the ways of Sheathing of Ships he knew, and his Judgment or Censure of them, which how just they are must be left to Experienc'd Men; however, I have been lately inform'd that the *Spaniards* make use of the same way still for their Gallions, which 'tis not likely they would if they knew any way better; they had indeed another help to keep out the Water in case of any failure in the outward Plank, and that is the filling all the Space between the Ribbs and Planks with a certain sort of Plaister which may be a security to the innermost Plank, but not at all to the outermost against the Worm or Springing of them; however, 'tis of good use to keep off a suddain overflow or entrance of the Water in case of either Defect. But the best way of all seems to be the *Chinese*, by the Varnish, which neither Worms nor Water, nor Heat will damnify; nor in their way of building their Junks, do they leave any vacuity in the thickness of the sides to need Plaister, but what is fill'd with Damar, which is in itself lighter than Water, and will swim on it. But that way is not practicable here in *Europe* where we want the Varnish, whereas the others are, especially that of Sheet Lead, of which Metal this Nation affords us great plenty, and the late invented Mill doth certainly out do all other for giving it a proper Form; besides, if Plaister were necessary, we have as good as the World affords, or which possibly may be better, we can have Pitch enough (much of the same Nature and Use with Damar) to prevent any suddain gushing in of the Water: But this only by the bye.

The strangeness of the Relation or History of the Ship found sunk in a Lake, some where in *Italy*, mention'd by *Leo. Bapt. Alberti*, and the shortness and imperfection thereof as deliver'd by him, made me very desirious to get a more full and perfect Relation thereof. I thought *Bayfius* in his Treatise *De Re Navali* might have taken notice of it, he having Written since that time; but he has never a word concerning it as I can find, nor do I find any

mention

mention of it in *Dassie*'s Book *de L' Architecture Navale*; but *Pere Fournier* in his Hydrography (Book the Fourth, Chap. the First) treating of the Navigation which was before the universal Deluge of *Noah*; says, it seems rational to think that (considering the long Life of Men before the Flood, and the populousness of those Times) there was no part of the World uninhabited, tho' we have no History of them but the Bible, and tho' that has not one word concerning it; and that not only the great Continents of Land, but there being Islands both in the Seas and Rivers, those also were inhabited which could not be suppos'd without the use of some kind of Navigation. Add to this in the third place, that 'tis reasonable to think that the *Antediluvians* were as ingenious, if not much more, than the *Postdiluvians*, for the inventing of Ships, and for the use of them, for the transplanting of Colonies, for Trading and for War. Moreover (says he) in the Year 1462, as is Recorded by *Fulgosus*, at *Bern* in *Switzerland*, as they were working in the Mines, at above a hundred Fathom deep in the Earth, there was found an old Wooden Ship built as ours are, whose Anchors were of Iron and the Sails of Linnen, with the Carkasses of forty Men. *Peirre Naxis* Relates a like History of another, such a one as was found under a very high Mountain. In like manner the Jesuite *Eusebius Neurembergius*, in the Second Chapter of the Fifth Book of his Natural History, says, 'That near the Port of *Lima* in *Peru*, as 'they were working a Mine for Gold, those which follow'd the Vein in the 'Mountain found an old Ship, which had many old Characters very differing 'from ours, which all People believed to have been there buried by the uni-'versal Deluge.——*Namq; Juxta portum Limæ in Peru cum eviscerarat avaritia terram, insecuta auri venam, Navigium inventum est sub ipso monte, quod a nostris, & hactenus fama & Scriptis antiquorum notis plurimum dissidebat. Creditumq; ab universis illuvie fuisse humatum.* There was found also in a very high Mountain of *Mexico* a prodigiously large Elephants Tooth, tho' in all *America* there was never yet found any Elephant. 'Without doubt (says he) all 'these things have been thus buried by the tumbling and overturnings of a 'universal Deluge, as well as the Wreeks of other Vessels which have been 'found at three Thousand Stadiums or Furlongs from the Sea, as *Strabo* re-'lates in his First Book. Thus far Father *Fournier* to this purpose. Nor do I find that he hath taken any notice or made the least mention of this Vessel, mention'd by *Alberti*, which, methinks, he should not have been ignorant of, especially considering the great Pains he has taken, and great Learning he hath shewn concerning the Subject of Shipping.

The *Heer Witsen* in his Book intitled, *Ael Oude en Heden dueysche Scheeps Bouven Bastier*, in the Fourth Chapter of his First Book, hath given us a somewhat larger account and more particular than *Alberti*, but quotes not the Authors from whom he receiv'd it; so that we must rely on his Reputation 'till we can be better inform'd. His Relation in *Dutch* is to this effect. 'In 'the time that the Pope, *Pius* the Second, possest the Chair (which I find was 'from *August* 1458, to *August* 1464) Men found in the *Numidische* Lake twelve 'Fathom under Water, in the Mud, a Ship, in length thirty Foot, and in 'breadth proportionable; built of *Cypress* and *Larix* Wood (which is a Species 'of Pine-Tree Wood) which was become of such an hardness, that it could 'neither be burnt nor broken, if it were needful. This Ship had lain under 'the Water for fourteen Hundred Years without the least perceivable Rotting 'to decay it: It was on the Deck done over with Pitch, and that cover'd with 'a Coat or Crust of a certain Pap or Morter made of Clay and Iron well tem-'per'd or beaten together, which art of mixture is now conceil'd; tho' others 'are of Opinion that this mixture was not made of Clay and Iron, but of Clay 'and Pitch well kneaded together. The Deck was cover'd with Paper, Lin-'nen Cloth, and Plates of Lead, which were nailed to the Planks with Cop-'per Nails guilded. This Ship (a wonder) was found so stanch, that not the 'least drop of Water was found to have soaked into its Hold; it had the length 'of an old *Trireme* Vessel, and the breadth of a Hulk. In the Hold was 'found the Hangings of fine Velvet of an Orange Green, and in the mid-'dle of the Floor a Copper Coffer fastned by four black Strings, which being 'open'd there appear'd an Earthen Urne or Vessel, which was ornamented

'with

'with a Gold Plate, and fill'd with Ashes; and because Men saw the Name 'Tiberius several times engraven upon some Leaden Plates about the Border 'of it, they conceiv'd this might be the place of his Sepulture.

This Account, tho' in divers Particulars different from that of *Alberti*, yet seems to be translated from the same Original History, which neither for them having mention'd by what Author it was written, we are yet to seek of the true account, which probably may be much more particular than either of these, or both of them put together; for that it is usual in second Hand Relations, to take notice of such Passages of the Original, as concern the present Subject they are treating of, and to omit many other Particulars, tho' in themselves much more remarkable; this therefore I further sought for in divers other Authors; and in *Riccioli*'s *Hydrography*, I found a further account of it, which also gave me a hint of the true Author: *Riccioli*'s Account is this, Chapter the thirty ninth of the Tenth Book, which whole Chapter treats of Ships that have been much celebrated for their Magnitude, Splendor, Voyages, or other very remarkable Conditions; among which, Page 340, he brings in the Ship of *Tiberius* as one very remarkable instance, whose History he thus describes, *Narrat Æneas Sylvius, suo tempore repertum in lacu Numicio Cubitis* 12 *Sub aquam, navem ex Larice Cubitorum* 20 *Bitumine & mixtura ferri terræque; nesciò cujus incrustatam, quæ per annos* 1400. *non computruerat. Siquidem in multis canalibus, ac fistulis incisum erat Tiberii Nomen; Existimatumq; in ea Cineres illius Tyranni inclusos fuisse.*

Thus we have found at length the Bush where this Game is seated, and whence it is to be started if we will have it, and I have follow'd it by its scent and Foot-steps to its Seat; but in what part of the Volume of the Works of *Æneas Sylvius* it is to be found I cannot yet discover, for his Tracts are many and make a bulky Volume together, which, whether it contain all that he writ I am not yet well inform'd; for he wrote very many particular Tracts, and left some imperfect and not ready for the Press, as *Conrad Gesner* informs us. This was the Man that, in *August* 1458, was made Pope, and who died in *August* 1464, so that he possest the Chair six Year; within which time it seems both these discoveries were made, (if at least they were two differing Discoveries, for possibly they may be only two differing Relations of the same Discovery) the one noting one sort of Circumstances, and the other, another. I cannot so well judge of the matter, 'till I find this Relation of *Sylvius*; however, 'tis obvious that what *Riccioli* makes to be only twelve Cubits, Mr. *Witsen* makes twelve Fathom, which is four times as much; and possibly this twelve Fathom or seventy two Foot *Fulgosus* might make one hundred Cubits, and yet all of them innocently without a design of imposing on their Readers, they writing from the Relations of others, and possibly from the failing of their own Memory to boot; for we find how rare a thing it is to find out the truth of a Fact, tho' 'twas done but Yesterday and almost at next Door, if allowances are not made for the Circumstances of the Relators, and the defects of every one's Memory and Comprehension; upon which account it is that I could wish that Relation concerning the Elephant lately found in *Germany* and made by the Colledge of *Gothan* might be inserted into a Transaction as well as that of *Tentzelius*, that Men might see how much the Humour and Inclinations of the Relators will diversify the Relation, and confound the Apprehension and Judgment of the Reader; and therefore I conceive it would not be amiss also to add to this last account the Sentiments of this Society, or at least of some of their Members, concerning the Substances sent by *Tentzelius* to be perus'd and examin'd by them; for there is no better way, I conceive, in the World to give a satisfactory account to Posterity of this Fact than this Course; for there cannot be made a good History, either of things Natural or Artificial, without curious judicious and accurate Observations, and Pertinent and Critical Experiments, that may be as thoroughly examin'd and verify'd, as a Geometrical Proposition by Persons sufficiently accomplish'd for such a Task. 'Tis not one possibly of a hundred is fit for such a Business, and yet such are necessary, and hence I conceive it is, that we have such a multitude of medicinal Observations made or pretended to be made by young Physicians, and possibly not one of five Hundred of any manner of real

Vide Philos. Transact. No. 234, p. 757.

Use

Use or Benefit; for that the most of such Writers are two much biassed by precarious Hypotheses, and many likewise Compose and Publish them only for Interest, that is, as Advertisements to make themselves the more known, and so to get Practice; and tho' this or that Symptom may be true and matter of Fact, yet the true Cause of the Distemper, and the reason of the Cure or Miscarriage of the Patient possibly was really quite differing from those assign'd by them; and tho' some of them may have been truly describ'd, yet those that know how small and inconsiderable Circumstances in themselves will yet make great and most considerable alterations in the Effects, will be more cautious than to take them all for true which are in reality quite otherwise; those therefore that relate an Experiment or Observation, should be both very understanding in the Subject, and very diligent in taking notice of, and relating the Circumstances of it; for that all that can be done in this way will be little enough of information to him, that is to make use of it for making Deductions and Inferrences therefrom, and indeed it will be hazardous to build any thing upon Foundations so uncertain; for even in the most perfect Accounts of this Nature, a Writer or Applier of it for the founding or examining a Theory thereby will find a necessity of ocular inspection and examination proper and fitted to his present Subject, either to obviate some Objection, or to give some further Light; for oft times the most considerable part of the whole Experiment may lie in some one trivial Circumstance, which not one of a thousand would otherwise have thought worth taking notice of, yet to him that knows what that Circumstance is that makes for or against his Theory which he is inquiring into, will judge it very considerable, and be sure not to omit the Scrutiny and Test thereof; and 'tis preposterous for any one to write an Experimental Natural History without making and examining the Experiments needful to the perfecting thereof, without making the Experiments himself, nay, and without the repeating of them, as Doubts may arise after the first Trial, or as he may need further information upon them; nay, without making them whilst he is writing, that he may trust, as little as may be, to his own Memory and Judgment. Thus in Anatomical Experiments and Observations, how many considerable Discoveries do we owe to such repeated Trials omitted wholly, or scarce hinted at in many preceding; For every discovery gives a new set of Doubts and Inquiries, as well as a new Light, not only *οὐ κ᾽ τρὶς Sed etiam decies repetita placebunt*, as I have very often experimented my self; nay, I have found it absolutely necessary, and even that not enough to make some Spectator to apprehend the Consequences thereof: But this only by the bye. Before I leave this Subject I cannot but take notice of a Doubt that arises from the variety of these Relations, and that is, whether the Sheet Lead were used for the Sheathing of the outsides of the Ship under Water, or only for the Covering and Housing of the Deck, as the *Heer Witsen* makes it; nor know I how to solve it without seeing the Original Relation, only I must not omit one Passage of *Riccioli*, which seems to hint the use of Sheet Lead somewhat Analogous to Sheathing, and that is this, describing the Ship of *Hieron*, whose Architect was *Archimedes.----Dimedia Pars navis per* 300 *operarios sex mensibus absoluta, rimæ asserum laminis plumbeis tectæ*, &c. My doubt on this Passage is, whether the Vessel were Caulked and Pitched in the Joints of the Planks under the Sheet Lead, or whether the Plates of Lead were only made use of instead of Caulking and Pitching, the description is at large in *Athenæus*, which I have not by me, and he, it seems, had it from --------, who writ a whole Book of the Description of it: It was in this Ship where *Archimedes* made use of his admirable Invention of his helical Pump, which he himself hath no where describ'd.

The small number of Authors that have recorded so remarkable a Phænomenon as this, informs us how little curious the World have been in the matter of Philosophical History, and thence how vain a thing it is to expect to find every such accident as this to be Recorded, tho' very remarkable in its self; for if these Ships were differing, then they have each but one Original Historian; for all the other Authors that have since mention'd them, seem to have borrow'd the Accounts from these two; but if the Relations were

only of one and the same Vessel (as methinks the Circumstances of the time and the being sunk deep into the Earth seem to intimate) then we have but two Historians that take notice of so remarkable a Fact; and those so discordant in their Stories, that one knows not which of them to give Credit to; the one making it to be found in the *Lago de Nemi*, about twenty Miles from *Rome* towards the West; the other making it to be found near *Berne* in *Switzerland*, when 'tis not known that ever there was any Lake there, as *Fulgosus* mentions and Objects. It is therefore unreasonable to reject all Hypotheses that suppose other Accidents to have been the occasions of producing Petrify'd Substances, than those Recorded in History, especially if they happen'd before Printing was in use, or possibly Writing commonly known; for even since that time many considerable Phænomena have been very slightly hinted only, and scarce taken any notice of; as for instance, the Comet that appear'd in 1580, which produc'd but one diligent Observer and Historian, which was *Mich. Mastlin*, and the great Earthquakes and Catastrophies in *China*, which are Recorded in the *Mercurie Hollandois*, and no where else that I know: So 'tis probable this newly happening Earthquake at *Constantinople* would have been quickly forgotten, and probably never recorded to Posterity, if the *Gazett* and News Papers had not taken notice of it: But this only by the way.

As to this accident of the Ship, I conceive it to have afforded so many particular Informations worthy to have been Recorded, that I could wish it had happen'd in a more curious Age; at least I conceive it very desirable, that the Original History of it, such as it is, might be sifted out and inserted in a more proper place to be found, than where it is said to be at present.

The misfortune of Inventors.

The Memoires of the *Parisian Academy* have furnish'd many curious Discoveries both Mathematical and Physical, yet divers of them or of the same kind have been first discover'd in this Society, tho' not entertain'd with that approbation, which they have there met withal; nor are the *English* so nimble in Publishing what they discover themselves, nor so sharping to arrogate to themselves what they know to have been first discover'd by others; (as I do find divers to be) who will leave no means unattempted to make all their own, tho' there be never so evident Arguments against their Cause. But tho' this be a Practice to be abhor'd by every ingenious Man, and the bashfulness of the other be blameable, yet there is somewhat to be said both for the one and the other Party, that may seem to countenance these proceedings of them. As first, 'tis a discouragement to any one to Publish that which he finds by Discourse is generally disapproved. A Man may rationally enough distrust his own Thoughts and Reasons, nay, and even his Senses too, if he finds those he converses with to be of another Opinion, tho' acquainted with the Arguments that prevail'd with him, at least 'till he finds, that it was done for some Sinister Designs to defraud him of his Discovery. Next, when by publishing, more Opponents or Emulators (which are both Enemies) are produced, than approvers or indifferent Persons, who at best will do him no good; 'tis thought better to abstain with quietness, than with Labour and Industry, to create new Troubles. But on the other side 'tis certain, however, that ambitious Minds will try all means to obtain their Designs; they find that such Practises often prevail, and therefore *Quid tentare Nocebit*; they find that the generallity of Men are not much concern'd for the first Discoverer, and that they usually take him for such, who first acquainted them with it; and for one Reader that can disprove them, or detect them of Plagiary, there are a thousand that can not, and for those that can, they find ways to evade and by Confidence carry the point, and even with a general Approbation and Advantage: 'Tis, I confess, a general Observation, that seldom the first Inventer reaps either Honour or Advantage by his Invention, but on the contrary, those that come in at a second Hand acquire them both. But be it as it will, certain it is, that many Discoveries pretended to in the Works, of the *French Academy*, were first made here and elsewhere, nay, and many of them publish'd too in Print, and some of them also in the *French* Language, which yet they will not own, or mention to have seen. I shall instance but in two or three things: The First is that of *Torricellius* about

Several Matters mention'd by the French Academy were first found out here.

bout his Invention and Demonstration of the *Solidum Acutum Hyperbolicum*, which was Publish'd by him, together with his other Works at *Florence* in the Year 1644, and that without Contradiction by *Roberval* ever since; yet now a Letter is trumpt up, and some Papers found that must needs persuade us that *Torricellius* stole it from *Roberval*. The like slur is cast upon the Works of Mr. *James Gregory*; both which Persons have given sufficient Proofs by their other Works, that they had very little need of stealing from *Roberval*, who has not yet made it evident, nor any other for him, that he was Master of either of their Problems, 'till since the publication of them by the said Authors.

The Second is the discovery of the Glade of Light observable in the Evenings in *Febr.* and *March* each Year, which was first made by our Dr. *Childrey*, and an Advertisement of it Publish'd in his *Britannia Baconica*, in the Year 1660; which Book was Translated into *French*, and Publish'd at *Paris* soon after, which was long enough before it is pretended to be discover'd there. However, the second Person has the Title of the discovery, and the first is defrauded of his due Praise. I could add a hundred other Instances to prove this Assertion; but I shall not at present spend time thereon, tho' it may possibly not pass without some Reflections on another Occasion, that every one, as near as may be, may have his due Praise. For my own part, I think it ingenuous to mention any thing of theirs, which I have occasion to make use of, and to own all such things as theirs, as I find to be new or ingenious; and that First, Because I would give every one that which is due to him. But, Secondly, Because I find it necessary to back a Doctrine with a *French Approbation*. I know there are many things will not be regarded, 'till they have that Stamp to make them current, and then they will readily pass with the present Age and Humor.

A Remark out of the French Memoires.

In the Memoir of the 31st. of *June* 1692, (so 'tis marked) I find an Observation concerning a Petrify'd Substance produc'd and examin'd by the *Royal Academy*, with some Reflections on it made by Mr. *De la Hire*, which because consonant to some Discourses I have formerly made in this place, I thought might countenance somewhat the Doctrine I then deliver'd, I have also render'd the same in *English* before I make Reflections upon the same.

'The Cabinets (says he) of the curious are fill'd with all sorts of Bodies 'Petrify'd, as of Plants, Fruits, Woods, and of divers parts of Animals, 'but Naturalists are not yet agreed about the cause of their Production; some 'supposing them to be Stones so shaped by accident, but others suppose them 'produced by a Water that has a power of converting those several Sub-'stances into Stone, after it has long pickled them; probable Reasons are 'alledg'd for each Opinion.

'Mr. *L' Abbe de Louvoys* sent to the *Academy*; a Petrifaction, which may 'serve to decide this Controversy, namely, two peices of the Trunk of a 'Palm converted into Stone, they were brought from *Africa*, with two other 'pieces of a Palm just like them, but not Petrify'd, the better to compare 'them together; the Petrifactions are *true Flints*, as appears by their hard-'ness, by their Colour, and somewhat of Transparency, by their Sound, 'which is clear and sonorous, and by their Gravity, which is more than ten 'times that of the unpetrify'd; yet these two Flints are so like to the two 'pieces of Wood, that there is no shew of Reason to conceive, they should 'be so formed by chance.

'One of these Flints which is two Foot long, and about four or five Inches 'Diameter, is a piece of the Trunk of a Palm Barked of its Rind; in this 'may be seen all the Fibres of the Wood of the bigness of $\frac{1}{3}$ of a Line, some 'of which are forked; they run the length of the Trunk and are hollow like 'Pipes. The Pulp, which is between the Fibres, which serves to join them 'together, is chang'd into a kind of *Gluten*, but very hard.

'Mr. *De la Hire* gives a Reason of the hollowness of the Pipe, *i. e.* that 'the outward Parts being dry'd before the middle, when they are dry, they 'are by the outward Parts kept from shrinking, and so the Pipes become 'stretched from the Center outward *(which is the same Reason with that I have 'given for the blebbs that appear in the Glass drops.)*

Now,

'Now, tho' some might fancy (yet without the least probability) that this 'with straight Fibres might thus be formed by chance, yet 'tis impossible to 'conceive so of the other piece, which is a part of the bottom of the Trunk; 'for this is not only compos'd of streight Fibres as the other, but its Bark is 'all garnish'd with small Roots as big as one's little Finger, and about three 'Inches long, which is cover'd with a thin Skin, which contains an infinite of 'small Fibres like Hairs; in the middle of each of these Fibres is a ligneous 'Chord, that one may call its *Nuel* or Pith, about $\frac{1}{3}$ of the bigness of one's 'Finger, whose hollow was fill'd with a Pithy extended Substance. All which 'Parts are also exactly shaped in the Flint, where are visible not only the 'long streight Fibers, but the Roots and all the small Fibres of a blackish 'transparent Substance, but the Pith in the middle is of a whitish opaque 'Substance, and in the most of the small Roots it is hollow; which Mr. *De la* '*Hire* conceives to proceed from the same Cause that he before assigned.

'It is evident therefore (says the Author) that this was no *Lusus Naturæ*, 'but that these two Flints were originally two pieces of the Trunk of a Palm 'afterwards chang'd into the Substance of a Flint; and what *Father Duchatz* 'reports in his Physical and Mathematical Observations, doth decide the 'Controversy, and leaves it without doubt.

'This Father there says, that the River that passes by *Bakan* in the King-'dom of *Ava*, has, for the space of ten Leagues, or twenty eight Miles, 'the vertue of Petrifying Wood, and that he had seen great Trees Petrify'd 'thereby so high as the Surface of the Water reached, but that the other 'parts of them remained still dry Wood. He adds, that those Petrify'd 'Woods were as hard as the Flints of a Fire-lock; and such indeed was the 'hardness of the two pieces of which we have been speaking.

'This Account of *Duchatz* is to be found in the Second Volume of Obser-'vations made in the *Indies* by the *Jesuits*, sent thither by the King of *France*, 'but Corrected and Printed by the care of *P. Gouye*; I have not yet seen the 'Book, but by the Account of it I find in these Memoires, I conceive it will 'be well worth the procuring, as containing many other curious Observations, 'and Histories of Matter of Fact.

Remarks & Deductions from the former Account.

This Memoire of Monsieur *De la Hire is much the same with what I have formerly presented to this Honourable Society*, and have Printed among some other Observations made with *Microscopes*; wherein I examin'd the Shape, the Colour, the Hardness, the Weight, the Brittleness, the Incumbustibleness, the Solidity, *&c.* of it; for I found it to be for its appearance to the naked Eye, perfectly like a piece of Wood, and to have the visible Grain of Wood, and farther by a Microscope, I found it to have all the Microscopical Pores like Wood; I found it of the colour of Wood, but of the hardness of a Flint, and that it would cut Glass: I found its Weight to be to Water as $3\frac{1}{4}$, which seems to be much the same with this of Mr. *De la Hire*; only he compares its weight to that of the Palm Wood, which, by his description, must be much lighter than Water, and mine was only comparative to Water. I found it incumbustible in the Fire, tho' dissolvable by corrosive Liquors. I found it Brittle and Friable like a Flint, and to feel cold to the touch, as a Stone, or Mineral Body usually doth; from all which I concluded it to have, at first, been a piece of Wood, and afterwards, by some Petrifying Water or Vapour, converted into the Substance of a Stone or Flint. And I find that from the very same Arguments, the *French Academy* draw the same Conclusions as to this Substance, and they confirm it by the Observation of *P. Duchatz*; this therefore passing there for a good Argument, I see no reason why it may not also be a good Argument here, and why the same will not also pass for the Petrifactions of other Bodies both Vegetable, as Leaves, Fruits, Roots, and also Animal, as Shells, Bones, Teeth, Scales, *&c.* which are found to have the same Qualifications, that is, the Shapes, Colours, Textures, *&c.* of those animate Substances, nay, and often times the very Bodies themselves not Petrify'd, tho' included in Petrify'd Bodies, as Stones or Minerals; must these be questioned or rejected, only because such Substances are found in places where we cannot give particular Histories of their pristine Estate, and how they come to be there placed and transformed, or so inclosed; or because

possibly

possibly we are not able to produce patterns of Creatures now at hand, and in being, which are exactly of the same Shape and Magnitude as the Academy did produce, to Authorize, or at least incline them to be of that Sentiment; certainly the same Argument that is cogent for the one, ought not to be less valid for the other; for if the finding of Coines, Medals, Urnes, and other Monuments of famous Persons, or Towns, or Utensils, be admitted for unquestionable Proofs, that such Persons or things have, in former Times, had a being, certainly those Petrifactions may be allowed to be of equal Validity and Evidence, that there have been formerly such Vegetables or Animals. These are truly Authentick Antiquity not to be counterfeited, the Stamps, and Impressions, and Characters of Nature that are beyond the Reach and Power of Humane Wit and Invention, and are true universal Characters legible to all rational Men.

Now, if these are such (as to me they seem to be, notwithstanding I cannot tell the time when, or the certain History how, they came to be there disposed and ordered as they are now found) then certainly it cannot be irrational to conclude at least, that there have been some precedent means that have produced these Effects; and that those means have been such, as we have from Histories and Relations within the times of our own Memory, Experience and Information, that they have produced much the like, which tho' they are not exactly the same, nor possibly by much so great and powerful as they must necessarily be granted, that did effect those we now discover; yet I think it not unreasonable to conceive, that there may have been much greater and more powerful Agents than those we now have had; yet still of the same kind, and acted by the same Powers; for if there are now newly such as have raised, removed, cleft and torn Mountains, have made Lakes, fill'd and levelled Plains, stopped and turned Rivers, spouted out Sea-water at a great distance from the Sea; raised the Sea-shore above the Surface of the Sea and left it dry, with the Fish, and the remainders of them to cover the Surface of it; at other places to raise the bottom of the Sea, which was many Fathoms under Water, and place it above the Surface, and many such other wonderful Effects; then certainly it cannot be unreasonable to suppose, that there may have been much greater in former Times, whilst the matter was yet unconsumed and dispers'd up and down in more places, and more Copiously, and that more Powerful and Effective.

But it is Objected by some, That for such Persons, Places, or Things, of which we find now the Relicks; we have Histories that tell us what, who, and when they were; whereas for the other we have no such Histories in being, nor during the times whereof we have any Histories, can we find any parallel Instances that can countenance such Mutations, Changes, and Catastrophies as are, and must be supposed to solve the Phænomena. *Greece*, *Ægyt*, *Italy*, *Spain* and *France* have continued the same; no new Lands have been raised out of the Sea, much less Hills or Mountains. Besides, there are many of those Bodies that we now find, both Animal and Vegetable Substances, that are as perfectly like the Species of those supposed Creatures now in being; and therefore we are not to suppose, that any Species could be utterly destroyed, which yet that Supposition seems to make necessary, if well consider'd, and the Consequences thereof produced.

To which I Answer, First, That tho' we have no true History, when, or by whom, or by what means the *Pyramids* of *Ægypt* were built; yet all that have seen them do conclude that they were built by Men, and that those Men were good Masons and Architects and Engineers; and that they were not produced of that Shape or Magnitude, by a *Vegetative Power*, or by a *Plastick Faculty*, *or by meer chance*, *or the accidental concurrence of Petrifactive Atoms*. Nor can I see any reason to conclude, that the vast *Obelisks* that have been transported from place to place, and erected, were so ordered by Conjureing or Diabolical Magick, tho' I may not be able to tell by what means they become so ordered; I should rather be inclin'd to believe that they were so made and placed by the Industry, and Invention, of some knowing and ingenious Mechanick, who had some Contrivances to perform his undertaking that I am ignorant of. Nor do we make it an Argument that these

Pyramids were never made by Men, because no History does tell us when the like have been made since. Besides, I conceive it would have been a very absurd Conclusion, if any one should have asserted that those Horns, I lately mention'd here, were a *Lusus Naturæ*, and not the parts of any living Animal, because he could not tell of what Creature they were; or if he should have concluded that the Species of the Creature that produced them were lost, because he knew not where to find it. Certainly there are many *Species* of Nature that we have never seen, and there may have been also many such *Species* in former Ages of the World that may not be in being at present, and many variations of those *Species* now, which may not have had a Being in former Times: We see what variety of *Species*, variety of Soils and Climates, and other Circumstantial Accidents do produce; and a *Species* transplanted and habituated to a new Soil, doth seem to be of another kind, tho' possibly it might return again to its first Constitution, if restored to its first former Soil.

The Conclusion. But I say again, that we have, since the times wherein Histories have been Written, many Instances of the like Changes and Catastrophies, as I have suppos'd to be the necessary Consequences of this Theory of Petrifaction, and several so lately, that the sound of them is hardly out of our Ears; so that we need not be beholding to antient Historians, to tell us when and where they have actually been produced; for first there is no place in the Earth that we do know, nor can we indeed know any such, that is now and ever has been exempt and free from such Mutations, as I have supposed; who can tell what part of it hath ever been and ever will be exempt and free from Earthquakes? And tho' Histories should inform us that during the times of which they writ, there had been no such Crisis of Nature (which yet would be a very improbable Assertion as being a Negative) yet it were impossible to be assured by them, that there had never been any before that time, nor never would be for the future.

And, Secondly, There is no impossibility in the Supposition that every part hath, at some time or other, been shaken, overturned, or some way or other subject to Earthquakes, and transformed by them; and when we consider how great a part of the preceding Time has been *adelon*, or unknown, and unrecorded, one may easily believe that many Changes may have happened to the Earth, of which we can have no written History or Accounts. And to me it seems very absurd to conclude, that from the beginning things have continued in the same state that we now find them, since we find every thing to change and vary in our own remembrance; certainly 'tis a vain thing to make Experiments and collect Observations, if when we have them, we may not make use of them; if we must not believe our Senses, if we may not judge of things by Trials and sensible Proofs, if we may not be allowed to take notice of and to make necessary Consectaries and Corollaries, but must remain tied up to the Opinions we have received from others, and disbelieve every thing, tho' never so rational, if our received Histories doth not confirm them; this will be truly *Jurare in verba Magistri*, and we should have no more to do but to learn what they have thought fit to leave us: But this is contrary to the *Nullius in verba* of this Society, and I hope that sensible Evidence and Reason may at length prevail against Prejudice, and that *Libertas Philosophandi* may at last produce a true and real Philosophy.

This was read in the Royal Society *July* the 25*th.* 1694.

LECTURES

LECTURES

CONCERNING

Navigation and Aſtronomy.

Several Lectures relating to the improvement of NAVIGATION, *read in the Year* 1683.

IN theſe the Author at firſt gives an account of his Deſign, viz. *to treat of the Theorical part, two things neceſſary to be known,* viz. 1ſt. *The Situation of places, in reſpect to each other, and the diſtance between them.* 2dly. *The ſafeſt and neareſt Courſe to be kept to attain the Port deſired. Sea Charts falſe. The uſe of Journals. Of the ſituation of the places. Of the Figure of the Earth. Of an Antient Learned Age. Arguments for the Round and Oval Figure of the Earth: An Objection againſt the Oval Figure anſwered. The Earth pretty nearly of a Spherical Figure. Of the Meaſure of a Degree by the Antients and Moderns; that they differ. Of an univerſal Standard for Meaſure. The Pendulum propo'd, with Objections againſt that way. A Degree propoſed for a Standard. The uſe of an univerſal Standard. That the Earth ſhrinks. The ways of meaſuring a Degree.* 1ſt. *The Aſtronomical ways. Methods to find the Latitude. The inconvenience of Refraction. Stars near the* Zenith *beſt for this end.* 2dly. *The Geographical or Mechanical ways of meaſuring a Degree. The uſe of the Inflective property of the Air. A way to diſcover a Ships diſtance off at Sea. Of the ways yet known of diſcovering the place of a Ship on the Sea.* 1. *Celeſtial.* 2. *Geographical. Of the true notion of the Horizon. Whence the Looming of the Sea. A Propoſal for a Natural Univerſal Standard for Meaſure.*

R. W.

NAVIGATION is a paſſing from place to place upon the Sea, by the help of ſome Veſſel; ſo that to *Navigation*, the firſt thing neceſſary is the Veſſel or Engine to Float or Swim upon the Water, to the end that it may be moved to the Place, and by the way we deſign. *What Navigation is.*

For this there are requiſite two helps; Firſt, Somewhat to move it: And, Secondly, Somewhat to guide or direct that Motion; in the ſupply of which two in all particulars to the beſt advantage, conſiſts the Art of *Navigation.*

Of the firſt of the Three, namely, of the *Ship*, or of the Form, Structure, or Make of the Veſſel, much more may be ſaid and done than has been hitherto, but I ſhall ſay nothing at this time, it being a particular Mechanical Art, and ſo more proper for another Occaſion, where I may have Reaſon to treat more largely and more particularly of it. Nor ſhall I at all meddle now with the Second Head, namely, concerning the ways of giving Motion to the Veſſel, which may be by various means performed, either by Animate or Inanimate Movers; but the moſt commonly uſed are either Sails by the help of the Wind, or Oares, by the ſtrength of Men. Tho' there may be other Ways and Means (much more Advantageous and Commodious than what are at preſent) made uſe of for the ſame purpoſe, as poſſibly I may afterwards manifeſt.

The

The principal Matter I here design to treat of, is concerning the Third thing requisite to the Art of *Navigation*, and that is the way of guiding or directing a Ship or Vessel, so as to pass from Place to Place, or from Port to Port the nearest, surest, safest, and speediest way: In doing of which I shall not meddle with the Mechanical Part, or the Business of the Mariner or Steers-man, or he that guides and moves the Rudder to Kun or Steer the Ship in this or that Course or Rumb, that being more properly taught and learnt at Sea by Practice; but shall confine my self only to the *Theorical* part, which is proper to the *Pilot* or *Master*, who directs the Steers-man, what Course to take, and which way to Steer the Vessel.

The Author's chief design in this Treatise, viz. The Theorical part.

Things necessary to be known in this part of *Navigation* are principally two; First, The true Situation of places in respect of one another, and of the interjacent Seas, both as to the *Longitude* and *Latitude*, and thence the *Rumb* and *Distance*.

Two things to be known.

And, Secondly, The safest and nearest Course (all things considered) that is to be kept for attaining the desired Port; for the most direct Course and shortest distance is not always the best way, but that way which is safest, that has the best and surest helps of Winds and Currents, is least endangered by Rocks, Shoals and Storms.

For both those in part, but for the first wholly we must at present be beholding to the Discovery and Observations that have been made by diligent and inquisitive Navigators, and other Artists, who have been assistant to the making and rectifying our Maps and Charts, which tho' they may labour under many Errors and Imperfections, yet 'tis to be hoped that the Industry of ingenious and skillful Artists may much amend and rectify those Failings, and reduce the Descriptions to a much greater certainty and exactness; and in time give us such Maps, as may be a true Picture or Representation of the Surface of the Earth and Sea, which is the first principal thing. I need not instance in the great Errors that are to be found in our present Maps, nor in the Discrepancy they have one with another; since none that has been any way conversant in them can be ignorant thereof: However such as they are we must be content to make use of them, 'till by the collected Observations of some that have already communicated their Knowledge, and others that may for the future labour in this Work, there be a compleater set of Mapps and Charts Graved and Published a-new for the Benefit of Mankind. For the doing of which I could suggest many things that would very much improve their usefulness, both as to *Geography*, and *Hydrography*, or *Navigation*; of which I shall say more hereafter upon another occasion.

Errors in the present Sea Chartes.

Secondly, The other part is partly Theorical, and party Historical.

The Historical Part consists in the Relations of Voyages that have been or are now made to any known Part, wherein we may find an account of what Course they have hitherto observed to be the best to be kept from place to place, what Seasons of the Year, what Currents are to be met with, and at what times; what Winds blow at certain Places and Seasons, what safe and convenient Harbours lie in the way for Victualling, Watering, Careening, and the like: What Sands, Rocks, Shoals, *&c.* are to be avoided; what variation they have found of the Compass at this or that part of their Course, or Ports they have touched at, and at what times they were observed because of the continual Variation of the Variation; what signs they have of ensuing Storms, and what methods they have used to secure themselves; and many other of the like Nature----. And it were much to be desired that the Journals and Observations of all Navigators were in some certain place retained and preserved, that Recourse might thereto be had for extracting and methodizing all such Observations into a compleat History of such particular Voyages, and for the compleating a general Theory. For tho' many considerable things are known to divers skillful Navigators to those parts, partly from their own Observations, and partly from the informations they have had from others, yet a very great number of Observations and Methods, that have been formerly and lately known and observed by divers others, have been lost and forgotten, and are not now to be found. And to speak o Artists now living, 'tis to be feared that even those things which they them-

The use of Journals

se-

ſelves know, when they Die, will be loſt, and others that ſhall follow them, will be fain to begin upon a new ſcore with their own Obſervations; ſeveral of thoſe may poſſibly be handed from one to another by Diſcourſe and oral Tradition; but that at beſt muſt needs be very imperfect, ſince we find that Men themſelves forget in a little time their own Obſervations, and this or that particular Circumſtance will ſlip out of their Memory, eſpecially in matters of number; and certainly there could be no better way to preſerve them for future Uſe, than by treaſuring them up in ſome one certain place, where they might be ſafely preſerved: And it were as much for the obſervers Intereſt ſo to do, ſince it would put him upon obſerving as well as upon writing his Obſervations, and 'twould prompt him to recollect things taken notice of, whilſt the impreſſions of them are yet freſh in his Memory, by which means he would not only fix them more laſtingly in his own Memory; but it would be an occaſion to him of making his Obſervations much more certain and determinate, and of minding many other conſiderable Circumſtances, which he would otherwiſe not at all have regarded; as any one that makes trial will eaſily be convinced of; this therefore, we hope, Time may produce.

The Theorical Part, which is that I aim principally to Diſcourſe of, is a knowledge or Art, by which Directions are obtained for Guiding and Steering a Veſſel from any one place to any other, whereof we have the Situation given and all the material Circumſtances, that have been taken notice of to be uſually met with in Voyages made to thoſe Parts; for 'tis with Voyages at Sea oftentimes as it is in Journies upon the Land, that the fartheſt way about is oft times the neareſt way thither: The cauſe of which, in Sea Voyages, is to be aſcribed either to the Winds or to the Currents and Tides; of which I ſhall ſay more hereafter. And tho' the general Theory would direct you to Sail or Steer by the ſhorteſt and ſtraighteſt way through the open and free Sea from one place to another, yet the intervening of theſe and ſome other Circumſtances do make you take a very differing Courſe, and go ſometimes this way, and ſometimes that way, for the better attaining your end. As when they Sail to the *Barbadoes*, they do not Steer on the direct Rumb that leads thither, but Sail a-way more towards the South, that they may get into the Trade or Eaſterly Winds, which may carry them from thence more directly and ſpeedily towards their Port; whereas in the direct Rumb they meet with Calms or contrary Winds and Currents, which would take up much more Time, and cauſe much greater inconvenience; 'tis plain therefore, that both theſe parts are neceſſary, *viz.* Firſt, True Charts of the Situation of Places: And, Secondly, A true Hiſtory of the Conveniences and Inconveniences of paſſing by this or that Courſe. *The Theorical part.*

For the firſt of theſe, namely, for the knowing of the true Situation of Places to one another, it is requiſite to underſtand, Firſt, the Figure of the Body of the Earth: And, Secondly, The Magnitude. Concerning the Figure of the Earth; there have been very many, and thoſe very differing Opinions among the ancient Philoſophers, but whether their Opinions are truly related to us, or whether they had any Grounds or Reaſons for thoſe Opinions we are uncertain, becauſe little is ſaid concerning them. *Anaximander* is ſaid to have ſuppoſed it like a Column; tho' yet conſidering his skill in Aſtronomy, 'tis hardly to be believed. *Leucippus* like a Cylinder or Drum. *Cleanthes* like a top or double Cone, whoſe Points were at the Poles, as ſome ſay; but others, that he ſuppoſed it like a Diſh, hollowed in the middle, but riſing towards the Edges, that the Sea might not run over, of which Opinion *Heraclitus* is alſo ſaid to be. *Anaximenes* and *Empedocles* are ſaid to have ſuppoſed it like a round Table, or a round Plain, being the top, as it were, of a mighty Cylinder or Column, for the bottom of which they aſſigned no bounds; of which *Ariſtotle* in his Book *De Cælo*, and *Plutarch De Placitis Philoſophorum* give an account. Of this Opinion are moſt Men who are ignorant in Aſtronomy and Geography, and that becauſe the viſible appearance, they always have of the Earth, is a very large Plain covered with the Heavens as with a Hemiſphere, and becauſe the Land was always bounded by the Sea, and that the Limits or Bounds of that Sea was not known, it was ſuppoſed *For knowing the Situation of places.* *Of the Terraqueous Figure, the Opinions of the Antients.*

that the Sea was bounded by the hollow Hemisphere of Heaven, and thence that the Sun, Moon and Stars that Rose and Set, did rise out of the Sea, and set or descend again into the Sea, which was the occasion and ground of those Expressions and Fables of the antient Poets; and even to this day ignorant People, that have been no better informed, are from the same Cause, as I have already mention'd of the same Opinion; for this cause also it was, that some were of Opinion, that τὸ πᾶν, or the whole of the World was Water, and that there was a kind of Arch or Firmament of Heaven, which kept off the Waters that were above this Arch from coming to the Waters which were beneath the Arch, upon which the Earth floated, as it were a Dish; and that beneath the Earth that kept up the Waters above, was the space, wherein the Air and Meteors were placed-----. This also was much countenanced by the visible appearances both of the Earth and the Heavens, and so needs not much of Arguments to make it pass with the Vulgar and Illiterate, and such as have not been used to consider and reason about these Matters. Hence comes it, that even to this Day, we may every where find People who retain as absurd Imaginations, and who still look upon Antipodes as impossible Fictions, and the Product only of the Authority of Seamen and Travellers to tell strange things; nor has it been only the Opinion of the Vulgar and Illiterate, but even of many otherwise very Learned and Excellent Men, such as were several Fathers of the Church, who, from their want of this sort of Knowledge, and from their misunderstanding some Texts of the Scripture, have zealously opposed the Opinion of the roundness of the Earth and of Antipodes.

Parmenides, among the Antients, is said by *Diogenes Laertius*, to be the first that ever asserted the Earth to be a round Ball or Globe, and seated in the middle of the World, and the first, that set out or limited the habitable Parts of the World, and bounded them by the Frozen *Zone* on the one side, and the Torrid or Burning *Zone* one the other side, as is related of him by *Plutarch* in his Treatise *De placitis Philosophorum*: This Man flourished in the sixty nineth *Olympiad*, that is, about five Hundred Years before *Christ*. But tho' this Person were an extraordinary Philosopher and great discoverer of Nature, and so might possibly receive this Opinion, yet we find by the fore-mentioned Book of *Plutarch*, that this Opinion is ascribed to *Thales*, who lived above a Hundred Years sooner; and if we had not been defective in the History of antient Times, without doubt we should have been informed that Astronomy and the Theory of the World, revived by *Copernicus*, was, long before *Thales*, well known, and if so, then the roundness of the Body of the Earth could not be a thing unknown to so learned an Age; of which learned Age, beyond all the Histories now to be met with, *Hugo Grotius* has given us a Collection of Testimonies.

of an antient learned Age.

Simplicius in his Notes upon *Aristotle*, mentions, that *Calisthenes* (who upon the taking of *Babylon* was presented by *Aristotle* to *Alexander* the Great) had several very antient Writings of Astronomers very long before that time, namely, of 1903 Years, which, according to the common Account, must fall about threescore Years after the Flood, and consequently, if Astronomy were so early so well known, the Figure of the Earth could not be unknown; for whatever strange Opinions some of the Philosophers might have, who had only contemplated some of the lesser Bodies and Productions of Nature which were within their reach, yet most certainly those that were skillful in Astronomy could not be ignorant of its Form, which we may plainly enough prove from their assigning the Eclipses of the Moon to be from the shadow of the Earth; but especially if the System of *Aristarchus* were so very antient, wherein the Earth is supposed a Planet.

Of the Sphærical Figurr of the Earth.

But to omit any further mention of the Opinions or Theories of the Antients concerning the Figure of the Earth, it is now supposed or granted by all Philosophers, Astronomers, and Geographers, that the Figure of the Body of the Earth is Globular, or every way equally round, or of a Sphærical Figure, and accordingly the Model of it is commonly made of that Figure, a Globe, and the Parts or places of it are set down and described upon the Superficies of a perfect Globe, and so the distances from place to place are computed

computed as upon such a Sphærical or bending Surface; and many Arguments are commonly brought to prove this Opinion, which, because they are to be met with in almost every Geographical Writer, I shall pass by at present; some only I would here take notice of, that tho' it be so generally assented to, and concluded by all, yet I conceive there is no one positive and undeniable Proof to evince it against some I have lately met with, who would have it to be somewhat of an Oval or Egg-like Figure, the Axis of its motion being supposed the longest Diameter; or of another, who supposes it may be of an Oval Figure the contrary way, and that the longest Diameter of it is the Æquinoctial, and the shortest the Axis; the reason of the first was alledged to be, for that the Sun does exhale and draw up into the Air from the parts of the *Torrid Zone* a great quantity of Water and other volatile Materials from it into the Air, and drive them towards the two Polar Parts, where they again præcipitate and falldown in Rain, Snows, Hails, *&c.* and so turn to Ice, and so raise the parts thereof towards the Pole, and diminish the parts about the *Torrid Zone*: But the Answer to this Argument is very easy, that if the Water be most raised within the *Torrid Zone* and rain'd down again in the Frigid, then it would follow, that there must be a continual passage of Water from the Frigid towards the Torrid, and possibly it must carry more parts along with it in its return towards the Æquinoctial in the Form of Water, than from the *Torrid Zone* back to the Frigid in the form of Air: This therefore will be a better Argument for the second Hypothesis than for the first, but 'tis judged no positive and certain Argument for either, since what it carries back towards the Æquinoctial, serves only to fill up the Caverns in the bottom of the Sea: The Argument alledged for the second Opinion, was, that the Globe of the Earth being whirled round upon its Axis, the parts near the Æquinoctial have less Gravity than the Parts near the Poles; but tho' this be more significant than the former, yet it may be said that the Body of the Sun, tho' it be moved upon its Axis as well as the Body of the Earth, yet the Figure thereof, as far as we can discover by the Telescope, is still perfectly round. Now the proportion of the Diameter of the Sun to the Diameter of the Earth being greater than the period of the Sun's Revolution to the Period of the Earth's; it follows that the parts of the Sun move swifter than the respective parts of the Body of the Earth. Now, tho' it be alledged that the Body of *Mercury* passing through the Body of the Sun in the last Conjunction observed by Monsieur *Gallet*, was by him said to appear of this Figure, yet no such appearance was taken notice of by others that observed the same; and if it had, 'tis not yet known whether *Mercury* be moved round upon its Axis or not, and therefore no certain conclusion can thence be deduced. But as neither of these Assertions is sufficiently proved, so I must needs say that the absolute roundness of the Ball of the Earth does yet want a positive Proof; for no one of the Arguments or Experiments, yet brought to prove that Figure, are sufficiently exact and positive to prove it; for tho' they do most of them prove it to have a Figure which is near a round, yet they do not prove it absolutely; for First, It cannot certainly enough be discovered by the Eclipses of the Moon; for the shadow may be somewhat Elliptical either way, and yet the appearances not sufficient to determine the difference; for we find that no Observation hitherto made doth exactly agree with any Calculation yet made; and to what to ascribe the difference is not hitherto agreed. Next, none of the measures of a Degree, tho' some of them, as particularly that of the *French* lately Published by the *Royal Academy*, are made with great exactness, for each of them only shew what measure was found of a Degree of the Meridian in that Latitude; but they differ enough one from another to shew that no two of them compared together will be sufficient for this purpose. Further, tho' two of them should pretty near agree, as that of Mr. *Norwood* here in *England*, and that of Mr. *Picart*, yet to make them significant for this purpose, the same examinations should have been made Eastward and Westwards, to see whether the Parallels would have answered to the respective Latitudes; and therefore if these Proofs be not sufficient, much less will the Observation of Seamen, whose computations of Leagues sailed, are by no means accurate enough to determine this matter,

Of the Oval Figure thereof.

What the Author mentions here of the Oval Figure, is more largely treated of and demonstrated Page 355. Supra.

ter; for there may be a considerable difference, and yet they unable to detect it.

Objection against the Elliptical Figure.

Against this the most material Objection is, that if the Body of the Earth should be Elliptical, as there is some probability that it is so, not with the longest Diameter in the Axis, which would make it of an Egg form, but with the longest Diameter, in the plain of the Æquinoctial, which would make it of a Turnep or Bowl Form, and that because the Rotation thereof must necessarily make the parts of the Earth, which are carried the swiftest with that motion, have an indeavour outwards, or from the Axis of Rotation, as we find in all Bodies moved with such a motion; which indeavour must necessarily take off from the Gavitation of those Bodies towards the Center, and thence if the power of Gravitation be every ways from the Center equally forcing towards the Center, the parts of the Earth towards the Æquinoctial must have less Gravity than the parts of the Earth that are nearer the Poles; and consequently there must be a longer Cone or Cylinder near the Æquinoctial to counterpoise a shorter near the Poles, and consequently to keep the Water of the Sea in a Counterpoise, there must be a rising of the Sea above the Sphærical Surface near the Æquinoctial, and a depression of the Sea below that Sphærical Surface near the Poles, which makes it of this Turnep or Bowl shape.

From the pointing of the Perpendicular.

Against this, I say, the greatest Objection is this, either the Perpendicular doth point directly to the Center of the Earth, or it doth not: If it be asserted that it points directly to the Center of the Earth, then the Surface or the visible Horizon would discover such a variation from perfect Sphæricalness by an obliquity of its plain to the Plumb Line, which then would not be Perpendicular to it.

Answered.

To which I Answer, that this Obliquity being but little, it would not easily be discovered by reason of the Refraction of the Air near the Horizon, yet if it really be so, I grant it may with great care be found, if a place convenient for such an Observation, and the Experiment be purposely and with great care made, as at some promontory of Land running Eastward or Westward into the Sea, where the Surface of the Sea or the Horizon thereof may be seen both to the North and to the South. But this I do not find has ever yet been observed as it ought to be, and therefore there may be such an appearance, and yet not hitherto detected. But, Secondly, If it be asserted that if the Plumb-Line do not point to the Center, then this would be discovered by the different account of Leagues sailed East and West, from the Leagues sailed North and South, to answer to a Degree, or by the differing length of a Degree in differing Latitudes; to which I Answer, that I do confess that there would be really such a difference, but yet I say no Observation hitherto made could detect it; there are wanting therefore many Observations necessary for the verifying and positively demonstrating this Question, which, tho' it has scare been ever yet mentioned by any Writer, yet I judge it may be well worth the while to have it exactly tried and examined; for tho' it hath been generally believed and asserted, that the Figure of the Earth is exactly Sphærical or Globular, yet I assert that there is not one, that I have ever yet met with, that has proved or demonstrated it so to be; and to me it seems very probable from some Physical Considerations, that it may be considerably otherwise; of which I have discoursed much more largely on another Subject, wherein I have shewn the necessary Consequences, and the several Proprieties thereof, which are much differing from the Notions hitherto commonly received.

Accurate Observations are yet wanting.

The Earth pretty nearly of a Sphærical Figure.

However probable it is, that 'tis pretty near the Sphærical Figure, and therefore, 'till it be some ways found to be otherwise, the computation of distances may be so made as if it had been positively proved so to be, and the measures of distances made accordingly; which brings me to the second necessary to be known, and that is the true Magnitude of the Body of the Earth compared to the common known measures, as that of a Foot, Pace, Fathom, Stadium, Mile, League, or the like.

The measure of a Degree attempted by several of the Antients and Moderns.

For this then we have an account of very many Experiments and Trials that have been made both heretofore, and of later Days; but if we compare them together, one would be apt to imagine, either that they were very imperfectly made, or else that we are very ignorant of their several particular measures,

measures, or else that there may be a real difference of the measure of a Degree taken at several Latitudes of the Earth; for *Aristotle* makes it 1111 Stadia, *Eratosthenes* 700, *Possidonius* 666, and *Ptolomy* 500, and the *Arabians* yet less; but in truth we know not what ways they took for exactness, nor what measure any of them made use of compared with those in use at present among us; and therefore it will be much less difficult not to err our selves, than to know whether the Antients err'd or no.

If we consider the Modern Experiments for this purpose, we may find that Mr. *Norwood* in the Year 1635, did find the Meridian Altitude of the Sun on the eleventh of *June* to be 59, 33′; and that two Years before that, *viz.* on the eleventh of *June* 1633, he had found the Meridian Altitude of the Sun at *London* 62° 01′, whence he concludes (not making any allowance for declination, Refraction, or Parallax) that *York* was more *North* than *London* 2. 28. Now by measuring the distance by Chains of ninty nine Foot long, or six Rod of 16½ to a Rod, he found it to be 9149 Chains, or 905751 Feet; whence he concludes in a Degree there are 367196 or 367200 Feet, which is sixty nine Miles and an half and 236 Feet, whence there will be 6120 Feet in one Minute or a gradual Mile, which is 840 Foot more than our Statute Mile which is 5280 Foot.

The last Experiment that has been made for determining this measure, is that of Monsieur *Picart*, and the Gentlemen of the *Royal Academy of Paris*, who with great exactness of Instruments and great Skill and Care in performing, examin'd the measure of a Degree and found the same to be 57060 Toises or Fathoms of the Castle of *Paris*, each Fathom or Toise containing six Parisian Feet, and thence a Degree contains 342360 Parisian Feet; and the Parisian Foot being to that of *London* as 16 to 15, a Degree will contain 365184 *English* Feet, or 69 Miles and 864 Feet; which is almost $\frac{1}{6}$ part of a Mile, a sixth part of a Mile being 880 Feet, so that by this Account a Degree is less than what Mr. *Norwood* makes it by 2012 Feet, and consequently a Minute or gradual Mile will contain 6086⅔ Feet, which is longer than a Statute Mile 806⅔ Foot, which is almost a Sixth, *viz.* 880. Now having the measure of one Degree, it will be easy to find the measure of the Circumference of the whole Earth, there being 360 such Degrees in a great Circle of it. 360 times 365184 gives 131566240 Feet in the Circumference of the Earth, or 24915 Miles and 504 Feet.

These two last Mensurations are less than that which was made by the *Arabians* about the Year of our Lord 827 by several skilful Mathematicians at the command of *Almaiman* an *Arabian* Prince, in the Plains of *Mesopotamia*, they finding a measure of a Degree, which, reduced to our *English* Measure, amounted to 370222 Feet; so that That of Mr. *Norwood* is less by 3022 Feet, and that of Mr. *Picart* 5038; so that *Norwood* is less by about 1/20 part of a Degree, or about half a Minute, and *Picart* is less by a 72½ part of a Degree, or almost an *English* Mile.

To what their Discrepancy may be ascrib'd and of the difference of measures.

What to ascribe the Reason of these differences one from another to, is pretty hard to say, but most probably it is partly the differing method each of them took, and partly also the uncertainty of the comparative Magnitude of the measures they each of them made use of; for to go no farther back than Mr. *Norwood*, we are not well assured but that the Foot he made use of was less than the Foot we now make use of by 181½ part by which he differs from *Picart*, which is about half a Centesm; for the Standard Foot we now use was since that time agreed upon by a Club of our Mathematical Instrument-makers, of whom Mr. *Elias Allen* was the chief; we will not now mention any other cause, tho' possibly there may be another more considerable than either But not to trouble our selves with what the measure of a Degree has been, 'tis only necessary for our present Enquiry to know what really it is now, reduced to a known and certain and invariable measure, in which all Nations may agree; for 'till that be done, our measuring the Course at Sea by the Logline is false and leads into great Errors and Mistakes; for if with the Logline we measure a League, or the 60th part of a Degree, and account it to hold but 15840 Foot, or 2640 Fathom, and it really contains 18259⅓ Feet, or 3043 Fathoms, then the Course measured by such an erroneous measure must needs very much confound our reckoning

The Logline at present leads into errors.

Of an universal Standard for measure.

It will be necessary therefore in the first place to rectify our measure and the length of our Line.

1st. The Pendulum propos'd for that end.

Many have been the attempts and designs both of Antient and Moderns to perform this necessary *Præcognitum* to Geography and Mechanicks, but to this Day it remains a thing to be sought after. The last and best way hitherto thought of is, that by the length of a *Pendulum* vibrating Seconds of Time measured by the Sun's middle motion in the Ecliptick, reduced to the Æquinoctial or right a ascensum, which, for ought I know, was first invented by the *Royal Society*, tho' it has been since published by Monsieur *Hugens*, Monsieur *Picart*, and divers others. Or which were yet more easy to be found and more certain, by reason that the Sun's true *Anomaly* is not yet ascertained by the length of a *Pendulum* vibrating a Second of Time, by the diurnal Revolution of some notable fixt Star; because, in all probability, that is always equal and the same at any time of the Year, and in any Year, either past or to come. And tho' the ingenious *Kepler* has from his Hypothesis of the turbinating Power of Light supposed that the turbinating or diurnal Motion of the Earth upon its Axis is accelerated and retarded in that diurnal Rotation, according as it moves nearer to, or further off from the Sun; yet there is no one certain and positive Experiment or Observation yet brought to prove any such inequality; and from another Hypothesis which I have of the causes of that motion, which is very differing from that of *Kepler*, I suppose there can be none such, and therefore 'till by some certain Observation, it be found to be otherwise, we may, with great Reason, suppose it to be at all times of the Year, the same; so that if a *Pendulum* be made of such a length as to make 86400 single vibrations in the time that any fixt Star passes from the Meridian, 'till it return to the same the next Night, that length may be taken for a perpetual measure of length or a Standard Yard, to which all other measures of Length, Breadth, Solidity, Capacity, Weight, or Power, may be reduc'd; and $\frac{1}{3}$ of that may be taken for the universal Foot, and two of those for an universal Fathom, and five of those may make a Rod or Pole; or which were yet better, to divide this length into ten, for Decimals or Hands, and each of those into Decimals which may be called Digits or Fingers, and each of these into Decimals which may be called Threads, and each of these into Decimals which may be called Clews or Hairs, and so onward by Decimal-subdivision, to continue downwards, so as you have occasion, of a smaller or smaller measure, which may be call'd Tenths, Hundreds, Thousands, ten Thousands, hundred Thousands, *&c.* and for greater measures to compute only by the number of such Yards, Arms, or Paces.

The length of a Pendulum vibrating Seconds.

Monsieur *Hugens* has determined the length of a *Pendulum* vibrating Seconds by the Sun, to be three Foot $8\frac{1}{6}$ Lines of the *Parisian* measure, accounting the Limits of his measure so taken, to be from the Center of Suspension, to the Center of Oscillation or Vibration, which is a Point to be found by a proportion which he assigns, depending on the length of the Diameter of the Ball to the length of the String by which it is suspended.

The Toise or Fathom of the Observations of *Paris*, which Monsieur *Picart* made use of for the measure of a Degree, was, according to the last establishment at *Paris*, compared with the Standard of the length of a *Pendulum* vibrating Seconds of Time conformable to the mean motion of the Sun.

The Toise contains six Parisian Feet, and the Parisian Foot to the *London* Foot is in proportion as 16 to 15.----Each of these Parisian Feet is divided into Duodecimals or Inches, and each Inch into Duodecimals or Lines.

Now, by many trials, he found the length of such a *Pendulum* to be thirty six Inches, and eight Lines and an half.

The *Pendulum* he used, as he himself declares, was made of a Ball of Copper of one Inch in Diameter exactly turned, and the first String, he used to suspend it by, was of a flat Silk. The length of the *Pendulum* he reckons to be from the Center of Motion to the Center of the Ball, omitting the part proportional taken notice of by Monsieur *Hugens*, the Ball being but a thirty sixth part of the length of the Thread; otherwise if the Ball be bigger, the proportional part must be taken notice of as making a considerable variation, the Vibrations

ons also observ'd were very short, otherwise there would have been a considerable variation in their Duration or Time; but afterwards finding that the Silk was apt to shrink and stretch by the least drineſs and moisture of the Air, it was found much better for that purpose to make use of a flake of Silk Grass, which is a sort of long and very fine Flax brought out of *America*, which is very flexible and yet very strong, and not subject to shrink or stretch. The upper end of this Flake was put between the Chops of a small Vice which held it very firm when pinched by the Screw, and the length was measured by a small Rod of Iron made exactly of the length of the String, when the Ball hung Perpendicular between the Head of the said Vice and the Ball.

This *Pendulum* was adjusted by two large *Pendulum-Clocks*, whose *Pendulum* had been by trials adjusted to move Second-Minutes by the mean motion of the Sun, and which were found slower by three Minutes and fifty six Seconds, at every return of the same Star to the Meridian; and that to such an exactness, that they differed not one from another, one single Second during many Days; the single *Pendulum* was so suspended and put into motion, that it vibrated the same way as the *Pendulum* of the Clock; and if it were of 36 Inches eight and an half Lines, it continued its Vibrations the same with those of the Clock, but if it were never so little either longer or shorter than that measure, it became, in less than an Hours time, sensibly differing; however he acknowledged that this length was not always found so precise, but that it seemed it ought to have been a little shortned in Winter and lengthned in Summer; but that, he conceives, ought to have been but the tenth part of a Line, and the excess on both sides being pretty near equal, he therefore made choice of the length of 36 Inches, eight and an half Lines, as the medium or middle length between that of the Summer and that of the Winter.

Now, if this were made the general Standard for the measures of all Countries, or that there particular measures, whatever they be, were reduced to this, then the knowing the proportion they bear to the Standard would manifest the proportions they have to one another, and so the measures given of a Degree in one place, by the measures of that Country might easily be reduced to the measures of any other; and so Experiments truly made might be as accurately examin'd and compar'd together.

But against this way of finding a natural, universal, and perpetual Standard measure of length there may be divers Objections not inconsiderable; as, First, That if the Gravitating Power of the Earth be greater in one place than in the other, as towards the Poles more than towards the Æquator, then the length of a *Pendulum* to vibrate Seconds, must also be considerably longer towards the Poles than towards the Æquinoctial, otherwise the *Pendulum* of the same length with what is determin'd in *France*, which is about the middle between the North Pole and the Æquinoctial, will go too quick near the Poles, and too slow near the Æquinoctial. Now, what I many Years since discover'd in this place, reading about Penduls for Longitude, and what I have now before mention'd concerning a probability, if not a necessity of such an inequality of Gravitation, and consequently of a Boul-like form of the Earth, does at least hint that some Experiment of that kind ought to be try'd at some place near the Æquator, to see whether it be so or not, and 'till that be done there can be no certain Conclusion made thereupon. *Objections against this Standard.*

Next, 'tis not impossible but that the Gravity or attractive Power of the Earth may be at some times greater than at others; for we see that there is hardly any thing in Nature that stands at a certain stay, but does sometimes increase and sometimes diminish; and if so, then that Iron Rod, that is the exact measure of the length of the String of the *Pendulum* this Year, will be differing from the length of the same, which was three or four Years since, and may be three or four Years hence; this therefore ought to be first examin'd by Experience, before any certain Conclusion can be made thereupon. *Gravity may differ in the same place.*

Thirdly, It is not yet certainly known but that the Gravitating Power of the Earth may be different at various Seasons of the Year, as when the Earth is in its *Apholion* and *Perihelion*; for which possibly there may be a plausible Reason assign'd; and if so, it will then be necessary to mention at what time *And at different Seasons.*

of

of the Year the measure is taken; for if the gravitating Power should be found to be lesser when the Earth is in its *Perihelion* in our Winter, than when in its *Aphelion* in the Summer, then the *Pendulum* must be accordingly proportion'd to the time of the Year.

Fourthly, If the Rotation or Diurnal Motion of the Earth should be accelerated in its *Perihelion* in our Winter, and retarded in its *Aphelion* in our Summer, as the ingenious *Kepler* supposes, and seems to assert from Experiments, then the quite contrary will follow, and the *Pendulum* must be shorter for the Winter than for the Summer; which will be necessary to be prov'd by trials, before any thing can be built thereupon.

Fifthly, If both these two last mention'd Effects are produc'd, and that they keep in some proportion one to another, then a *Pendulum* of the same length may serve at all Seasons of the Year; but if either exceed the other in that proportion, then must the length of the *Pendulum* be accordingly lengthen'd or shortn'd.

Sixthly, If the differing Density of the Air have an influence upon the Motion and Velocity of the *Pendulum* made in it, as most certainly it has, and that a Body in a dense Air moves not so quick, *Cæteris paribus*, as in a rarify'd Air, then the *Pendulum* must be shorten'd in the Winter, and lengthen'd in the Summer; and so the same measure will not last round the Year.

Seventhly, If the *Pendulum* be made of a Brass, Silver, or Iron Rod, then the length of the same Rod will be greater in Summer than in Winter, and consequently the space measur'd therewith will be found shorter in Summer than in Winter; for those and the other Metals, when hot, will have larger Dimensions than when cold, and so cannot make an exact Standard for the measure of length.

Eighthly, If the *Pendulum* be made with twisted Threads, then the Threads will be found to be longer in dry Weather than in moist, and so 'twill be necessary to take an account of the Seasons when the Experiments are made, and to reduce to exactness the limits of such shrinking and stretching.

I could mention divers other Objections against this way, tho' notwithstanding I conceive it to be the best and easiest that has been yet Publish'd; and with finding out the true limitations to all those Qualifications, it may possibly prove the best for use.

A Degree propos'd for an universal Standard.

There have been others who have thought the best way for the making an universal Standard for the measuring of length, to be the finding the exact length of a Degree upon the Earth; and to do that by most exactly determining two places upon the Earth that are both in the same *Meridian*, and differ from each other exactly one Degree of Latitude, observ'd by a very large and curious Instrument; which places being so found out, their true distance is to be exactly measur'd and found some one certain measure; then this length, to be divided into sixty equal Parts, which may be called Geographical Miles or Minutes, and each sixtieth part being subdivided into a thousand parts, may denote Geographical Paces, and each thousanth part, being again subdivided into five parts, may denote a Geographical Foot, and each of these fifth parts being again subdivided into twelve, may denote Geographical Inches; and these again subdivided into twelve parts, may denote Geographical Lines; and so subdividing onward by Duodecimals the least sensible length may be determin'd in proportion to the Circumference or Diameter of the Earth.

Objections against this way

But against this way of making a Standard for the measure of length there may be these things Objected; First, The great difficulty that there will be, First, To determine exactly by Astronomical Observation two such places to the certainty of five Hundred Foot. Secondly, In measuring their true distance.

Secondly, If the Body of the Earth be not exactly Sphærical, then the measure of a Degree, taken in one Latitude, will be differing from what it is in another, and so it must be determin'd, First, By trials exactly made in differing Latitudes, whether any such difference be or not, before any Conclusion can be made thereupon.

Thirdly,

Thirdly, 'Tis not improbable but that the Body of the Earth itself may shrink and grow closer together, and so grow lesser, that the Gravity thereof does continually press the parts thereof harder, and possibly closer together; and so 'tis possible the irregular Surface of the Earth may have been, in part, caus'd by the puckering of the Cortical Parts thereof; and if so, then the measures, this way found, will every Age grow shorter and shorter; which, possibly, may have been the Reason why the measures of a Degree, which have been taken in several Ages, have always been found shorter and shorter, the later they have been taken, as I before-mention'd.

Fourthly, The same Objections do lie about the shrinking and swelling of the last Substance that preserves the Standard, as in the former way. I could instance in some other Objections, but that I conceive these will be sufficient to shew the difficulty of procuring such a measure.

I have been more particular upon this Inquiry, for that this seems to be the very *Basis* and Foundation of Geography and Navigation; and, 'till this be well determin'd, all the Superstructure will be but infirm.

The use of an universal Standard for measure.

June 21. 1683. I did the last Day explain to you the necessity there was of a certain and determinate Measure or Standard of length; that might be so, not only to all the World at present, but that it be and remain to all Posterity for the future; that so, by means of that, all things that could be reduc'd to a certain Weight, Measure, Capacity, Power, *&c.* might, by that means, be compar'd, First, To that common Standard-measure, and afterwards one with another; because without such a natural and perpetual Standard, neither could the present quantities of things be compar'd with those of preceding Ages, nor indeed one with another at present; nor could future Ages have the true Use and Benefit in this Particular of the Obversations and Inventions of this present; for to instance in no other Particular at present, I shew'd you how every one of the measures of the Earth taken by any of the Antients differ'd both one from another, and all of them from the measures now last of all found; and how those quantities, which they took of a Degree, thereby seem'd to have diminish'd ever since the first that was taken this way. So that it doth necessarily follow, either that the Standard-measure, made use of by them, did continually increase or grow bigger, the longer it remain'd in the World, or that the very Body of the Earth itself, did really, from time to time, as it grew older and older, shrink into less and less Dimensions, much after the same way as we find divers animated Bodies, as Plants and Animals, upon growing old, really to do; whence, as I hinted, the Mountains and Vallies, and the like inequalities of the Earth's Surface might seem to be nothing else but the wrinkles and puckering of the Skin of the old *Vesta*. There is no impossibility nor absurdity in either of these Solutions or Suppositions. Nor will I determine or prepossess any with a positive assertion of my Opinion, which is the most likely; only this I may say, that there seems a kind of necessity to admit either the one or the other, if at least we will give any credit to the truth of the Relations, or to the certainty and exactness of their Observations (for it may lie also in either of those) but that seems not so probable; for my part I am inclin'd to believe that the Body of the Earth doth really shrink and grow less, by reason that the Gravity of the Earth doth seem to press and ram the parts thereof continually closer and closer together, and for that it seemeth not so natural to conceive that the common measure should continually grow bigger and bigger, especially, since it is believ'd rather that the size of Men grows less and less, and consequently it seems less probable, that the Foot, Fathom, Pace, and the like, which are deduc'd from the size of Mens Feet, fathoming and going, should grow bigger; but be that what it will, it seems at least to shew the great Use and Conveniency of a natural, universal, and perpetual Standard of length: I have already mention'd two ways that have been thought of and attempted for the making this universal Standard, and those were; First, The length of a single free *Pendulum* vibrating Seconds of Time.

That the Earth shrinks.

Secondly, The length of one Thouſanth part of a Minute or Mile found upon the Earth by accurate Aſtronomical and Geometrical Menſuration to be for a Geometrical Pace, and a fifth part of that for a Foot.

I told you alſo what Objections there lay both againſt the one and the other way, and I ſhew'd you alſo how thoſe uncertainties might be aſcertain'd, and the difficulties remov'd; but neither of them could be perfectly regulated and aſcertain'd without a great deal of Care, Pains and Skill, which yet (for all accurate Obſervations) is neceſſary to be done. I could have ſhew'd ſome other ways of making a univerſal, natural and perpetual Meaſure; but for the purpoſe of Geography and Navigation, theſe poſſibly, when rectify'd as they ought, may prove the beſt. I explain'd the laſt time how one of thoſe meaſures might be found or made by Obſervation; I ſhall now a little more particularly diſcourſe of the ſecond way, namely, That, by the true length of a Degree upon the level Surface of the Earth, found by accurate Obſervations. Now there are many ways to find out and determine the Magnitude of a Degree that are mention'd by Authors, and there may be many more; but they may be all reduc'd to two general Heads.

The ways of meaſuring a Degree.

Firſt, Such as require ſome Cæleſtial Obſervations to determine the Degree, or other certain part of a great Circle imagin'd upon the Surface of the Earth.

And, Secondly, Such as only require Obſervations made upon the Earth to determine the ſame. The Firſt, for brevity's ſake, may be call'd the Aſtronomical; the Second Geographical.

The Aſtronomical ways.

The Aſtronomical ways are two, *viz.* Firſt, The finding the difference of Latitude between two places lying due North and South of each other, or under the ſame Meridian, by accurate Obſervations of ſome Cæleſtial Bodies, whether Sun or Stars.

And the Second, The finding the ſaid difference of Latitude between two places lying in ſome other Poſition to each other, whoſe true Poſitions are known, and not in or very near the Eaſt and Weſt of each other, and ſo finding the proportional length of the part of the Azymuthal Circle, then finding by exact Menſuration upon the Earth, or otherwiſe with ſome known meaſure, the true diſtance between them in a ſtraight Line.

To find the Latitude of a place.

The Aſtronomical Obſervations neceſſary for the finding the true *Latitude* of any place may be either made in the Day or in the Night; by the Sun whoſe Altitude, Azymuth and Declination for any time of the Day being known, the *Latitude* may eaſily be found, but the beſt of all Azimuths is the true South and Meridian: For that Firſt, The labour of Calculation to reduce it to the Meridian is ſav'd: But, Secondly, Becauſe the Body of the Sun is there mov'd with a horizontal or level motion, and ſo does not ſo ſuddainly change its Altitude, but remain ſenſibly the ſame for ſome time. Thirdly, Becauſe the Body of the Sun is there moſt remov'd from the Horizon, and ſo will there have the leaſt Refraction, which, in this Caſe is very conſiderable, and muſt be avoided as far as may be. In the Night the Latitude of a Place may be found by the obſervation of the Altitude of any one known Star, whoſe Azymuth and Declination is known; but here alſo the beſt Poſition of any ſuch Star for this purpoſe is, when it is in the Meridian, and if it paſs the Meridian both Northwards and Southwards, the Zenith; the beſt is that to the Southwards; and of all Stars for this purpoſe, thoſe are beſt for ſuch Obſervations as paſs the neareſt the Zenith of the place. (Becauſe, as I ſhew'd before, the great incumbrance of all Aſtronomical Obſervations is thereby remov'd, namely, Refraction.) Now, the Refractions are always ſo much the greater, the nearer the Body obſerv'd is to the Horizon, but the nearer the Zenith the leſs; but the quantity of proportions of ſuch Refractions is not ſo certainly found, becauſe, neither is the Refraction the ſame at all places, nor the ſame at one and the ſame place at differing Seaſons of the Year, nor in differing times of the Day and Night,

Stars near the Zenith beſt for this purpoſe.

tho'

tho' the Sun or Star be in both those times in the same Altitude, and is not yet reduc'd to any certain Rule or Calculation: And therefore the best way of all, is that which doth wholly avoid that Inconvenience, which is the way that I above twenty Years since, for this very end and intention, explain'd to the *Royal Society*, and which, about fourteen Years since, I made use of in making my Observations for the finding the parallax of the Orb of the Earth among the fix'd Stars, which had hardly been possible any other way, especially to avoid all manner of Doubt or Objection; and that was the Observation of some Star which pass'd very near the Zenith of the place; where in a very clear Night there is no Refraction at all; and this was the way which Monsieur *Picart*, and the Gentlemen of the Royal *Academy* of *France*, have, since that time, made use of in their Observation for the finding the difference of Latitude between *Paris* and *Amiens*, which, upon this account, is much more accurate than any of the other ways which before that time had been taken by any, either of the Antients or Moderns who had made this Observation: For tho' I confess we do not certainly know what ways some of the Antients made use of, yet by considering of the ways they might make use of, we may with probability enough conceive, that it was not this way, by observing the Stars in the Zenith, especially since we do not find that they had any notion of Refraction at all, and therefore 'twas not very probable that they should provide against it, the notion or invention of Refraction being not much before *Ticho Brahe*, and he seems to be the first that reduc'd it to Rule; for tho' *Ptolomy* and some of the Antients did take some notice of the alterations of the Air, and of some alterations they caus'd in the appearances of Cælestial Bodies through them, yet it seem'd to be no more than this, That they conceiv'd that the grosser Air and Vapours near the Horizon did cause the Cælestial Bodies to appear greater near the Horizon than near the Zenith, which was a mistake likewise; for neither does the Refraction of the Air any ways cause such an appearance, but rather the contrary; nor is there indeed really any such appearance, if it be more curiously inquir'd into, it being only Optical, and rising from the imaginary greater distance of the Sun and Moon near the Horizon, where the known distances upon the Earth can be compar'd with them; for otherwise the Bodies of the Sun and Moon would appear less, as is very evident in the vertical *Diameter*, which is sometime a quarter less than it ought to be, as any one that will examine the Rising or Setting Sun, will plainly perceive, by the help of a Telescope fitted with a Micrometer. Again, The Refraction of the Air elevating the two extream Points of the Horizontal Diameter pretty near perpendicularly in the two Vertical Circles that pass through those Points; and all those Vertical Circles meeting in the Zenith, it follows, that the greater the Refraction of the Atmosphere is, the shorter will appear the Horizontal Diameter of the Sun or Moon, nor was this Propriety, whether known or not, made use of by any before *Ticho Brahe*, tho' ever since that time it hath been acknowledg'd and verify'd by all Astronomers, and yet 'tis not agreed upon, what the Proportions of it are; but a sort of randum Numbers are set down, of which the true ground is not assign'd, that I know, any where; and possibly the thing itself in strictness may be almost impossible, being uncertain even in itself, and being in a continual state of change.

Refraction does not make Bodies to appear bigger near the Horizon.

I need not, I suppose, mention the way how to come by the Latitude of a place where the Declination, Altitude and Azymuth is given, that being common and easily enough known. Nor shall I need to mention any other difficulties in this Astronomical way, but rather proceed to the second way how to find two places in any Position whatsoever, which are distant from each other a Degree of a great Circle of the Earth, or any other less assignable part without making any Observation of any Cælestial Body; which is that which I call the Geographical or Mechanical way.

This Mechanical or Geographical Probleme then may, by various Means and Instruments, be perform'd according to the particular way that is made use of for effecting thereof; the thing that is to be found being the inclination of the Perpendiculars of two distinct places one to another. This, as I told you, was most certainly found by finding where those Perpendiculars pointed

The Geographical way of measuring a Degree.

in

in the Heavens, by seeing how far the Zenith of the place was distant from this or that Star which pass'd the Meridian, the Zenith of the place being the continuation or upper end of the Perpendicular or Plumb-line of the place. This also may be found by Calculation from the height of the Sun or fix'd Stars taken in any known Azymuth. But the Geographical ways are by the level Lines of any two distant places, which level Lines are Lines at right Angles, to the Perpendiculars of those places; and in this way the Query is to find what Angle the two level-Lines make with one another, or with the Perpendiculars of the distant places. This way, were the Ray of Vision from place to place a true straight Line, might, by convenient Instruments, be made the easiest and the most exact; and it were possible this way to determine the quantity of a Degree even to a single Third, which would come within two Foot by measure, according to the quantity of a Degree collected from the best Observations which have yet been made. So that could the Mensuration of the distance be made as exact as the Observation of the level Line, or the certainty of the magnitude of the Body of the Earth, or of the quantity of a Degree, it might be adjusted to all imaginable exactness; and since there are some places upon the Earth which may be seen more than a Degree, nay, more than two Degrees distant, it were possible to determine it within one single Foot: For, First, By means of the level of Water, an Instrument to take the level Line may be made of any length desir'd, so as to be able to distinguish Thirds of a Degree; and since by the help of Telescopes, which may be made and easily used in a Horizontal Posture almost to any length, the sight can distinguish the parts of the Object to as great a certainty, there need to be no deficiency in the exactness of such Observations, were the Rays of Vision true right Lines. And by the same means of long Telescope Sights, the distances between such two Stations might as accurately be measur'd, as I shall mention by and by. There are various ways of performing it this way, mention'd in several Authors, but I think none more plain and easy than these I shall instance in.

As, First, From a very high Cliff adjoining to the Sea, the Altitude of the same above the level of the Sea being exactly measur'd, the Angle that the Perpendicular makes with the visual Ray, that touches the Horizon of the Sea, must be exactly observ'd; or else the Angle that the visual Ray makes with the Horiozantal or level Line; for in both those Cases the Effect or Consequence is the same; for the level Line being at right Angles with the Perpendicular of the aforesaid Angles so found, must be the complement of the other to a right Angle. As for instance, let CD represent the Surface of the Sea, A the Center of the Earth, BC the Cliff, the height of whose highest Point B above the level of the Sea is exactly known by measure, the Angle ABD is found by the Plumb-line BC, and the Telescope BG directed at the Horizon of the Sea D, or the complement thereof the Angle FBG is found by the level EF, and Telescope BG, having therefore the Angle ABD by Observation, the complement there of ABD is likewise given and in the same manner, if FBG be given by Observation, BAD equal to it is also given. Now by the common Tables of Secants you may from the length of BC and the Angle DBF or DAB easily deduce the Diameter of the Earth; for as the difference between the Radius and the Secant of the Angle at A is to the Radius, so is the height of the Cliff BC, to the Semidiameter of the Earth. I could have instanc'd in several other ways of finding the Diameter of the Earth from the knowledge of these two, of which *Cassati* in his *Terra Machinis Mota*, gives a great many, some of them complicated enough, but I mention this as being the most facile and simple way that can be thought upon, there being hardly any difficulty at all, either in the Instruments necessary either for the observing the Angle, or of measuring the height above the level of the Sea, or in computing the Consequence when the Experiment is made, or of finding the Meridian Line or Azymuth or Distance or Latitude, Longitude, or the like; which are necessary to be observ'd in other ways, and that with great accurateness, I thought the best to mention. So that one would imagine there could not possibly be any other way to equalize it for this purpose.

Table IX. *Fig.* 4.

But

But what I mention'd to you heretofore to be the incumbrance and perplexity of all Astronomical Observations, *viz.* the Refraction, or rather Inflection of the Air, is abundantly more considerable, and perplexing here insomuch that how plausible soever this may seem, yet this inconvenience interferring makes it almost wholly impossible: For the Rays of Vision which run as Tangents to the Surface of the Sea, are by the Refractiveness or rather Inflectiveness of the vaporous Air near the Horizon rais'd much higher than they ought to be, if they proceeded in direct Lines from the Eye or Sight of the Instrument at the top of the Cliff to the Horizontal Point D of the Surface: Which Refraction or Inflection, were it also certain, might, by some trials, be remedied and reduced to a Rule, but that being so extreamly uncertain, and various, and differing almost with every blast of Wind, and every several Degree of Heat and Cold, Drineſs, or Moisture, Gravity, or Levity of the Air, the Effects thereby produc'd are so various and uncertain, that 'tis impossible to reduce them to any certain Rule. *The inconveniences of this and the like ways from Refraction.*

However, for variety, I shall mention a second Geographical way which may be made use of for this purpose, *viz.* from two very high Hills which are very far remov'd from each other, as suppose 60, 80, 100, or more Miles, which yet are so situated, as that by means of a great Plain between, or else of an interjacent Sea, they are visible each to other, whereof there are many instances to be found in the World, and even in *England*, *Scotland*, and *Wales*. Let the inclination of the common visual Ray between them be exactly observ'd with the Perpendiculars or level Lines of both those Places, and thence deduce the true inclinations of the two Perpendiculars, or the two level Lines of those places to one another, whereby you will certainly have the quantity of the Angle of the Perpendiculars at the Center of the Earth, or the quantity of the Arch of a great Circle of the Earth that is interjacent between those places; then if the distance be over a Plain upon the Land by measuring the interjacent Space by Chains, Rods, Wheels, or Triangles of observation made from place to place, you will obtain the distance between those Stations, and consequently the Magnitude or Semidiameter of the Globe of the Earth. Or if the space interjacent be over the Sea, then by measuring a certain length of Ground at right Angles with the visual Ray, if it may be upon either of the said Hills, which is visible from the other of those Hills, and by exact Observation finding all the Angles of such a Triangle, you will easily and very exactly, and much truer than by any Mensuration made between them, obtain the same thing as the other way, namely, the true distance between them, and consequently the Magnitude or Semidiameter of the Globe of the Earth; for instance, in the Figure, let B and C represent the tops of two very high Hills distant from each other, by compute about threescore common *English* Miles, which are notwithstanding by means of a large Vale or Sea between them, visible to each other. By Instruments as before, find at B the Angle ABC of the Perpendicular AB with the visual Ray BC, and by Observations at C find the said inclination of the Perpendicular AC, and visual Ray CB, namely the Angle ACB; then either by an actual Mensuration of the Space or Distance BC, or by Triangles of Observation in *Snellius* his way, or else by measuring a certain length, as BD on the top of one of the Hills, as B, whose extreams B a D are visible to each other, and to the Point C of the other Hill, find any two of the Angles at B C and D, and from thence find the side BC, and having before all the Angles A, B, and C, you will easily find the Sides AB and AC which are the distances of those places from the Center of the Earth, and if the space interjacent be Sea, you will easily obtain the side AE, which is the Semidiameter of the Globe, or Sphærical Surface of the Sea, and consequently the true length of a Degree of a great Circle on the Sea, which, for Navigation, is the principal thing sought, and thence also collaterally may easily be found the several heights of those Hills B and C above that level, and the like. But this way, as the former, is also incumbr'd with the Refraction, or rather Inflection of the Air; so that the Line BC is not really a straight Line, but a crooked or bended Line, and so those places B and C are visible to each other much farther than they really could be, were there no inflection in the Air, *A second Geographical way.* *Table IX. Fig. 5.* *This way has its inconveniences.*

Air, but that the Ray that touch'd the Sea interjacent, did always proceed straight.

Micrography. p. 217.

We need not therefore trouble our selves either with those, or with any other of the like ways, tho' there are divers to be found dispers'd here and there in Authors, and more of that kind might be thought of, but they will be all in vain, since the Refraction or Inflection of the Ray near the Horizon, upon the exact observation of which so much is built, do so confound the truth of the Angle, that since great things are to be calculated from little, 'twill be in vain to think of coming at any possible certainty by the ways of Observation. Now, that this is not *Gratis dictum*, besides what I my self have observ'd, and Publish'd at large in the Year 1664, let me acquaint you with what the *French* have lately taken notice of in their way of trying by a Level: They observ'd then, that an Object which at break of Day appear'd in the Horizon, or Level-line, or a little above it, a little after Sun-rising appear'd below it; and the same appearance they found in the Evening, for the Object before Sun-set appear'd below the Level, which soon after Sun-set would appear in it or above it; insomuch, that in half an Hour's time the difference has been observ'd to be no less than three Minutes, which must needs cause a very great Error in the computation of the Magnitude of a Degree, and consequently the Magnitude of the Earth; for if there be three or four Miles Error in the space of less than a quarter of a Degree, it will amount to an Error of a fifth or sixth part of a Degree in a whole Degree, and so a vast Error in the Compass of the Earth. The cause of which appearances they conceive to be the Cold of the Night condensing the Vapours, and so making them to descend towards the Earth, leaving the higher parts of the Air more pure, thin and serene, which makes an Inflection of the Ray which is to pass obliquely through Media of such differing density, and so the Refraction or Inflection is the less. But yet, even then the Ray doth not pass without a considerable Refraction or Inflection; for which they give us Experiments of two Observations both made at Noon Day, by which the same Persons not only found therewas a Refraction, but that there was a considerable difference between one Day and another Day at Noon as to their Refractions. To this purpose in the Summer time, at Noon, in a clear Day, they observ'd the Tower of *Montlehery* from the top of the Tower of *Nostre Dame* at *Paris*, and found the Foot of the said Tower of *Montlehery* to appear exactly in the Level or Horizontal Line; but some Days after, at Noon also, observing the top of *Nostre Dame* Tower from the Foot of the Tower of *Montlehery*, they found it to be 11'. 30". below the level; but comparing the measur'd distance of those two places, and examining from the measure of a Degree, found the other way nameless by the Perpendicular Stars, they found that the Angle ought to have been 13'. 30". which is two whole Minutes difference in the distance of 81894 *English* Feet, or about fifteen Miles and an half; by which we may plainly see what exactness is to be expected from any Mensuration of the Earth that should be this way made; and therefore there can be no more certain way of determining the Magnitude of the Earth by measure, than the way I first of all propos'd, and that was by observing the Stars near the Zenith.

The cause of this Inflection.

The Use and Benefit of Refraction or Inflection.

Now, tho' this inflective quality of the Air be a great incumbrance and confusion of Astronomical Observations made both at Sea and Land, yet is it not without some considerable benefit to Navigation; and indeed in some cases the benefit thereby attain'd is much greater than would be the benefit of of having the Ray proceed in an exact straight Line. I shall not need to instance in the Observation made by the *Hollanders* that wintered upon *Nova Zembla*, who, by means hereof, found that the Night in that place shortned no less than a whole Month, which must needs be a very great Comfort to all such places as lie very far towards the North or South Poles, where the length of the Night, and want of seeing the Sun, cannot chuse but be very tedious and irksome. But then it may be said, that this benefit is only to a very small part of the World, and that the most inconsiderable and least frequented of all, by reason of the extreamity of the Cold, and want of other necessary accommodations for the use of Man. But yet we find that some of those Northern Parts have, of late Years, been frequented by Navigation

not

not without very conſiderable benefit and advantage in the returns, and may, in time, be very much more, when the Induſtry and Skill of future Undertakers ſhall diſcover Paſſages that way to the *Indies* or South Sea, which for ſeveral Reaſons, I conceive, may in time be effected, and with very great advantage frequented: But this only by the bye. The great advantage I conſider therein, is the firſt diſcovery of Land upon the Sea; for by means hereof the tops of Hills and high Lands are raiſed up into the Air ſo as to be diſcoverable ſeveral Leagues farther off on the Sea than they would be, were there no ſuch Refraction; which is of great benefit to Navigators for ſteering their Courſe in the Night when they approach near Land, and likewiſe for directing them in the Day-time much more certainly than the moſt exact Cæleſtial Obſervations could do by the help of an uninflected Ray, eſpecially in ſuch places as they have no ſoundings.

To diſcover a Ships diſtance at Sea.

And I doubt not but that by ſome Obſervations carefully made, the Inflections of the Air may be reduc'd to exactneſs enough, for ſeveral ſorts of Terreſtrial Obſervations which may be of great uſe in the practice of Navigation, tho' I very much doubt whether it will ever be exact enough for determining the meaſure of a Degree, and conſequently that of the Earth; the uſe that I chiefly intend of this diſcovery may be for determining the diſtance of a Ship at Sea by means hereof from a Land ſo raiſed: The way how I conceive this may be effected is thus. Firſt, The deſcent of the true Level-line below the apparent Level-line, for ſeveral diſtances, muſt be known by Calculation, the true Level being a Circular Line upon a Sphærical Superficies of the Earth, and the apparent Level-line being a tangent Line, it will be eaſy enough from the knowledge of the Earths Semidiameter to find this Deſcent.

Now the Semidiameter of the Earth from the moſt accurate Obſervations that have been yet made being $20923500\frac{4}{5}$ Feet, or $3962\frac{3}{4}$ Miles, and 180 Feet of 5280, which is our Statute *Engliſh* Mile, it will follow that the true Level-line will be eaſily found by the help of a Table of Secants; the Deſcent below the Horizontal Line for any determinate diſtance being always to the Semidiameter of the Earth, as the exceſs of the Secant of the diſtance above the Radius is to the Radius. But becauſe this Statute Mile is of no uſe in Navigation, Navigation always accounting the ſixtieth part of a Degree to be a Mile, and three of thoſe Miles to be a League, it will be neceſſary to reduce the Mile, we account by, to the meaſure of a Degree found, accounting it to be a full ſixtieth part of the length thereof which is found, and accordingly ought to be the Meaſures and Diviſions of the Log-line. Now, by the aforeſaid Obſervations there being no leſs than 365184 *Engliſh* Feet in a whole Degree, there will be $6086\frac{4}{10}$ Feet in a ſixtieth part thereof, and therefore the meaſure of every ſuch Mile ought to be accounted 1014 Fathom two Foot and $\frac{4}{10}$, and conſequently a League will be 18259, or 18260 Feet, or 3043 Fathom and two Foot; the Deſcent then for ſuch Leagues will be as follows, for one ſuch League, 7, 976688 Feet, or to make uſe of round numbers eight Feet, at two Leagues diſtance thirty two Foot, at three Leagues ſeventy two Foot, at four Leagues one hundred and thirty Foot; or if you will reckon by Minute Miles, then the deſcent of one Mile is $10\frac{2}{3}$ Inches almoſt, at two Miles will be three Foot and an half, at three Miles eight Foot, at four Miles fourteen Feet, or thereabout; at five twenty two Foot and an half, at ſix Miles thirty two Foot, at ſeven Miles forty four Foot, at eight Miles fifty ſix Foot, at nine Miles ſeventy two Foot. Now the uſe that may be made of this knowledge I conceive to be this, that when a Land is approach'd by aſcending the Shore or Maſt with a ſmall Perſpective Glaſs, 'till the Surf of the Sea upon the Shore be diſcover'd by knowing the height of the Eye, that ſo diſcovers it from the Surface of the Water by the Ship, a much nearer and truer compute of the diſtance thereof can be made than by any other way yet practis'd: But this only here by the bye, becauſe hereafter when I come to ſpeak of that Subject, I ſhall mention ſeveral other feaſable ways of doing it. I here only mention it upon the account of the Refractiveneſs of the Air, which tho' it ſpoil the accuracy of Obſervations for the meaſure of a Degree, yet in ſuch Obſervations as theſe it may ſerve well enough, at leaſt 'till better and more accurate be made uſe of.

Of reduceing the meaſure of a Mile.

Theſe

These two Fundamentals concerning the true Figure and Shape of the Earth, and likewise of its Magnitude being acquir'd, it remains in the next place to find out some means to distinguish every Point or Part of the Surface of this Globular Body in respect of any other; we are therefore to inquire what helps are to be found that are useful for this purpose: For upon the Surface of a perfect Sphærical Body, there is no one point but has the very same Respect to the whole Surface thereof, that any other Point hath; as suppose the Sphærical Body were of Chrystal or Glass perfectly Polish'd and Uniform, no one Point has any Mark or Characteristick to distinguish from any other, and a Point being once lost, 'tis impossible to find the same again, tho' it be turn'd a thousand times; because there is suppos'd to be no one Point of it that differs from any other, and they cannot be distinguish'd or measur'd from, and every point may be said to be the middle of the whole Circumference; and thence it is that the People of every Country and Place have thought themselves to be in the middle of the Earth, and all the Neighbouring Ambient Countries to lie towards the Extremities. Which Opinion always hath and always will possess the Minds of ignorant People, 'till by Learning and Art they are better inform'd; for seeing an extension of Land or Seas round about them on every side, and seeing the Sky whelm'd over them like a Dish or Hemisphere, the middle of which seems to be just over their Heads, and the Brims to touch the Earth and Seas at a great distance, they cannot without much thinking and considering (which few People care to do, especially in matters which they think not of immediate concern) they cannot chuse but be impos'd on by the appearance to their Sense, which seems so to represent it; and if so at Land, much more does it appear so on the Sea where there is no sight of Land, when the Superficial Parts of the Sphærical Surface have no remaining visible marks more than the Chrystal Ball. On the Land indeed, and in sight of Land there are many obvious helps to find and distinguish one place from another, and the Positions of one from all the other that are visible and accessible, as Hills, Vales, Mountains, Woods, *&c.* But the Surface of the Sea wants all those, and has nothing but a fluctuating changing Surface, which way soever you look 'tis all alike, you know not which way you go forwards or backwards, whether the Wind blows for you or against you, or the Current sets you near to or further from your Port; which was the cause why the Antients never durst venture out of the sight of Land but went along the Shores, they being not then able to distinguish, especially in cloudy or close Weather, which way lay the Quarters of the Earth or Azymuth. And indeed before Astronomy was known, the very Quarters of the Wind were not distinguish'd with respect to the Heavens, but only with respect to the Countries from whence they seem'd to come. Thence we find that they call'd one *Vulturnus*, another *Phœnicius*, a third *Africus*, *Olympius*, *Thracius*, *Hellespontius*, and the like, which were the Names of the Countries from whence they seem'd to come.

But the Diligence and Inquisitiveness of succeeding Ages has furnish'd us with better and more universal ways of distinguishing and naming the Quarters of the Winds, or the Azymuthes, or Divisions of the Horizon, and Positions of the Parts of the Surface of the Earth, and not only so, but of determining the distance of any place from the Points certainly fix'd upon this Globe of the Earth.

Of the ways yet known to discover the place of a Ship at Sea.

I shall therefore in the next place consider what means there are hitherto found and made use of for dividing, and distinguishing, and defining of the Superficial Parts of this Globe of the Earth, so as certainly to know any one Point of the Surface of it, from any other determin'd, whether upon Land or Sea; for that there are no two Points of the whole Surface but that have some ways or other their distinct Characteristiks.

There have been various ways invented of performing this Effect; those that are thought of the best, and so apply'd at present to use, may be reduc'd into two Heads, and these are Cælestial or Terrestial, namely, some Respects or Aspects of Cælestial Bodies, or Situation, Substance, Qualification, Form, *&c.* of some Terestrial Bodies.

The

The Cæleſtial are ſuch as are afforded by the Motion or Poſition of the Cæleſtial Bodies, *viz.* the Sun, Moon and Stars.

The Terreſtrial are either, 1*ſt.* Magnetical, by the help of the Compaſs, or Magnetical Needle: Or, 2*dly*, Computatory, by keeping account of the Courſe and Diſtance, ſail'd from a known place: Or, 3*dly*, By ſounding the depth of the Sea, and examining the Subſtances that are to be found at the bottom: Or, 4*thly*, By the Sight and Proſpects of ſome high and eminent Places which may be ſeen at a great diſtance upon the Sea, and from thence collecting the Poſition bearing and diſtance from them.

The Cæleſtial, and the two former of the Terreſtrial are of uſe in all places, the two laſt are more particular, and reſtrain'd only to ſuch places where ſoundings are to be found; for there be many places where there is no Bottom to be ſounded, and many others where no part of Land can be diſcover'd; in which Caſes recourſes muſt be had to the more general ways, by the Heavens, the Needle, the Courſe, and Diſtance.

The helps which the Heavens afford for diſtinguiſhing of places on the Earth either are, 1*ſt.* Their Poſition in reſpect of the Earth: Or, 2*dly*, Their Motion. By their Poſition they ſerve as helps to find the Latitude of a Place; and by their Motion they may, in time, ſerve to diſcover the Longitude. *The Caleſtial ways.*

Firſt, By their Poſition they help us to diſcover, that this vaſt Globe on which we live, and which ſeems ſo fix'd and ſteadfaſt, is mov'd round (like a Globe which is commonly made to repreſent it) on an *Axis*, or an imaginary Line that paſſes from ſide to ſide through the very Center thereof; or like a two Headed Top upon two imaginary Points, which are Diametrically oppoſite to each other upon the Surface thereof; each Revolution of which is perform'd once in twenty four Hours from Weſt to Eaſt, and thereby each part of the Earth, according to its Situation or Diſtance upon the Surface from one or other of thoſe two Points, moves or is mov'd in a Circle round the ſaid Axis greater or leſs, according to its diſtance from the neareſt of them; ſo that all the Parts that lie at equal, and the greateſt diſtance from them both are mov'd in the greateſt Circle of all the reſt. By means hereof is diſcover'd, Firſt, The Poſitions of Places one to another, in reſpect of their Revolution; that is, the Azymuths or Quarters of the Horizon, or uſual Limit of the Heavens; for by means hereof the Cæleſtial Bodies firſt begin to appear at one Quarter of the Horizon, and to croſs the Heavens over us, and to Deſcend, and Set, and Diſappear on the other; whence the former is call'd the riſing part of the Heavens, and the other the ſetting part, and the middle part between theſe two are call'd the Meridional, and the Polar, which is either North or South; and then an imaginary ſtraight Line ſuppos'd drawn between them either upon the Earth, or in the Heavens, is call'd the Meridian of that place where this Suppoſition is made. *By their Poſitions.*

Now that end of this North or South Line which goes towards that Quarter of the Heaven where the Star is in the extreamity of the Tail of the little Bear, near which is the Polar Point in the Heavens, is call'd the North, and the other end is call'd the South. Now, one or the other of theſe is always viſible both at Land and Sea in all parts of the Globe in a clear Night; but the Polar Points of the Earth, either in the North or South, have not yet been diſcover'd.

This North and South Line then is diſcoverable by means of the Heavens in every point of the Surface of the Earth, and by means of that, the Poſition of Places with reſpect to them, is eaſily known, and thence alſo all the other Quarters or Parts of the Horizon of any Place are eaſily diſcover'd; for a Line imagin'd drawn in the Plain of the Horizon through any place, cutting the former Line at right Angles, points out in the Limb of the Horizon, the Eaſt and Weſt,

These two Lines distinguish the Horizon or visible Limb of the Heavens into four equal Quarters or Quadrants, *viz.* The first between the North and East; the second between the East and South; the third between the South and West; and the fourth between the West and North. Now each of these Quadrants may be, and usually are subdivided into lesser Divisions. The Seamen generally content themselves in Steerings and taking Bearings, with a Division of each of these into eight parts, so that the whole Horizon is divided into thirty two Parts, which they call Points, because they are pointed out by their Compass or Winds, because of their taking notice in which of those Points the Winds blow; the first are the principal Points, *viz.* N. S. E. W., the Lines that divide these four Quadrants in half are the half Winds or Points, namely, NE. SE. SW. NW.; the eight Points in the middle of these are the Quarter Winds, *viz.* NNE. ENE. ESE. SSE. SSW. WSW. WNW. NNW. all these together make sixteen, and these being again subdivided into halves make sixteen more, which are the by Winds, *viz.* N. b E. N. b W. S. b E. S. b W. E. b S. E. b N. W. b S. W. b N. and N. E. b N. N. E. b E. S. W. b. S. S. W. b W. These again they do subdivive into four Parts in their Accounts cast up, or protraction of their Course. Astronomoers divide the Circuit of Horizon as they do all other, into Degrees, Minutes, *&c.* And so do Mariners in observations of Amplitudes and Variations of the Compass, tho' not in the Bearings of Lands and Islands.

Now, thus far the Heavens only serve for determining the Position of any Place whatsoever, with respect to the bearing of those Polar Points of the Earth I but now mention'd, but shew not at all how far they are remov'd or distant from either of those Points. This also the Magnetical Needle or Compass does in part discover, but not wholly without Rectification by the help of the Heavens, as I shall, in its proper place, explain. But this does little as to its determining the positive Point of this Place upon the Surface of this Globe, but only by the account of the Course Sail'd, 'tis knowu pretty near which way the Place lies, from whence the departure is made, and which way the Course lies to the Place bound to. Some further information therefore is requisite to determine the distance from these Polar Points, or from an imaginary Circle incompassing the Globe, lying at equal distance between them, call'd the Æauinoctial-Line, or more commonly the Line; of which I shall speak more hereafter.

This then the Heavens afford an help for, namely, by their Position or height above the Horizon, or the visible Limb of the Sky which seemeth to touch the Earth; but before I speak of this I shall a little further explain the true notion of the Horizon.

Of the true notion of the Horizon.

The Horizon, or, as the Seamen call it, the Orison, at Sea is the extream edges of the Sea which the Sky seems to touch, which, in clear Weather, is very easy to be seen in the Day-time, like a black Line bounding the Sky, and may be also plainly enough discover'd in a very clear Star-light-Night, especially when the Moon is pretty well inlighten'd, or in the time of the Twilight, when as yet the Stars are very visible; but when the Air is thick and hazy, tho' the Sun, Moon, or Stars may be discover'd when they are a pretty way above it, yet the Horizon cannot be distinguish'd, but the Sea and Sky gradually mix with one another, so as no Observation can then be made of it, there being no distinct visible separation.

This visible edge of the Sea is nearer or further off, according as the Eye that sees it is nearer to, or higher from the level Surface of the Sea; the proportions of which one to the other I hinted the last time, but shall now somewhat farther explain.

The sensible Horizon Mathematically consider'd, is an imaginary Plain touching the Globe of the Earth or Sea in any Place or Point thereof, which is to be consider'd; and this Plain is suppos'd to be extended to the extreamities of the universe every way; so that when any Star or Cælestial Body on the Eastern side of the Meridian appears in the Plain thereof, it is Rising, and when they appear in the Western side thereof, they are Setting; or according to the Copernican Hypothesis, the Horizon is an imaginary indefinite Plain, touching the Globe of the Earth at the place design'd, which, together

together with the motion of the Globe, is carry'd round once in a Day, and so twice in that time passes over the Cælestial Bodies that lie in its Zone; when the Easter-most side passes them, they are said to be Rising, and when the Wester-most, they are said to be Setting, both which Hypothesis equally solve the Phænomena; and upon this speculative notion of the Horizon, there is also suppos'd a Rational Horizon, which is also an imaginary indefinite Plain passing through the Center of the Earth, and parallel to the former, namely, at the distance of the Semidiameter of the Earth; which distance being extended to the fixt Stars, becomes wholly insensible, being view'd from the Earth, and so as to them, and even to the Planets superior or farther distant from us than the Sun, they become wholly the same, and the sensible and rational Horizon are one and the same imaginary Plain or Circle in the Heavens; but in the Moon especially, and in the Planets nearer to us than the Sun, they are, by curious and nice Observation, sometimes discoverable: But those Speculations more concern Astronomy, than Geography or Navigation, and therefore I shall say no more of them at present, but rather speak of a third Horizon, which is a real and visible Circle, and that which Navigators call the Orison.

The sensible Horizon, as it concerns Navigation, is not a Plain, nor a Sphærical, nor Conical Surface, but rather an imaginary *conoeidical* Surface touching the Sphærical Surface of the Sea in a Circle, which Circle is nearer or farther off from the Eye, which is in the Apex of the Conoeid, according as the Eye is lower or higher rais'd into the Air above the Surface of the Sea, and according as the inflective quality of the Air is less or greater; and from the same causes that the distance thereof from the Eye is diminish'd or augmented, does the imaginary Limits or Base of it, which is a Circle in the Heavens, descend lower and lower below the Rational, or notionally sensible Horizontal Line, or imaginary Circle in the Heavens. This is a third Horizon differing from both the other, and below them both in the Heavens; so that to the Eastwards the Stars and Planets appear to have pass'd the Nautical or Mariners Orison some time before they arrive at the Speculative or Notional Horizons, and in the West they have pass'd the Notional Horizons some time before they touch or arrive at the Nautical and Visible Orison. So that all those Observations which are made at Sea, either for finding the Azymuths, or for discovering the variation of the Compass, or for Altitudes, or the like, are every one of them Erroneous, and there ought to be a rectifying thereof made: For, First, How much the said Line appears below the true Level or Tangent Line of the place, by so much less is the Altitude of the Cælestial Body taken from it, than what it is taken at; and the Amplitudes in an Oblique Sphere will thereby also be considerably augmented more than what they should have been by the common Theory of the Sphere, Calculating as from a true Horizon; for all the Geometrical Rules that are made concerning the Notional Horizons, are produc'd from the consideration of the Globe, and of the Proprieties and Affections thereof, and of Plains either passing through the Center, or touching the superficies, and from the Hypothesis that the Rays of Light pass in straight Lines from the Cælestial Body to any Point of the Surface of the Earth, in which they suppose the Eye of the Observer to be plac'd; but because the Eye is never known to be exactly in the Superficies of the Surface of the Sea, but at some height above it; therefore the visible Orizon of the Navigator, if the Rays of Light were straight, would be a Conical Surface, and not a plain; and the higher the Eye is rais'd the sharper will be the Cone. But because the Rays of Light are not really straight in their passage through the upper and lower parts of the Atmosphere, but are by the Inflection of the unequal Density of the parts of that Medium inflected into Curves, whose Concave side is towards the Earth, therefore the Superficies of every visible Orizon is not a Conical, but a Conoeidical Surface, in the Apex of which is plac'd the Eye and the edge of the Sea, which is a Circle upon it, the Center of which is in the Perpendicular below the Eye, and thereof is very near as much below the Surface of the Sea under the Eye, as the Eye is rais'd above it; and as this Orizon on the Earth is a lesser Circle, and not a greater Circle, so the Basis of this

Conoeidical

Conoeidical Body, in the Heavens is not a great Circle, as is the Rational Horizon, but a leſſer parallel Circle below it, and that ſo much the more below it, as the Eye is higher elevated above the Surfaces of the Sea, and as the inflective quality of the Air is greater.

Now, if we firſt conſider the Rays of Light as ſtraight Lines, we ſhall find the Angles of the ſeveral Conical Superficies adapted to the ſeveral heights of the Eye, as I have already mention'd, and thence the diſtance of Objects may be gheſs'd where they are diſcoverable; but that which I here mention it for is in order to find the true Situation of any place upon the Sea, in reſpect of the two Polar Points where no Land is diſcoverable, which I ſhall next ſhew you is diſcoverable by the Heavens, by knowing the height of the Cæleſtial Bodies above the true Plain of the Horizon, or as Navigators commonly above the Line, they call the Oriſon. And I have been ſomewhat the longer upon this Diſcourſe of the Oriſon, becauſe it ſeems to be the Foundation of all the Cæleſtial Obſervations that are made at Sea, and if that be Erroneous, then all the Obſervations will be ſo too. It will therefore be neceſſary to have the true Theory thereof, both for Latitudes and Amplitudes, or Azymuths; I ſhall therefore add one Obſervation concerning the Mariners Oriſon, and ſo conclude this preſent Diſcourſe.

Whence the Looming or Glaring of the Sea.

The Obſervation then is this, That there are ſome Conſtitutions of the Air, near the Surface of the Sea, that do really elevate the Oriſon above the true Horizon or Level-line, and that is at ſuch times as the Sea is ſaid by the Sea-men to *Loom* and *Glare*, as if it were Smooth'd and Poliſh'd, whereby the Surface of the Sea ſeems to be lifted up above its own level Surface into the Atmoſphere incompaſſing it: And this I have often taken notice of, and as near as I could gheſs from what Obſervations I was able to make; I judge it to proceed from a denſe, and, as it were, foggy Air which lieth equally ſpread upon the Surface of the Sea, not extending above ten or twelve Foot, or there about, above the ſame, and there terminating in a kind of Level, the Air above it being perfectly clear and tranſparent, but this under Air having a Fogginess or Hazineſs in it, nothing can be ſeen through it but only what appears above it; ſo that at a diſtance (tho' nothing of it can be perceiv'd at the Ship) it appears to coaleſce with the very Sea, and the Surface of this ſeems to be the Surface of the Water; ſo that by this means the Mariners Oriſon inſtead of being below the true Horizon, is really rais'd above it; and conſequently Altitudes taken from that will be too low, and additions ought to be made to the Altitudes found, to bring them nearer to the true Horizon. Now, how to rectify this and the other Irregularities of the Oriſon, I ſhall ſome other time give an account.

THe Author having mentioned in the foregoing Diſcourſe ſeveral Methods that have been propoſed for finding and ſettling an univerſal Standard for Meaſure, I thought it not improper to inſert part of a Lecture read about 1683 upon that Subject, and omitting the beginning of it, which treats only of the ſeveral unſucceſſful ways yet attempted, the reſt of the Diſcourſe is as follows. R. W.

A new Standard of Meaſure propos'd.

WHat I have farther to add, as to the finding a Natural Univerſal Standard for Meaſure, is a Conception of my own, of a way differing from any other way whatſoever that I have ever heard of, which, I conceive will afford a Natural Standard for Weight and Meaſure at all times, and in all places, and which, I conceive, will not be very difficult to perform, if trial be made with convenient Care and Accurateneſs; not that I pretend to diſcover any new Thing or Propriety which none have ever obſerv'd before, no, 'tis that which all ſee and all know, and as trivial as the pendulous vibrating Motion, which, in Contempt, hath been call'd Swing Swangs, tho' the Application and Uſe of it, found by *Galileo*, hath ſince prov'd of ſuch excellent uſe; and poſſibly this alſo which I ſhall mention may not be unimproveable to much better uſes than I ſhall now mention.

It

It is I doubt not ſufficiently known to all preſent, that all fluid Bodies whatſoever from the *Homogeneity* of their Texture and *Heterogeneity* to the incompaſſing fluid *Medium*, have a power of Conglobation or forming themſelves, when in ſmall parcels into Globular Bodies, and that the ſmaller they are and the leſs difference of weight, the nearer they approach to a perfect Globular Figure, and the bigger and more differing the contain'd, and containing Fluids are, the more doth the form of the contain'd differ from that perfect Sphærical Figure, and there is one certain quantity of every ſimple Fluid, which, in ſome certain *Medium*, will make the Conglobated Figure to be flatted or ovall'd; ſo that the longer Diameter to the ſhorter ſhall bear a certain aſſign'd proportion; for inſtance, to take the moſt remarkable, namely, 2. to 1. I conceive then, that this quantity being certainly found, and moſt accurately meaſur'd, will afford a natural and perpetual Standard of meaſure; for inſtance, let *Quickſilver* perfectly depurated, and *Rain*, or *Diſtill'd Water* be the two Fluids; I ſay, there is a certain quantity of *Quickſilver* which, in ſuch *Water* will be form'd into an ovall'd or flatted Body, ſo that the Horizontal Diameter to the Perpendicular ſhall be as 2. to 1. This longer Diameter I make a Primitive and Natural Standard of length, and the weight of this Body of *Mercury* ſo ovall'd, I make the Primitive Sandard for Weight; the ſame may be done with any other Fluid.

This may be alſo done by purely refin'd *Gold* or *Silver*, whoſe Purity may be found by the proportion of weight it beareth to Rain-water; for if a certain quantity of Gold be melted and pour'd out upon a perfectly ſmooth and horizontal Surface of a Stone, this will form itſelf into an Oval Body, whoſe Horizontal Diameter to the Perpendicular, will be as 2. to 1.

The ſame may be done with any other Metal beſides Gold, but only we cannot be ſo ſure of the purity and unmixedneſs of the Metal, as we may be of Gold.

It would be too long now to mention the various ways there may be uſed for exactly finding, determining and meaſuring this Figure, but I deſign at ſome other time to entertain the Society with the Experiment and Trial thereof, which will make all things more evident and plain.

THe way mentioned at the end of this Diſcourſe of exactly meaſuring the Figure and Shape of any Body, I find deſcribed in another Paper, read December *the third*, 1683. *and is as follows.*

R. W.

The knowledge of Nature and Art is advanc'd by the diſcovery of ſuch things, as ſerve like Engins or Organs, to make ſuch further Inquiſitions in either as the Natural Faculties of Men, without ſuch aſſiſtances, are not able to perform; and therefore how trivial and ſlight ſoever a thing may ſeem before the Uſe and Application thereof be known, eſpecially to ſuch as have no occaſion or curioſity for ſuch Inquiries, or who have not conſider'd the Conſequencies that may be drawn therefrom, yet to ſuch as really have, I doubt not but they will find Reaſon to think them valuable. Of this Nature were the little Globules of Glaſs apply'd to the uſe of Microſcopes, from whence have proceeded moſt of thoſe curious Diſcoveries made by the inquiſitive Mr. *Lieuwenhook*. I could inſtance in the Pendulum, and ſeveral other ſuch Applications of things, in themſelves inconſiderable, to proper purpoſes, which have produc'd admirable Diſcoveries, which would hardly have been done without them; but that would be too tedious for ſuch an Aſſembly, who are already well acquainted with them.

The great uſe of the Suns Rays let into a dark Room.

That which I ſhall acquaint you with at preſent, is an Experiment or Method rather, by which ſeveral very conſiderable Diſcoveries may be made both in Nature and Art. It is, in ſhort, a way of contracting a very conſiderable quantity of the Rays of the Sun into a very ſmall Point or Space, the ſmaller the better, from which they iſſuing again with great Brightneſs and Radiancy may be able, by the differing Refraction and Reflection which thoſe

Rays ſuffer in their way, to deſcribe upon a ſmooth, white plain the true ſhape of the Body interpos'd between that radiating Point, and that ſmooth expanded white Plain. This in itſelf is very plain and obvious, and is very little differing from the way now commonly known, it being no other than the fitly placing one or two Convex Glaſſes againſt an hole cut in the Shutter of the Window of a darkn'd Room, ſo as that the Rays of the Sun may paſs in through the ſame directly and be collected into a Focus, and from thence again ſpread and diverge into the Room, ſo to as be caſt upon the Table aforeſaid. The Experiment itſelf, tho' I cannot now exhibit, yet there are ſeveral of this Honourable Society who have ſeen and been witneſſes of ſome of its Effects. Tho' there are many more yet behind which I ſhall hereafter ſhew, ſo ſoon as the Sun comes in the Room I have fit for it.

By this then I diſcover various motions of the Medium or Air, not otherwiſe viſible, as alſo the Emanation of Steams out of Bodies of ſeveral kinds not otherwiſe viſible; likewiſe ſeveral other Natural motions of tranſparent Bodies, not otherwiſe, that I know of, to be ſeen.

By this you plainly ſee the matter of a burning Candle or Lamp, which is diſſolv'd by, and mix'd with the Air, to aſcend from the ſame like a great Stream of Water running at the Tail of a Sluce or Bridge, which doth alſo plainly illuſtrate the appearances of the Blaze of Comets.

Theſe are ſome of the uſes of it for diſcovery of the Operations of Nature.

Next, for the uſes of it in Art; it moſt reſpects the Art of Painting and Statuary, as by this may be drawn the exact out Lines of any Body that is to be deſcrib'd on a Plain, and theſe truly as they do appear to the Eye plac'd at convenient diſtance, as that of a Man's Head, Face, Hands, or Body, in which it is ſo curious, that every Hair that appears without the ſolid part of the Head, Hand, or Body, is truly repreſented in its Place and Magnitude.

By this the out-lines of Birds, Beaſts, Shells, Fiſhes may be taken: As alſo the true ſhape of ſmall Plants as they are whole and intire, or the Leaves, Flowers, Seeds, *&c.* of greater Plants.

By this the true out Lines of a Flower-pot, with all the variety of the Poſtures of the Flowers that compoſe it, may be repreſented and drawn; all which are very uſeful for Painters, or ſuch as would draw ſuch Delineations.

By the help of this, and a pair of Compaſſes, may be truly drawn all Parabolas, Hyperbolas, and Ellipſes, which are of good uſe in projections of the Sphære, Dialling, Perſpective, and the like.

There are ſeveral other uſes that may be made of this Experiment or Method, which I omit at preſent, 'till I can exhibit again the Experiment.

And I have contracted this Diſcourſe that I might only ſumm up the Uſes and Applications thereof, without ſpending your time in hearing the Cauſes and Reaſons thereof.

The

THe following Discourses were read the later end of the Year 1684, and contain several Matters relating to the former Subject of Navigation; there is in the beginning a Repitition of some things formerly treated of, which could not well be struck out, without breaking the thread of the Discourse; and the most part of the Author's Treatises in this Volume, being Lectures read at several times, it was necessary for him to make some Repetition of what had been before said for the better understanding of what was to follow; nor could they have been omitted here without a new Modelling and Epitomizing the whole, which made me rather trespass upon the Reader's Patience, than attempt to Alter or Abridge any thing of the Author's Sense; and indeed I thought it more advisable to give them as he left them, than adventure upon such an undertaking.

This treats first of the Nature and Generation of a Globular Figure and its Proprieties. Of the Circles of the Terrestrial Globe. Of the Prime Meridian. Of the Parallels. Whether the Perpendiculars respect the Earths Center. Of the Variation, and its unfitness for finding the Longitude. Of the change of the Latitude and Longitude of Places. Why the Circles have been divided into three hundred and sixty Degrees. Of the difference between the Eastern and Western Literati. A new Duodecimal Progression propos'd. Several Maxims laid down, and several ways for finding a true Meridian and the Latitude.

R. W.

I Have, in some former Lectures in this place, explain'd in general the Art of Navigation, shewing by what Helps and Methods, and from what Principles the Navigator may be able to direct his Course through the Ocean to the place design'd, and at any time to be able to know in what part of the Sea his Vessel is Sailing.

For the performing of which I shew'd in general, that it was requisite that our Navigator should, First, Be very well skill'd in Geography, or the true description of the Earth and Sea, upon the Surface of which he is to make and compute his Course. And, Secondly, That he should be very knowing in all those Particulars, which may serve him for Marks or Directions to know and distinguish the Parts one from another. *The Requisites for a Navigator*

In order to understand the description of the Earth more effectually for this purpose, it will be requisite to determine,

First, The Figure of the Body of the Earth, and the several Proprieties belonging to that Figure, that so we may the better be able to comprehend the difference between a curve and a plain Superficies, and what Lines will be useful to be drawn or suppos'd on it, and from the knowledge of those be the better able to find and determine, *Four things to be determin'd.*

In the Second place, the Magnitude of this Body by known Measures, and to examine and prove the Ways and Methods of measuring the same; both such as have been already either experimented or invented, and such others as may be thought of or try'd for the future; for upon a true knowledge of these two are founded all the other Superstructures in this Art; these two cannot be truly and exactly obtain'd without a clear knowledge. 2.

Thirdly, Of the motions of this Body, and what Effects are thereby produc'd pertinent to this purpose, namely, what Circular and other Lines are thereby design'd, and ought to be understood on the Surface of the Earth. 3.

The motions of this Body are either Total or Partial; the Total are, First, Gravitation. Secondly, Magnetisme. Thirdly, Rotation upon its own Axis. Fourthly, Circumvolutation about the Sun Excentrically. Fifthly, Menstrual, Cycloeidation or Undulation. Sixthly, Libration. The Partial are either of the Water or Air; of the Water are, First, The general motion of the Seas, as, First, Currents. Secondly, The Tides, or of Rivers running into the Seas. Of the Air are either constant, or, Secondly,

The

The uncertain Winds, and both of them either Moderate or Excessive; all which ought, as near as may be, to be brought to a Standard of Mensuration, without which all the Art we hitherto know or make use of, will not sufficiently inable us to keep a true Reckoning or Account of the Ships way in passing or crossing the Seas, or how we change our Situation Eastward or Westward, especially in respect of the fix'd parts of the Earth; for 'tis one thing to measure our way through the Superficial Parts of the Body of the Water in which we float, and another thing to know how great a part, and upon what Point or Azymuth we have pass'd over the Earth at the bottom of the Sea; the parts of the Earth at the bottom remaining fix'd and steady, but the Water of the Sea being carry'd various ways, and with differing Velocity over the same, in several parts of it.

4. Fourthly, The differing Substances of which the Superficial Parts of this Body consists, as of Earth, Water, Air, and the several Extents, Boundaries, and Qualities of each, and how posited with respect to the Cælestial Bodies and proper Motions of the Earth; that is, as to Longitude and Latitude, *&c.* for without the assistance of Cælestial Observation, we have not as yet helps sufficient to distinguish the Superficial Parts of the Earth one from another, at least not upon the Sea where there are no Land-marks to be discover'd.

Having already treated in the foregoing Lectures of the several Opinions touching the true form of the Earth, I shall not now repeat any of them here, but proceed to shew several other Properties thereof necessary to be known, in order to the better understanding the Subject in Hand, *The Art of Navigation*; and, in the first place,

Supposing it, as 'tis believ'd by most, tho' prov'd by none, to be of a perfect Globular Figure, and consequently the Surface of the Sea, as well as that of the Land, to be Sphærical, we will in the next place proceed to consider of the Proprieties of this Body, because 'tis upon the Surface of this Body that all our Voyages and Mensurations are to be made and not upon a Plain; for tho' the level of the Sea doth, to a vulgar Eye, seem to be a Plain, and generally most common People do believe or suppose it to be so, yet 'tis past dispute, that it is Sphæroeidical, and has a Curviture answerable to the Curvity of the Superficies of the Earth, tho' it be not so easily found by the prospect of the naked Eye.

The properties of a Globular Figure.

And that we may the better find out and examine the Properties thereof, it will be fit to consider how a Sphærical or Globular Figure is generated. I need not premise either Definition, Postulata or Axioms for this Explication, because so much, as I have here occasion to mention, will be easily enough understood without them, and common words of Expression will be significant and defin'd enough for this purpose.

A Globular Superficies how generated.

A Sphærical or Globular Superficies may be conceiv'd to be generated by the Conversion and whole Revolution of a Semiperiphery upon its Diameter; and a Globular Body may be conceiv'd, generated by a whole Revolution of a Semicircle upon its Diameter: As, let ACB represent a Diameter bisected at C, and upon the Center C, and distance AC. Let ADB represent a Semiperiphery, every Point of which is equally distant from the Center C; suppose then this Periphery to be revolv'd round upon the Diameter AB remaining fix'd, this Periphery shall describe a Globular or Sphærical Superficies, every Point of which Superficies shall be equally distant from the Center C; for since the Sphærical Superficies is describ'd by the Rotation of the Periphery ADB, no one Point of it can be further from, or nearer to the Center C, than any one Point of the Semiperiphery ADB; but every Point of the Semiperiphery ADB is equally distant from the Center C; therefore every Point of the whole Sphærical Surface so generated, is equally distant from the Center C; this distance is always equal to the Semidiameter of the Periphery, *viz.* AC, or CB.

Table IX. *Fig.* 6.

Next,

Next by this Rotation upon the Diameter AB, every Point in the Semiperiphery ADB will deſcribe a Circle in the Spherical Surface: All which Circles are parallel to each other ; for ſince that any two of them are deſcrib'd by two Points of the Semiperiphæry, which two Points retain the ſame diſtance or place in the Semiperiphery for the whole Revolution, and that That diſtance is the ſhorteſt that can be meaſur'd upon the Sphærical Surface, it follows that any two of them will be parallel, and ſince one of the two may always be one and the ſame Circle, and any other Circle may be the other, it follows. that all theſe Circles, ſo deſcrib'd, will be parallel to each other 2.

Thirdly, ſuppoſing from any number of Points, as E E E, how many ſoever Perpendiculars, let fall or drawn to the Diameter AB, as EF, EF, EF, which will therefore be parallel to each other, becauſe they are all Perpendicular to the ſame Line, and in the ſame plain of the Semicircle ADB : By the Rotation of the Semicircle ADB; every one of the Lines EF, EF, DC, *&c.* will deſcribe a Circular Plain, and every one of theſe Plains will have its Center in the Line AB. Thirdly, Every one of thoſe Plains will be parallel to each other, becauſe the Lines deſcribing them are parallel to each other, becauſe they are at right Angles with the Axis, therefore the imaginary Superficies deſcrib'd by them, is a Plain. Next, 3.

Fourthly, The Diameter AB will be Perpendicular to each of thoſe Plains and will paſs the Plain in the Center thereof. 4.

Fifthly, Theſe Plains will be bigger and bigger the nearer the Perpendicular that deſcribes them, is to the Center C ; and the biggeſt of all will be that deſcrib'd by DC, that being the longeſt Perpendicular ; and becauſe DC is equal to AC, therefore the Circles deſcrib'd by thoſe as Radii, ſhall be equal, that is, ADB, *&c.* and the Circle deſcrib'd by the Rotation of DC ; therefore theſe Circles ſhall be great Circles, therefore great Circles ſhall divide the Sphærical Superficies into two equal Parts, becauſe AD is equal to DB, and conſequently the Sphærical Surfaces deſcrib'd by the Rotation of them. Therefore all great Circles upon a Globe are equal to one another ; and becauſe ADB is half a great Circle, the Points whereof A and B remain fix'd, whilſt the Simiperiphery is revolv'd round ; and ſo the ſame will paſs through every Point of the Sphærical Surface deſcrib'd by it, all which concur in the Points A and B ; therefore all thoſe great Circles do biſect each other in the Points A and B : Therefore all the leſſer parallel Peripheries cut theſe great Circles at right Angles, and are all biſected by them : therefore the Plains of the leſſer Circles are at right Angles with the Plain of the great Circles that biſect them ; therefore the Angles made by any two Poſitions of the Semicircle at the Axis of its motion, make equal Angles in all the parallel Circles and equal parts of Arches in all the Peripheries of them. 5.

And becauſe the Center C may be ſuppo'd to remain fix'd, and the Points A and B may be ſuppos'd fix'd in any other two oppoſite Points of the Sphærical Surface already deſcrib'd, as X and Y and the Semiperiphery ADB may be ſuppos'd revolv'd upon thoſe Points or Poles as AB upon the Axis ACB, therefore this Revolution of XDY will deſcribe the ſame Sphærical Surface with the former, which will deſcribe other great and leſſer Circles in it ; all which will have the ſame Reſpects and Proprieties to each other, as the former had among themſelves ; therefore the Plains of all great Circles paſs through the Center, the Diameters of them being always equal to the Diameter of the Sphære ; therefore all great Circles biſect each other ; therefore the Plain of all leſſer Circles cut or paſs through the Globe beſide the Center ; therefore all Plains paſſing through or cutting the Globe, cut it in Circles, and if they paſs through the Center cut it in great Circles, and if they paſs beſide and not through the Center, cut it in leſſer Circles ; therefore all leſſer Circles are parallel to ſome great Circle, which is in the middle between the Poles A and B ; therefore the ſame Points that are the Poles of a great Circle, are

the Poles alſo of the leſſer Circles that are parallel to it; therefore all Sphærical Surfaces that interſect each other, do cut each other in the Periphery of a Circle, and conſequently in a Plain; therefore the Line drawn between the Centers of two ſuch interfering Globes ſhall paſs the Center of that Plain at right Angles or Perpendicularly.

Theſe Proprieties of a Globular Body and Sphærical Surface, which follow as Corollaries from the way of the Generation of them, and ſo need little Explanation for the evidencing the demonſtration of them, will be ſufficient at preſent for the Explanation of ſuch Diviſions and imaginary Circular Lines as have been made uſe of by Geographers, for the better Deſcription, Limitation and Diviſion of the Superficial parts of this great Globe of the Earth; as for the other kinds of Lines which are not Circular but Sphærohelical, ſuch as the Rhumbs or Magnetical Lines, thoſe I ſhall hereafter diſcourſe of in their proper places, and explain all thoſe Proprieties which are peculiar to them, and of uſe in Navigation.

Geographers then have repreſented this great Globous Body of the Earth by a great round Ball or Globe, whoſe Surface is Sphærical and Smooth, and on the Surface of that they have deſcrib'd the various parts of the Superficies of the Earth bearing ſuch Form, Poſition, Magnitude and Variety one to another, as the real parts of the Earth do one with another; and therein have taken notice of the Poſition, Shape, Magnitude and Boundaries of all Lands, and Continents, Iſlands, Peninſulas, Iſthmus's, Promontories, Mountains, Plains, Deſerts, and other remarkable differences, as are known, of the parts of the Earth which appear above the Water; as alſo of all the Boundaries and Extents of Oceans, Seas, Gulphs, Bays, Channels, Streights, Lakes, Rivers, and the like; where the Water covereth the Face of the Earth; as the beſt Diſcoveries hitherto made, can furniſh them with the information of. Theſe, I ſay, they have delineated and deſcrib'd upon a Globous Body with what exactneſs and skill they are able; and tho' I conceive it to be far from that fulneſs, exactneſs and truth of Repreſentation that is to be wiſh'd; yet comparing what is now known and deſcrib'd, with what was known to the Antients, we ſhall find more than a new World has been of late Ages diſcover'd: And indeed the very World itſelf; for 'twas a long time before it was known what the Figure or Magnitude of the Earth was; and there was a time, when the belief of Antipodes was accounted and puniſh'd as a Hereſy. Every one then believ'd his own Country to be the middle of the Plain of the Earth, and that the utmoſt Limits of it, which touch'd the Vault of Heaven, were the Sea, into which the Sun, Moon and Stars deſcended when they Set, and out of which they aſcended again when they Roſe; and the utmoſt extent of Land ſeem'd no more than what a Conqueror was, in a little time, able to over run and vanquiſh.

The Earths Figure firſt found by the Greek Mathematicians.

It is hard to conceive, how Men from ſuch a ſtate of Ignorance ſhould arrive at ſuch a degree of certainty of Knowledge, as the World has at preſent attain'd; how they came to know that the Earth was a round or globular Body; nor have we any Hiſtories that do inform us; but we firſt met with it among the Mathematical Philoſophers of the Greeks, who, 'tis probable, from the curioſity of their Cæleſtial Obſervations, and from the ſtrictneſs of their Arguing came to find and demonſtrate the truth thereof; and then to indeavour to find out alſo the certain Magnitude and Meaſure thereof by Obſervations and Menſurations purpoſely made. Theſe Cæleſtial Obſervations, I conceive, were the firſt occaſions of their diſcovery of the true Form of the Earth, and 'tis by means of thoſe that the Magnitude of it hath been, and is to be truly diſcover'd, there being ſo many unanſwerable Objections againſt all the other ways of attempting it, that I think it wholly impracticable to any tolerable degree of certainty.

Cæleſtial Objects then, 'tis probable, were the Marks that guided them to this Diſcovery, which were ſufficient for this purpoſe, whether they were ſuppos'd to move round the Earth whilſt that was ſuppos'd to ſtand ſtill and fix'd, or whether they were look'd on as fix'd and immoveable as to the Diurnal Motion; and the Earth itſelf, according to *Ariſtarchus Samius*, or our

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late *Copernicus*, were suppos'd to be whirl'd round upon an Axis once in twenty four Hours.

Before the revival of this Opinion the Body of the Earth, tho' accounted but a Point in respect of the expanded Universe, yet was it suppos'd to be of such a solid, Dense and sluggish Nature, as not to be mov'd out of its place or posture, tho' the whole Universe, which was so many Millions of Millions of times bigger and more noble, was suppos'd to whirle about it with an incredible Velocity, and all to wait and administer to it; which yet at the same time was said to be damn'd to the worst of places (as it was accounted) the Center of the whole Creation, where it was affirm'd to be made up of the very Dreggs and Dross of the *Chaos*, to which all the vile and baser parts of the Universe continually descended, and was there excluded, as it were, and thrown out of the very Communication of the rest of the Creation. To maintain this Opinion the whole Creation was strangely Metamorphos'd, the most glorious Cælestial Bodies were depriv'd of their greatest Powers and the best places of the Universe: First, For their Powers they were rarify'd almost to be no Bodies, and suppos'd more light and spungy than Air itself; and next they were wholly depriv'd of the Power of Motion, so as to be suppos'd to be carry'd about by certain Orbs, in which they were suppos'd plac'd, and in them to be only Passive and not Active at all; and thus as sitting in Chariots to be whirl'd round this despicable Point of the Earth, for the more State and Pomp. On the other side to make this seem more probable, the whole *Expansum* or *Æther* was consolidated into more than adamantine Hardness and Transparency, and divided into Sphæres or Orbs within Orbs Concentrical, Excentrical, Progressive, Retrograde, and together with these qualities of Hardness and Transparency, there was added to this Substance that fill'd the Æthereal space so great a smoothness, as that all these Orbs could pass by each other without loosing any part of their motion by rubbing, and such an impenetrability as not to wear out or wast each other by Grinding or Fretting; and yet to heighten the wonder they were suppos'd to be Sonorous and Tonick, and to out-do all the Musick besides in the World, by the harmonious Melody of the Symphonick Sphæres; which Harmony yet was so sublime as not to be heard or understood by any but such as were gone out of themselves and had left those Corporeal Senses, which other Mortals here make use of, behind them, and were transported into an Exstacy of Contemplation and Attention. By this contrivance the Universe was all made solid and impenetrable, except only what space was left below the Concave part of the Moon's Orbe, which Concave part was the inside of the Walls of this Prison to which the Earth was condemned, beyond which no Terrestial Matter could penetrate, nor any Earthly Power reach; nor indeed could they reach so far, because this Concave Superficies was lin'd with a very thick Coat of the Element of Fire which had Power to consume and disperse all that which rising from the Earth, or inferior Regions of the Air, should attempt to invade and penetrate the Heavens. Thence Comets or Blazing Stars were suppos'd Sublunary and Aereal Meteors, and to be kindl'd by this Guardian Element of the Fire, and by that to be variously thrown from place to place like other Meteors and falling Stars, retorting their ill influence back again to the Earth from whence they were sent; or like Squibbs and Powder-Serpents drove to and fro by the blaze of their own Tail. Thus former Artificers contriv'd the Heavens into Wheel-work, and supposing themselves to have establish'd their Machinations by Suppositions, which freed them from the fear of Discovery or Contradiction they did a long while amuse the World with their Hypotheses. But later Astronomers finding, by accurate Observations, that Comets did pervade all those spaces which they had fill'd up, began to discover their Fictions to be groundless, and soon after found out a much more probable Solution of all the Phænomena of the Heavens, by placing the Sun in the Center of the Planetary Systeme, and instead of whirling round the Heavens once in twenty four Hours, they found or believ'd at least, that the Body of the Earth itself turning round upon one of its Diameters as an Axis, caus'd all those appearances of change, which was formerly ascrib'd to the motions of the Heavens, suppos'd to be caus'd

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by the rapidity of the Sphære call'd the *Primum Mobile*; but taking which Supposition we will, as to what principally concerns the distinguishing of Longitude and Latitude in Geography, it will come much to the same thing.

We suppose then that the Earth is, by all common Observations, found to be a round Body, and suppos'd to be mov'd round upon two Points in its Surface or upon an imaginary Axis or Diameter of it, and that it makes a whole Revolution to the same Position again in respect of the Plain through the Sun once in twenty four Hours thereby making Night and Day; and supposing an imaginary Plain passing through the Center of the Sun and the two Polar Points of this motion, this Plain will describe upon the Surface of the Earth every moment that it moves a great Circle, and so in a Revolution infinite of great Circles passing through the Polar Points and dividing the whole Surface of the Earth into a Morning and Afternoon half; the Morning half will be that which is moving towards the Sun, and the Evening half that which is moving from it: These great Circles are call'd Meridians, because when any Point of the Surface of the Earth comes by its motion into this Plain, the Sun is in the Meridian of that place, and are usually drawn in Lines upon the Globe which is made to represent the Earth; but because to draw them all would perfectly cover the Surface of the Globe, there being no moment passing without an alteration of it in respect of the Superficial Parts of the Earth, therefore on smaller Globes they usually draw but twelve of them, which divides the whole Surface into twenty four parts answerable to the Hours of the Day and Night, but in greater Globes they treble that number answerable to every third part of an Hour or twenty Minutes of time.

Of the prime Meridian.

And because these imaginary Circles alter every moment, and all have the same respect to the Heavens, so that from thence there is no reason why they should not be drawn over some places as well as others, that there might be a certainty where to begin to number them; there hath been several attempts or profers by several Authors to place under that which they call their first or beginning Meridian, this or that remarkable place of the Earth. *Ptolomy* accounted his first Meridian from one Degree West of the Westermost *Fortunàte Islands* or the *Canarys*, and thence accounted his Longitude or distance Eastward, 'till he arriv'd to the Easter-most Border of *China*, supposing thereby to have compris'd all the Habitable part of the World.

Upon the farther discoveries of late times of Lands more to the Westward than these *Canaries*; some have taken the Meridian passing through the Island of St. *Nicholas* one of the Islands of *Cape Verd*. And *Hondius* has chosen for his first Meridian that which passes through the Island of St. *Jago*; but *Gerrardus Mercator* has plac'd his first Meridian over the Island of *Corvo*, one of the *Azores*, because at that time the Magnetical Needle or Compass had no variation from the true Meridian Line in that place, which he therefore judg'd would be a very good mark to find it again in succeeding Ages: But as there are other Meridians in which the Compass has no variation, so it has been since his time found that there is a variation of the variation of the Magnetical Needle; and tho' the Needle then varied here at *London* to the Eastward, yet since that time, *viz.* about thirty Years since, it had no variation here at *London*, and is now very considerably gone towards the West. Some others have made the first Meridian that which pass'd by the most Eastwardly part of *Brasile*; *Arnoldus*, and *Wendelinus* have chosen the Island of St. *Vincent* for their first Meridian; and *Jodocus Hondius* has taken the same in his Globe making it pass through *Iceland*; *Robert Dudley* in his *Arcano del Mare* places it at the Island of *Pico* one of the *Azores*; but *Gulielmus Blaw*, and most of the *Dutch* Mapp makers, begin their reckoning from the Pike of *Teneriff*. The *French* Geographers, by order of *Lewis* the XIIIth. in the Year 1634, plac'd their first Meridian to pass through the Island of *Ferro* one of the *Canaries*, as is testify'd by *Brietius* in his Parallel between the Antient and Modern Geography, much the same with that of *Ptolomy*. Another prime Meridian was constituted by Pope *Alexander* the first, as a Boundary between the *Spanish* and *Portuguese* Division or Conquest of the World, and that was after a long Debate, but never any final Decision or Determination suppos'd to pass through the Mouth of the River of *Amazons* and that of *De*

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la Platta, as *Langrenus* has made it in his Mapp (which, whether they lie both under one Meridian or not, no one yet knows) And the *Spaniards* were to be proprietors of all Lands they diſcover'd to the Weſtwards of that Meridian, and the *Portugueſe* all to the Eaſtward; but theſe two meeting each other in the *Eaſt-Indies* again, caus'd much Diſpute. However, the *Spaniards* keep the *Philippines*, tho' it be thought to intrench upon the *Portugueſe* half. Other Geographers have taken other beginnings, which has caus'd a very great Confuſion, in particular Geographical Mapps, it being difficult to know from what prime Meridian they begin their Account.

Beſides theſe, the Aſtronomers have made choice of other Meridians for their Aſtronomical Calculations, as *Ticho Brahe*, and his followers, take the Meridian of *Uranibourg*, being in *Huena* an Iſland in the *Sound*. *Origanus* takes that of *Frankfort*, *Maginus* that of *Venetia*, *Eichſtadius* that of *Stettin*, and indeed almoſt every new Writer makes the Meridian of the place of his abode the firſt Meridian, and refers all the reſt to that, which breeds a great and needleſs Trouble and Confuſion in Geography; and it were very much to be wiſhed that they had, or would for the future agree upon ſome one to which all might be refer'd. There is not yet found any very conſiderrble ground in Nature why one ſhould be agreed to rather than another; that of the direction of the Magnetical Needle in the true Meridian Line would have looked ſo much like ſuch an indication of Nature, if the Hypotheſis of *Linton* and *Nantonier* had been true; but ſince Time has diſcover'd that thoſe were but groundleſs Hypotheſes, that pretence is vain.

That of the prodigious high Mountain of the Pike of *Tenariff*, which *William Bleaw* and the *Dutch* take notice of in their Charts, is likely enough to be a laſting Mark, and 'tis conſiderable enough to diſtinguiſh it from all other Mountains yet known in the World; and lying conveniently in the way of Shipping, may, for ought I know, be as proper as any other place whatſoever, provided all agree to make their Compute from it; and the computing Eaſtwards may ſerve well enough ſince it is now generally us'd; but had it been to be now eſtabliſh'd, I ſhould think it had been much more according to Nature to have computed the contrary way.

Next, the Earth being ſuppos'd to be moving round upon this Axis, may be ſuppos'd to have infinite Circles deſcrib'd upon the Surface of it, by the infinite Points of the great Circle that thus it moves round withal, which will therefore be parallel to one another, becauſe all are deſcrib'd by the ſame motion upon the Axis; that Point of it which is in the middle between the two Poles deſcribeth a great Circle, which is call'd the Æquator or Æquinoctial Line, and all the other Circles will be leſſer Circles, which being parallel to it are call'd Parallels; all theſe Circles croſs the former Meridians at right Angles, and ſo every one of them are, by every one of the former, divided into two equal parts. *Of the Parallels.*

Theſe parallel Circles are drawn upon the Globe that repreſents the Earth, but not all of them, for that would cover the whole ſuperficies of the Globe, but only ſo many of them as may, together with the Meridians, ſerve to diſtinguiſh and divide the Surface thereof into Trapezia of a convenient bigneſs, and are generally proportion'd to the number of Semimeridians, *viz.* ſo many between the Æquinoctial, and either Pole, as there are Meridians, as at every Five, Ten, or Fifteen Degrees diſtance from the Æquinoctial Circle, from which they begin to be accounted.

Nov. 13th. 84. I explain'd the laſt Day various Opinions concerning the Figure of the Earth on which we live, and ſhew'd you why, tho' it has not been ſufficiently prov'd by any Obſervations yet made, that it is poſitively of this or that Figure, yet by comparing all together it ſeems moſt probable that the Figure of it is Sphærical or Globular, or at leaſt ſo near it as not eaſily to be diſcover'd of any other, by the ſhadow of it in the Eclipſes of the Moon, nor by any other Obſervations yet made for meaſuring the Quantity or Magnitude of a Degree upon the Surface of it, which is the only certain and poſitive way of performing it: For tho' 'tis certain that the quantity of a Degree, or a three hunder'd and ſixtieth part of the whole compaſs of it has been meaſur'd in ſeveral Latitudes, and ſome of them with care enough; yet 'tis

also certain, that most of them have been made by unaccurate Methods and uncertain Measures; so that they are wholly useless in this particular, by reason we cannot make a pertinent comparison between them; nor do I know any other certain and uncontradictable way of proving it, than by either first actually measuring the quantity of a Degree upon the Earth in Latitudes very differing, as of one lying very near the Æquinoctial Line, and of another, as near as may be towards either of the Poles; and those Mensurations to be made as near as may be by the same Persons, with the same Instruments, and the same Measures, and with the same Exactness and Care; by the comparing together of which two Degrees so measur'd, it would plainly appear whether those Degrees would prove equal or unequal; for if they prov'd to be unequal, then it would plainly appear that the Figure of the Earth was not of a perfect Globular Form, but some way or other *Oval*; if the Degree near the Æquinoctial be found longer than near the Pole, then the greatest Diameters of the Earth are in the Plain of the Æquinoctial; if on the contrary, then the longest Diameter is in the Axis of its Revolution: This is supposing that the Perpendicular Lines pass through the Center of the Earth, whence would follow a second method of examining the Figure of it, and that is by examining whether the Horizontal Line be at right Angles with the Perpendicular; for if the Perpendicular be not found at right Angles with the visible Horizon, then will the obtuse Angle be on that side of the Perpendicular which is next the longest Diameter of the Earth, and the Acute towards that which is the shortest; it may therefore be easily try'd upon the same Place or Promontory where the Horizontal Line of the Sea can be seen both Northwards and Southward with some exact Instrument fitted with a long Plumb-line and a large Telescope set at right Angles with it, by which the visible Horizontal Line may be observ'd to what exactness it shall be desir'd, by turning the Instrument in the same place, and viewing the level of the said Line through it Northward and Southward. But if upon examining the Horizontal Line this way, it shall be found that the Perpendicular is at right Angles with the Horizontal, and yet by the other way of trial, by measuring a Degree in several Latitudes, it be found that the Degrees are differing, it will be an Argument that the Perpendiculars do not always respect the Center of the Earth, but that they cross the Axis in some other part thereof, which is out of the middle, sometimes towards one Pole, sometimes towards the other; which may be true, and yet none of the Observers, that have hitherto been, may have found, or taken notice thereof; one Reason of which may have been, that they have not hitherto suspected it, and therefore did not inquire after it. But tho' it be probable enough, that the Body of the Earth is nearly Globular, or rather was so form'd at first, that being the most perfect and regular Figure, and that, of which the other Celestial Bodies seem to be of, yet since we find that there are other varieties in Nature, as that of the Ring about the Body of *Saturn*, and even here upon the Earth, that of the differing Variation of the Magnetical Power thereof, I think it may not be improper to suspect, that there may be such an uncertainty of pointing in the Perpendicular or Plumb-line, 'till by certain Observations we are assur'd, and 'tis not safe in Philosophy to leave inquiry 'till a certainty be found. It was for some time believ'd, that the Earth itself was a great Load-stone, and that the Poles thereof were the same with the Poles of its diurnal Motion; and that the variation of the Needle from that North Point was occasion'd only by the approximation to the sides of great Continents, and according to that Theory, the causes of the several variations of the Needle at several places were assign'd to be for this or that Continent, or this or that Ocean near adjoyning. But upon further Inquiry it was found that there were several Instances, that contradicted that Theory, and that the Needle seem'd to respect some Poles that were not in the Poles of the diurnal Motion, but at some distance from them: These were said to be some vast great Rocks or Mountains of Load-stone at certain distances from the Poles of the diurnal motion; which Poles the Needle was suppos'd always to respect, and thereupon *William Nautonier* of *Castlefrank* in *Languedock*, wrote a large Book, which he Printed in the Year 1603, wherein he describes

A way to determine the Earth's two Diameters.

Whether the Perpendiculars respect the Center.

The Needle respects not the Poles of diurnal motion.

describes his Theory thereof, and furnishes it with Instruments and Tables fitted to find the Longitude thereby. Much about the same time one Mr. *Anthony Linton*, our own Country-man, a Minister I suppose, Publish'd a small Tract in *English*, under the Title of *News of the Complement of the Art of Navigation*, in which he pretended to shew a way for discovering the Longitude by the help of the variation of the Needle, and goes upon the same Hypothesis that the Earth was one great round Load-stone, and that the Poles thereof were at a certain distance from the Poles of the World, or those of the diurnal Motion; that there were, as it were, proper Magnetical Meridians, and a Magnetical Æquator and Parallels corresponding, all which bore the same respects to the Magnetical Poles, that the Meridians, Æquator, and Parallels of the diurnal Motion did to the Poles of the World; and thence he shews a way how to find the Longitude of any place by Sea or Land, in the Day or Night. But later Observations have found, that this Magnetical Variation varies, tho' yet the parts of the Earth do not seem at all to have alter'd their Position; this was found by Mr. *Foster* and others, in the Year 1635.

Variation unfit for finding the Longitude.

Hereupon Mr. *Bond* makes a supposition, that these Magnetical Poles were in the Air, not in the Earth, and out of the Poles of the World at a certain distance from them, and that they were two, one North and another South; that the Magnetical Axis cross'd the other Axis in the Center, but that the Poles made a Revolution about the Poles of the Earth in a certain period of Time, but that at the same time all over the World the Needles respected these Poles both by variation and dipping; by this he suppos'd the Longitude might be found in the same manner as *Linton* and *Nautonnier* had before suppos'd; but by comparing several Observations together it is found that this Theory will not hold neither. And the ingenious Mr. *Halley* has examin'd and compar'd Observations so far, that he judges it reasonable to admit four Magnetical Poles in the Earth, two of which are near the South, and two others near the North Pole, by which he finds the most accurate Observations of variation will be solv'd very rationally.

Four Magnetical Poles.

These Instances I mention to shew that tho' the Supposition of Dr. *Gilbert* were very ingenious, and seem'd very rational, and in many things agreed with the Phænomena of the terrella or round Load-stone; yet was it not a sufficient Argmment for all others to desist from inquiring farther, and examining whether upon trial all the Phænomena would answer to the Theory, and whether it would always remain the same that he in his time did find it; for things of this Nature being so far remov'd from common and vulgar Observation, and the very Maxims and Grounds of them being taken up upon I know not whose, Credit, I conceive, it might be worth inquiry by Experiment to examine whether they be really so or not, how generally soever they be believ'd or consented to; for 'till that be positively prov'd by certain Observations, there may be good Reason to hesitate upon the Reception of any Hypothesis how plausible soever it may appear.

This I mention on the occasion of considering the form of the Body of the Earth, and of the pointing of the Perpendiculars to the very Central and middle Point thereof; which, tho' it be generally taken for granted, and very agreeable to the general Phænomena, yet I think there are very good Arguments may be produc'd that may make the thing questionable, since I do not find that there has ever yet been made any Observations or Trials accurate enough to determine positively whether it be certainly so, or otherwise. 'Tis true, that it is certainly near enough to that Figure of a Globe, that the common Observations and accounts of Seamen cannot disprove it; and therefore as to that use, and so far as the accurateness of that Art is hitherto practis'd, it can make no sensible difference; but yet if that Art be carry'd to a much higher degree of Perfection, as 'tis not impossible but that it may, it may be very considerable in that particular also: But 'till that be done we will be contented to agree to the common receiv'd Opinion, and consider of it as of a Globe perfectly round, at least as to the Surface of the Ocean, that part which is of principal consideration in the business of Navigation.

The

THe following short Discourse relating to the Magnetical Variation, and the more exact way of observing that and the dipping of the Needle, I thought best to insert it in this place; for I do not find that the Author has any where perfected this Theory of Magnetism, which it were to be wish'd he had done, as likewise that he had carry'd several other Subjects on to a greater pitch of Perfection, which indeed has been the misfortune of a great part of the Discourses publish'd in this Volume.

R. W.

A Discourse of the Magnetical Variation, read July *7th.* 1686.

THe causes of Gravity and Magnetical Attraction are so far remov'd beyond the reach of our Senses, that the greatest part of Philosophers who have indeavour'd to give us an information thereof, have rather made us more sensible of their and our own Ignorance and Inability to do any thing therein, some making it Corporeal, some Spiritual; but what either of them mean either by Corpuscles or Magnetical Effluvia, or Atoms, or Magnetick Vertue, or Hylarchick Spirit, or Anima Mundi, when you come to inquire to the bottom you find, that neither they nor we know what is meant, and we do as good as say 'tis so, because it is so; the Reason of which I conceive to be, that Men are usually very impatient of the Labour of examining and trying, and of going the long and tedious way of coming to a certainty of knowledge by Experiments, wherein the progress is very slow, and, as it were, step by step; but affect rather to leap into a Theory at once, and make to themselves an Hypothesis upon some few Observations they have met with, or some few Experiments they have try'd, or some pretty Conception or Hypothesis they have accidently pitch'd upon that pleases them, to which with a little Shouldring they can make every cast to run, as it were, directly, though at last it miss the mark; yet, rather than they will indure the trouble of farther search by Trials or by Examinations and strict Reasoninings, they are contented to take up with somewhat that may serve to amuse.

It was for some time believ'd, that the Magnetical Needle did always respect the North and South Poles, not of the Earth, but of the Heavens, and that the Pole-star was that wherein the vertue did lie. In process of time it comes to be discover'd, that this vertue was not in the Heavens, but in the Earth, and that the Magnetical Needle, had, in some parts of the World, a considerable variation from the Meridian of the place, the North end declining in this part towards the East, in that towards the West, in some places more, in others less; but that this variation was fix'd and perpetual to the place, and that by reason, said some, for that there were to be found in the North certain Rocks or Mountains of Load-stones, which attracted the North end of the Needle to them from all parts of the World. But this, in a short time, also vanish'd as appearing ridiculous, and not answering to the Consequences that must have follow'd from it. Instead of which another cause is introduc'd for the variation, and that is the great Continents that lie either on this or that Hand, and the great Sea that lies on the other: Hence it was suppos'd that Variations would be found always regular, and the same in the same place at all times, as proceeding from the greater attraction from the parts of the Earth; which were more prominent and elevated, and which were not likely to be alter'd by time; at least, not enough to make a sensible variation of the variation. This was Dr. *Gilberts*, but in process of Time this was, by Mr. *Gillibrand* of this Colledge, and some others, found to alter, and there was found a variation of the variation of the Magnetick Needle in the same place, and that not verify'd in one, but in thousands of places. This overthrew all the former Hypotheses, and we are now to seek a new one; Mr. *Bond*, and Mr. *Philips*, and some others, have been hammering at a new Hypothesis, wherein they make the Magnetick vertue to be in the Air, and so the Magnetick Poles to be moveable in Circles round about the Poles of the Æquinoctial, and the Magnetick

netick Axis of the Earth to have a Conical motion about the Axis of the diurnal Revolution: Which Conical motion they suppose to be perform'd in a certain number of Years; so that at length the Polar Points of the Magnetick vertue after they have revolv'd a periodick Circle, return from the same Point from which they did begin. Others have taken other Hypotheses, and rais'd other Conclusions and Consequences from them; but still after all we are yet to seek whether this motion of the Magnetick Polar Points be in straight Line, or in a Curve as in a Circle, Ellipse, or some other more irregular Figure; whether it move round the diurnal Pole or some other Point; whether it move Eastward or Westward; whether it move nearer or farther off from the Pole; whether it move quicker at one time than another; whether it will return or continually proceed; whether there are only two or more Magnetical Poles; whether the Magnetical Axis of one, or Axes, if there are more than one, pass through the Center of the Globe, or besides it, and if more, whether parallel to each other, or Oblique, and whether one only hath a motion or whether both; whether these motions keep the same Velocities or differing; and many other the like Queries might be made; I could add a hundred, of which we are still to seek, and cannot give a positive answer, because there are not yet materials enough of Observations to build a certain Theory upon; and the Observations that have been hitherto made have been so gross and imperfect, that little of certainty can be concluded from them, and therefore such Observations can only be rectify'd by Time, by reason that the Degrees and Steps of this progressive motion are so far undefin'd, that some Years must be stay'd before the alterations that are made in the interim in the motion can be made sensible, and when sensible, they are very imperfectly defin'd. Hence, I suppose, it may have proceeded, that we have lately heard of some such Magnetical Observations as have seem'd to prove a station of that motion, and some others of a differing Nature, which, in probability, have proceeded from some imperfection in the Observation.

For if we consider the Nature of such Observations, how many Requisites there are necessary to make any one as it ought to be, we shall quickly find that our store of fit materials to work upon will be exceedingly small; and that upon examining into or querying upon such Observations as we meet with, we shall be apt to throw by and neglect as useless the greatest part: for there are but a very few in the World that are fit and able to make such Observations, or that know what is Pertinent and what Impertinent: Fewer there are that will be at the trouble of doing what they know fit, and tho' Skill, and Will be joyn'd, yet if Instruments and other assistances are wanting, they will come short of Perfection.

As tho' an Observer knows how to find the true meridian of the place, how to place his Needle, what inconveniences to look after for preventing (as the removing of all such Magnetical or Chalibeate Bodies as influence the Needle) how to observe the Angle the Needle makes with the Meridian Line, and the like; yet if he wants fitting Instruments, whether Mathematical or Magnetical, to do these Requisites and convenient Assistances, and a sufficient stock of Perseverance and Industry to prosecute the trials to the utmost exactness, the effect will be imperfect, whatever is look'd after beyond that exactness: For instance, after all other Requisites are found, if there be wanting such a Needle as will certainly distinguish to the sixth part of a Degree, then any such Observations are wholly useless in such Inquiries where a much greater accurateness is requir'd; and for the making them significant, there is no other way but staying a sufficient number of Years, and the courser the Observations be, the greater number of Years are requisite to make them equally useful; and even then they are altogether useless for answering many other Queries; as if it should be queried, whether the progress for that whole interval have been equal or unequal, and if unequal, what those Degrees have been and at what times, whether in differing Years, or differing parts of the same Year? *&c.*

Now since Time is that which cannot be alter'd, and that therefore Posterity only are like to have the Fruit of our Labours and Indeavours of that kind, I thought it would be best to make such Instruments as would make that sensible in a very short time, which, by the common, could not be but in a long, by those means if possible to reduce our Observations to use within the compass of our own Lives; for if a Needle could be made that should distinguish the alterations or the variation of the Variation, as nicely to the parts of a Minute as the present Needles do to the parts of a Degree, then should we discern as sensible an operation or alteration in one Year, as by the other in threescore, and in ten Years as in six hundred; for that all other requisite accurateness can be procur'd, as to distinguish the Meridian Line, the division of the Angles, the interpos'd space of time, the removal of impeding or altering materials that may influence the Needles.

Divers have attempted to procure Instruments fit for this purpose, some by Needles of great length, others by shorter view'd with Glasses or Microscopes, others by other ways, as by one of the late Leipsick Acta may be seen; every of which I conceive to be sufficient for this purpose, and do only aim to discover the divisions of the same Angle; that which I am now describing does that indeed of Consequence, but directly and immediately it magnifies or multiplies the Angle, by making that a Degree which is really but a Minute, and so by consequence contracting of time.

'Tis then, in short, is no other but this,

A Needle is fix'd at right Angles upon a very light and straight Axis of Wood or Brass, which Axis hath at each end the point of a very fine and sharp Needle, the finer and sharper the better, which is easily enough procurable: these Needles points are to be put into two small Center holes, made fit for them in a Ring, or Frame made after the shape in the draught.

THus far the Author. The Figure of the Instrument is represented in the ninth Plate, Figure the first, which may be understood without farther Explanation, which the Author has omitted.

Nov. 20. 1684. In my last Lecture I explain'd to you these two last Lines or Circles which are usually drawn upon the Superficies of a Globe made to represent the Body of the Earth, which were, First, All great Circls passing through the two Polar Points of the Earth, or those Points upon which the Body of it, or the *Primum Mobile* is continually mov'd round once in twenty four Hours, or the time of a natural Day, which are call'd Meridians. And, Secondly, All those Circular Lines, which may be suppos'd to be describ'd by all the Points of any one such Meridian, turn'd round upon the said Globe, suppos'd to stand still; or by the conversion of the Globe upon its Poles, the Meridian being suppos'd to stand still, the effect being the same in both cases as to this particular. These Lines or Circles are call'd Parallels, either because they are all parallel to one another, or rather because all the lesser of them are parallel to the middlemost and great Circle, which is call'd the Æquinoctial, Æquator, or most commonly be Seamen, the Line.

These two sorts of Circles are the principal made use of in the Description of the Superficial Parts of the Earth, and to which all other Lines made use of either in Geography, Astronomy, or Navigation are reduc'd, these alone serving to shew the Position and Situation of the several parts of the Earth to one another, and to determine the positive Point or Spot upon the Artificial Globe, every real place upon the Surface of the Earth ought to have, and *Vice Versa* any place situated on the Globe may be found upon the Earth: And being once so determin'd, 'tis suppos'd by most, that it is always the same, that is, the same place upon the Superficies of the Earth being once adjusted both as to its Longitude and Latitude, shall always remain and continue the same both in respect of the one and the other Position. As suppose this City of *London*, if the Latitude and Longitude be once certainly observ'd and determin'd, and so posited on the Globe, it is suppos'd that it shall always remain and continue to have the same in all succeeding Ages, without

without any Variation or Deviation from the same, whatever Deviation or Variation doth happen in the Cælestial Bodies without it. This, I say, is suppos'd or believ'd by the most Geographers and Astronomers: But yet not by all; for there have been, and there now are some, as particularly Monsienr *Pierre Pettit*, who have not only suppos'd, but positively asserted, that these also have a Variation, and that after a certain time both the Latitude and Longitude of many places, upon the Surface of the Earth, hath a sensible change and difference; and to confirm this he hath compar'd many Observations Recorded by the Antients, of the Latitude of divers places, as particularly those of *Paris*, *Rome*, and some other eminent places with later and modern Observations of the Latitudes of the same places; whereby 'tis found, that there are very considerable differences between them, which he ascribes to the variation of the Poles of the Earth. Certain it is, that later Observations concerning the Latitudes of several very eminent places of the World do very much differ from those that were assign'd them by the Antients; as particularly that of the famous Accademy of *Greece Athens*, whose present Latitude is found to differ almost two whole Degrees from what was formerly assign'd to it, as I have been inform'd by the Ingenious and Learn'd Traveller Mr. *Francis Vernon*, who with great care made the Observation. I could instance also in *Constantinople*, and several other eminent places not mention'd by Monsieur *Pettit*, but I shall omit them at present 'till some farther and more accurate trials be made for this purpose, and upon this occasion mention only, that, I conceive, it would not be amiss that there should be some Observations purposely made to examine this Theory, and reduce it to a certainty, for 'till that be done it is but Hypothetical to suppose the Polar Points of the Earth fix'd or moveable, there being as great a possibility of their moveableness, as there was of the Magnetical Poles, before the discovery thereof made by some of this College in the Year 1635. That, I suppose, which prompt'd Monsieur *Pettit* to make this assertion, or at least gave him a hint for this Inquiry, was a kind of mistake of *Joseph Scaliger* in an Epistle of his wrote to *David Rivaltus* upon the occasion of the Explanation of the variation of the Magnetical Needle from the true Meridian, made by Dr. *Gilbert* in his Book *de Magnete*, Publish'd not long before. This Epistle was Printed with other Works of his at *Paris* in the Year 1610. but written in the Year 1604 for by his Discourse he would seem to explain the Reason of the Magnetical Variation of the Meridians themselves, which he pretends must needs follow from the Theory of the præcession of the Æquinoctial Points, and yet at the same time he says, that the *Cynosure* or Tail of the lesser Bear was never farther from the North Pole of the World than now it is. But in short (to spend no more time upon declaring and explaining this Opinion) I say, 'tis very evident he understood not what he said himself, or if he did, 'tis certain he grosly mistook the Explanation of the matter, and has been long since confuted by *Maginus*, who was then professor of Astronomy at *Padua*.

The Latitude and Longitude of places varies.

Now if there be any ground for this Opinion, then must also follow an alteration of all the Meridians and Parallels imagin'd to be made upon this Globe of the Earth; for if the Polar Points, or the Axis of the diurnal motion of the Earth does vary, those must also vary with it, and consequently the Positions and Distances of all places, in respect of them, must vary also; and consequently, as *Scaliger* says, the Positions or Meridians of Dials, will, after a certain time, be false, as will also the very Dial itself, as if it had been remov'd and plac'd in a wrong Latitude and wrong Position. However, the Position and distances of places one to another will contain the same, tho' they differ in respect of the Heavens; and therefore if those be procur'd, tho' both the Latitude and Longitude of all should be alter'd, this Description or Picture of the Earth, upon the Artificial Globe, would remain true and unalter'd, and other Meridians and Parallels might be drawn over them.

But to leave this Digression for the present, I shall proceed to consider of the Divisions usually made upon these Circles describ'd upon the Artificial Globe.

All

The divisions usually made on the Globe.

All these Circles then both great and lesser are divided, or suppos'd to be divided into three hundred and sixty equal parts, which are call'd Degrees, Grades, Steps, but none of them are number'd quite round, save only the Æquinoctial, which noteth the divisions of Longitude, but all the rest are first divided into four equal parts, which are call'd Quadrants, and each Quadrant into ninety; what the reason was at first of pitching upon this number of three hundred and sixty, I know not, there being no Reason in Nature for this more than for some other Divisions, tho' the Astrologers make much thereof, and build much thereupon; but the most likely seems to have been this, that the Radius being equal to the Subtense of a sixth part of the Circle, did very naturally prompt them to that Primary and natural Division of it into six equal Parts or Sextants; which division also did both bisect and trisect the whole Circle, and gave them the Halfs and Trines, or Thirds; then bisection being the easiest of all other Sections, the bisecting the Bisection gave them the Quadrisection, Quadrants, or Quartiles of the whole; from these Quadrants setting off the Sextants either way, gave them the Duodecimals or Twelfs of the Circle, or the Thirds of the Quadrants or Quartiles. These Duodecimals in the Ecliptick, of which I shall hereafter speak, are call'd Signs, which signifies Marks, Divisions, or Sections of the Ecliptick. Thus far the cause of their Divisions seem'd reasonable enough, more especially for the New Moons being twelve in the Year; as did also their next of subdividing each of these into halves, making four and twenties or Hours, into which number they divided the Natural Day, or one whole Revolution of the Earth. But the *Chinese* and *Tartars* contented themselves with the Duodecimal, dividing the whole Revolution only into twelve Cha. which we must call Bi-hours; tho' on the contrary, they divided their Zodiack into twenty four parts, which we must call half Signs, being produc'd only by Bisection upon the first Sextants; but why the Eastern and Western *Literati* differ'd afterwards, is not easy to guess.

Of the reason why the Circles are divided in 360.

Difference between the Eastern and Western Literati.

And whether the Western *Literati* did divide these twenty fourths into fifteenths, that they might introduce into the Circle both Trisection and Quisection, which are both necessary to this subdivision, I dare not determine. That which seems to have been the most likely occasion, I conceive to have been the nearness of this number of three hundred and sixty to the natural Division of the Zodiack, by the annual motion of the Sun, which every Day doth almost measure such a space, compleating its Circuit in three hundred sixty five Days and a quarter almost, as the Revolutions of the Moon in a Year might prompt them to make use of the Duodecimal Section for the Zodiack. But whatever were the Occasions or Reasons that prompt'd them to these Divisions, certain it is that now all do agree to make use thereof, and call this twelfth part a Sign, and the three hundred and sixtieth part a Degree; and thence each Sign containeth thirty Degrees, each of these Degrees they again subdivide into sixty equal parts, which little parts they call Minutes or Primes, each of these Primes subdivided by sixty, give Seconds or Second Minutes; a sixtieth part of a Second is a Third, a sixtieth of a Third a Fourth, and so onward by Sexagesimal Subdivision, to Fifths, Sixths, Sevenths, in a continu'd Geometrical Progression, as far as is needful; for what Reason they have pitch'd upon this Sexagesimal Progression, I cannot imagine, unless it were because they had divided the Sextant (which, as I told you, was the first and most natural Division of the Circle, its Subtense being equal to the Radius) into sixty Degrees; but certain it is, that it is much more incommodious for Calculation than the common Decimal way, and much more than a Duodecimal, which might be invented; for that the Sexagesimal must take two places for every Ascent, whereas the Decimal takes up one place only for one Step or Ascent. So also might a Duodecimal, if rightly order'd, by making two new single Characters for ten and eleven, and making the Character of ten serve for twelve or Dozen; then the next or third place will be Grosses, the fourth Dugrosses, the fifth Gros Grosses, the sixth Du gros Grosses, and so onward, answerable to Unites, Tens, Hundreds, Thousands, Ten Thousands, Hundred Thousands, *&c.* in the Decimal progression of places. And tho' possibly the Names and

Practise

Practiſe of it may ſeem at firſt a little uncouth and ſtrange, yet a little uſe will eaſily overcome that difficulty, and make it manifeſt to be a much better Progreſſion than the Decimal, which is now generally uſed: But this only by the bye.

I ſhall next proceed to ſhew how theſe Diviſions are made uſe of in thoſe two ſorts of Circles. Firſt, Then, the Æquinoctial, and all the leſſer Circles, begin their Diviſions from the Section of them by that half of the Meridian which is call'd the firſt Meridian, which paſſes through the *Atlantick* Ocean, of which I have already ſpoken; and the Diviſions of them are accounted from thence Eaſtwardly, 'till the whole Revolution be compleated and end in this firſt Meridian in three hundred and ſixty. But the Diviſions made upon the Meridians begin to be number'd or accounted from the Æquinoctial, and end at each Pole in ninety, which expreſſes the ſeveral Latitudes of thoſe places that lie under them, or their breadth or diſtance from the Æquinoctial Line, either towards the North or South Pole.

Now, the next thing is to conſider, how both theſe Lines and the diviſions of them, proper and peculiar to any one place, may be actually found at that place, which is the ultimate end and reſult of all that is ſought for in the Art of Navigation; for theſe being truly found for any place, they preſently ſhew its true Poſition and Situation in the reſpect of all other known and determin'd places upon the Earth.

The end of the Art of Navigation.

In order to perform which Inquiry the whole Art of Navigation is contriv'd, and all the aſſiſtances that can be procur'd, either from Nature or Art, are fetch'd in and made uſe of; and all indeed that can be found, tho' very many and very curious and ingenious, are little enough, and too few to accompliſh the ſame to that certainty and accurateneſs that is to be deſir'd, and is neceſſary to compleat and perfect the ſame.

Two Helps.

The Helps then that are made uſe of are either afforded, Firſt, By the Heavens and the Cæleſtial Bodies, ſuch as the Sun, Moon, Planets and Stars.

Or, Secondly, By the Terreſtrial, or ſuch things upon and in the Body of the Earth itſelf, as afford Indications and Characterſticks proper and ſufficient to direct the Geographer and Hydrographer, for diſcovering and determining, by known meaſures, how every place is Poſited and Situated in reſpect of thoſe Lines I have already mention'd; and thence of determining their Poſition and Magnitude in reſpect to one another in regard of other imaginary Lines, which are taken in from Art to aſſiſt the Mariner in his Computations and Accounts; ſuch as are the Rhomb Lines and other great Circles which are neither Meridians nor Æquator, but ſuch as are neceſſary to be ſuppos'd either for computing the way of the Ship, or Courſe ſteer'd, or for computing and reſolving Triangles, or for giving the Poſition and neareſt diſtance between place and place, in a great Circle or determin'd Azymuth.

Three things to be found by the help of Cæleſtial Bodies.

Three things then may be found out by the help of the Cæleſtial Bodies.

Firſt, The Meridian Line or North and South Line, and conſequently all the other Azymuth Lines or Points of the Horizon on either ſide of the Meridian.

Secondly, The Latitude of any place, or the diſtance of that place from the Æquinoctial or the middlemoſt of all Parallels between the two Poles.

Thirdly, The Longitude of any place, or diſtance of the Meridian of the place from the Prime Meridian agreed upon.

Several Maxims premis'd.

But before I proceed to ſhew how theſe three things are to be found by the help of Cæleſtial Bodies, I conceive it neceſſary to premiſe ſome few Maxims which are not obvious to any, but ſuch as have by diligent Obſervation found out and demonſtrated the certainty thereof. The grounds and method of which Inventions would be as little to our preſent purpoſe as it would be tedious here to repeat. I ſhall rather chuſe to acquaint you with the Reſult or Concluſion which may be taken for granted, 'till ſome more curious and exact Obſervers, than have hitherto been, ſhall find and demonſtrate

the contrary, ſome of which may be done by Land Obſervations, but not by ſuch as can be made at Sea.

1. The Firſt Maxim then (of which we are ſufficiently aſſur'd for this purpoſe) is this, That the diſtance of the fixt Stars is ſo very great and immenſe in reſpect of the Magnitude of the Earth, that its whole Body is but as it were an inſenſible Point; ſo that the Figure, Appearance, Poſition and Diſtance of all the fixt Stars, to, or from, one another, doth to the naked Eye, or aſſiſted by the beſt common Inſtrument, appear exactly the ſame, whether the Eye be plac'd in the very Center of the Earth, or in any Point of the Superficies, or any other Point of the whole Body. So that not only the Center of the Earth may be taken to be the Center of the imaginary Concave Sphære wherein all the fixt Stars are plac'd, but any other Point whatſoever of its whole Extenſion or Corporeity.

2. A Second Maxim of the *Ariſtarchians* or *Copernicans* is this, That the diſtance of the fixt Stars is ſo incomprehenſibly great, that tho' the Earth be ſuppos'd to move round the Sun in a Circular or Elliptical Line, whoſe Diameter is ten thouſand times the Diameter of the Earth, yet that even this whole Circle, in compariſon of the imaginary Orb of the fixt Stars, is but a Point, and that therefore with the naked Eye and common Inſtruments no difference can be diſcover'd of the Diſtances and Poſitions of the fixt Stars in reſpect of one another, tho', as I have elſewhere ſhewn, there is a way to find a difference by the help of very long and good Teleſcopes, fixt at Land, but no Inſtruments at Sea can diſcover it; which is enough for our preſent purpoſe.

3. A Third Maxim is, That two Points of the Earth do ſteadily point or direct towards two Points among the fixt Stars in the Heavens, which Points are call'd the two Polar Points, the two in the Heavens being Perpendicular over the two on the Earth; and the Diameter of the Earth paſſing through theſe Points, is call'd the Axis of the World, and ſuppos'd to be continu'd to the fixt Stars: And tho' this Axis be carry'd round in the Orb of the Earth in a Parallelifm, and ſo deſcribes an Elliptical Cylinder, whoſe longeſt Diameter is the Diameter of the Earth's Orb about the Sun, yet ſo vaſtly are the fixt Stars diſtant, that this whole Ellipſis, among the fixt Stars, appears but a Point, and the Axis of the Earth ſeems to reſpect one and the ſame Point among the fixt Stars quite round the Year.

4. A Fourth Maxim is, That all Perpendicular Lines reſpect the Center of the Earth, and that the level of Water, and other Liquors is a plain and at right Angles with this Perpendicular in every Point of the Surface of the Earth.

5. Fifthly, That every one of theſe Perpendiculars, ſuppos'd continu'd to the fixt Stars, will, by the diurnal Rotation of the Earth, deſcribe, among the fixt Stars, a Circular Line; which Circular Line, anſwering to the Perpendicular or Zenith of any place, will appear the ſame round the Year, to any Inſtrument that can be us'd at Sea.

6. Sixthly, That the level of the Water, or any other Liquor ſuppos'd continu'd to the fixt Stars, will actually divide the whole Sphære thereof into two equal parts, tho' it be out of the Center of the Earth, and upon its Surface; and tho' the Body of the Earth itſelf be ſuppos'd to be as far diſtant from the Center of that Orb, as it is diſtant from the Center of the Sun.

7. Seventhly, That the viſible Angle of any Cæleſtial Body, with this Perpendicular or Zenith Line of any place, or with the plain of the level of the Water or Horizon, will be the ſame (as to any thing that can be diſcover'd by Inſtruments at Sea) as if the Center of the Inſtrument were in the Center

Center of the Earth, and that Center of the Earth were always in the Center of the Sun, and that Center of the Sun were the true Center of the Orb of the fixt Stars; and thence

Eighthly, We are to conclude that all Obſervations of the fixt Stars, wherefoever made upon the Surface of the Earth and Sea, will give the ſame appearances, as if the Eye or Center of the Inſtrument (by which ſuch an Angle is meaſur'd) were at all times in the Center of the Orb of the fixt Stars. 8.

Ninethly, That all Obſervations to be made of the Poſitions of the Sun in reſpect of the fixt Stars, will be the ſame, as if the Eye and Center of the Inſtrument were plac'd in the Center of the Earth; and that whether the Sun be ſuppos'd to be mov'd about the Earth, or the Earth about the Sun, the viſible appearances of the Place, Line, or Point of the Sun among the fixt Stars, will be in both caſes the ſame. 9.

I ſhall not now meddle with the appearances of the other Planetary Bodies, becauſe at preſent, for this purpoſe, I ſhall not have occaſion to make uſe of them, but reſerve the conſideration of their appearances to another part of this Diſcourſe, wherein I ſhall more particularly treat concerning the ways for finding the Longitude of places by Cæleſtial Helps.

Firſt then, for finding the true Meridian, or North and South Line of any place, there are very many and very differing ways that have been invented and Publiſh'd by ſeveral Authors for this purpoſe, of which ſome are much more difficult and complicated, and præ-ſuppoſe ſeveral things to be known which require another method than this I am now diſcourſing of; which may be very uſeful for performing other kinds of Problems, but are not ſo proper for what I here intend: Others that are more ſimple and plain, and yet ſufficient to perform this effect; ſome of theſe are more proper to be made uſe of at Land, others are more eaſy and practicable, and can be made uſe of at Sea as well as on the Land. *Ways for finding the Meridian.*

Theſe ways are either, Firſt, By help of the Sun in the Day-time, or by the help of the fixt Stars in the Night.

Thoſe, by the help of the Sun, are twofold; Firſt, By the help of an Azymuth Compaſs to obſerve the true Azymuth or Amplitude of the Body of the Sun in its Riſing in the Morning, and Setting at Night of the ſame Day in the Winter half Year, or the ſaid Amplitude of the Sun in Setting at Night, and riſing the next Morning in the Summer half Year; for by dividing the Angle, made by thoſe two Azymuths, into two equal parts, the Meridian Line for the place where it is inquir'd and obſerv'd is given, the Meridian Line this way found, is that which is moſt commonly us'd, and will be near enough the truth for any common uſe, as for finding the variation of the Compaſs for the place where it is made, *&c.* But yet, it is not exactly true, nor can it in ſome more curious Inquiries, be made uſe of, and that, Firſt, By reaſon that all the times of the Year, unleſs it be on the very ſolſtitial or longeſt and ſhorteſt Days, and even then alſo unleſs the Solſtice be exactly at Noon, the Sun is either increaſing or decreaſing its Declination; and ſo the Sun is really in a differing parallel in the Morning from what it was at Night of the ſame Night, and in an other parallel at Night than what it was in the Morning of the ſame Day, and conſequently the Riſing and Setting Azymuths or Amplitudes do not make equal Angles with the true Meridian Line; but the nearer the Sun is to either of the Solſtitical Points, the leſs the Error, and the nearer the Æquinoctial, the greater. *By the Sun two ways.* 1ſt. *Way.*

Secondly, The Meridian this way found is not exact, by reaſon of the differing Refraction of the Air in the Morning from what it is in the Evening, which I my ſelf have very often obſerv'd here at *London*, and may be much more conſiderable in more Southern Countries, where the difference between the warmth of the Air at Sun Riſing and Sun Setting is much more conſiderable than in this more temperate Climate, tho' on the other ſide that greater

greater difference of Refraction may, I confess, make a much less difference of Azymuth or Amplitude where, the Sun's Rising and Setting is nearer to a Perpendicularity to the Horizon. However, some uncertainty is thereby caus'd, and in no case, but what I before mention'd, is exact: However, this is better than the way that is most made use of at Sea, for finding the variation of the Magnetical Needle or Compass, tho' yet it be far enough from the accurateness desirable; for the way by them generally practis'd is not by comparing the Morning and Evening Amplitude together, but either the Morning or the Evening alone esteeming the apparent Amplitude to be that which by Instruments or Calculation for that Day and Latitude they are in, the true Amplitude ought to be, allowing nothing at all for Refraction; in which case the visible Amplitude, by Refraction, makes more difference from what it truly ought to be, than two Amplitudes compar'd together, tho' suffering differing Refractions, will produce.

A Second way of finding the Meridian of any place by the Sun, is this, First, By the help of an Azymuth Compass to observe the Azymuth of the Sun about three Hours before Noon, at the same moment another Person with some convenient Instrument observing the true Altitude of it above the Horizon, then staying 'till about three Hours after Noon, and watching diligently when the Sun is descended to the same Altitude or height it was observ'd at in the Morning, and noting the true Azymuth thereof, and proceeding to divide the Angle between the two Azymuths, this way found by the Azymuth Compass, into two equal parts; this doth give the Meridian Line, and at the same time the variation of the Compass. This is abundantly more exact than the former way; for, First, The Sun is to be taken when at a considerable height above the Horizon, and so by that means is free for the most part from Refraction, whereas the Refraction in the Horizon is sometimes exceeding great. Secondly, The times between the two Observations being but short, as four, five or six Hours at most; the difference that is caus'd by the Sun's altering its Declination, is not so sensible as in a longer time; and therefore this of the two is much to be prefer'd, and is sometimes made use of at Sea also.

Now these Azymuths may be easily enough observ'd upon the Land, where a Horizontal Floor may be procur'd convenient for this purpose; but at Sea, where the Ship is roul'd and turn'd by the unsteady Surface of the Waves, it seems more difficult. But even there also Art has not left the Mariner without a convenience of a Horizontal Plain, which may be call'd fix'd, and that is the Compass Needle or Chard conveniently suspended in a Box; for by its suspension it maintains its Level, and by the Magnetical Vertue of the middle it keeps its Position in respect of the Points of the Horizon, notwithstanding all the unsteadiness of the Vessel in which it is carry'd: But of this and other Instruments, I shall hereafter discourse more at large.

There is another way of finding the Azymuth by the Sun or Stars at all times, either of the Day or Night, and that is by the help of exact Clocks, either with a Pendulum, or some other exact way of equally and exactly measuring and dividing of Time; and this method will be the most easy, the most exact, and most practicable at Sea, such a Clock at all times giving the true time of the Day or Night, if it be set with care at the Rising and Setting of the Sun, and then either by some one of the Projections (for it may be done by all the three usual Projections with ease) or by the Doctrine of Triangles; the Azymuth of the Sun or Star, for that time, is given, the Latitude being suppos'd known; but the Meridian is given, tho' the Latitude be not suppos'd known, and without either Projection or Trigonometrical Calculation, if the times of Rising and Setting be noted; for if by the said Clock the exact time when the Sun is risen just above the Horizon in the Morning, so that the under Limb of it just touch the Horizon, be taken notice of and set down; and the time when the under Limb of the Sun just touches the Horizon in the Evening be constantly observ'd, it will be easy to know what Hour and Minute by the said Clock, will denote either the

Hour

Hour of Twelve at Noon, or the Hour of Twelve at Night; that is, when the Sun shall be in the Meridian of the place; for by halfing the time interjacent between the Rising and Setting, or between the Setting and Rising, you have the time of the Sun's being in the Meridian to be shewn by the said Clock; and, if it be desir'd, the Clock may, by this way, be daily adjusted to the Meridian of the place. As suppose by the Clock (not yet adjusted to the Meridian of the place, but yet going equally and adjusted to the length of the Day) it be observ'd, that the Sun in Setting just touches the Horizon at 1h. 26′. by the Hand of the Clock, and that the next Morning, when the Sun in Rising be just got clear above the Horizon, the Hand of the Clock points at 11. 48′. it will be easy to find what Hour, by the Hand of the said Clock so continuing moving without altering or setting the Hand, shall denote the Hour of Twelve for the following Day; for halfing the time between 1h. 26′. and 11h. 48′. which is 10h. 22′. you have 6h. 37′. for the Hour of Noon the following Day; for half the difference between 1h. 26′. and 11. 48′. being 5h. 11′. this being added to 1h. 26′. the Hour of Setting will shew the time of Midnight to be by the Clock 6h. 37′. and consequently the Hour will be the same when the Sun will be in the Meridian the next Day. Against this way it may be Objected,

First, That tho' the Clock be adjusted to the middle motion of the Sun, yet that That will not be true for the length of any Day in the Year without regard to the proper Æquation of Time for the Day of Observation. This I grant is so; but as the difference between the length of any one Day and any other is not very great, so will this difference be yet much less considerable, if it be made use of for to shew them, when is the time to observe the height of the Sun in the Meridian; and not much more considerable, if the knowing the time when the Sun is in the Meridian, the Line of North and South be to be found, or the variation of the Needle; but yet if it be thought necessary or considerable, it is easily provided against by a Table of Æquation of Time. *An Objection against this way obviated.*

But then there may be a Second Objection made against this way, and that is, that a Ship being suppos'd under Sail doth continually alter either its Latitude, or its Longitude, or both; and so, tho' the Clock so observ'd and adjusted, would at Land, or when the Ship lies at Anchor, serve to find the time when the Sun is in the Meridian, yet, by reason of this motion and progression of the Ship, the direction this way obtain'd cannot be just. This I grant is also a real cause of variety, and much greater than the former; yet 'tis not so great, but that it may be provided against, allowance being made for the same according as the case shall require; for by the Course Steer'd in the mean time, and the progress in that Course being taken notice of by the common way of keeping the Course, and distance Sail'd by the Logline and Compass, it will be easy to know, near enough for this purpose, what allowances are to be made, both in regard of the alterations of one and the other; and so the time of Noon (when the Sun is in the Meridian) may be accurately enough (for all uses at Sea) known and observ'd. And as this may serve to find the time, when the Sun is in the Meridian, in the Day, so may it serve to find the time when any notable Star, whose right Ascension is known, comes to the Meridian at Night; and so consequently (the declination of the Star being also known) of finding the Latitude of the place, by taking the Altitude of the said Star, when thus known, to be in the Meridian.---Which is the second way of finding the Meridian by the help of Cælestial Bodies in the Night. *A second Objection obviated.*

Now as the Meridian may be found by Stars, with the help of such a Clock, so may it be found out by the Amplitudes of their Rising and Setting, or their Azymuths observ'd with an Azymuth Compass, when they are found to be of the same Altitude, before they come to, and after they have pass'd the Meridian; the same methods being us'd, as I have already shewn, are necessary to be observ'd in finding the Meridian by the Sun.

A fourth way of finding the Meridian by the Stars near the Pole.

A Fourth way of finding the Meridian Line by the help of Cælestial Bodies is by such of the fixt Stars near either of the Poles, as in the place where the Observation is to be made, do neither Rise nor Set, but continually appear above the Horizon; this is done by noting their greatest Eastern and Western Digressions, by the help of an Azymuth Compass; for by comparing those two together, and halving the difference, the Meridian Line is easily known, and at the same time the variation of the Needle for the place, where such Observations shall be made. Now the Times and Positions of these Stars, when in their greatest Eastern and Western Digression, may be easily found, if the Day of the Year be known, and the right Ascensions and Declinations of those Stars be also known, and a Mapp be at hand to shew the Situation of those Stars in respect of one another, and in respect of the Polar Point, about which they seem to move; which is in part done in the Instrument call'd the Nocturnal. In making these Observations also, such a Clock, as I but now mention'd, will be of very good use to find the time precisely, when they are in their greatest Elongation from the Meridian.

These are (among multitudes of ways that have been proposed by Astronomers, Geographers, and Natural Writers) the most easy, plain, and obvious ways to be understood and practis'd by any one, not otherwise skill'd in Astronomy, nay, most of them even without knowing the Latitude of the place where the Observation is made, or the declination of the Sun, or place of the Planets or fixt Stars; which I have chosen the rather, because to me they seem more simple and prævious to them all; and therefore I chose first to discourse and explain them, after the ways of finding the Meridian, and consequently the variation of the Compass.

Of finding the Latitude.

The next thing that is to be obtain'd by Observations of Cælestial Bodies, is the Latitude of the place, or the distance of that place either Northwards or Southwards from the Æquinoctial Line. This is found various ways, both in the Day by the Sun, and in the Night by the Stars; and that with much ease after the true Meridian by the former method, and consequently the variation of the Compass for the place of inquiry, are first known; for by means of the Compass, so examin'd, the true Meridian Line is continually pointed out upon the Sea; and so it will easily appear when the Sun or Stars are in that Azymuth. The same thing is also found by the aforesaid Clock; then the declination of the Sun, or the true place of the Sun, for that time, being known for the Day, and the declination of the Star, to be observ'd, being known for the Night Observation, both which are express'd in Tables calculated for that purpose, by observing the Altitude of either, when in the Meridian, above the Horizon, and making allowance for the declination of the Body so observ'd, either by Addition or Subduction, as the Case requires, you find the height of the Æquinoctial Circle, which is the same with the distance of the Pole from the Zenith, the Complement of which is the Altitude of the Polar Point of the Heaven, or the distance of the Zenith of the place from the Æquinoctial Circle in the Heaven, or the Latitude of the place from the Line or Æquinoctial, suppos'd to be drawn upon the Earth.

The

THe Author having, in the foregoing Descourses treated of the Refraction or Inflection of the Air, as likewise concerning the drawing a true Meridian Line, and taking the Latitude of the place exactly at Land, I thought best to insert here the Abstracts of some Astronomical Lectures of that Subject, and give the descriptions of some Instruments contrived by him for the nice taking and dividing of Minute Angles, and some other useful Astronomical Instruments and Contrivances; especially, since I do not find them any where Published in any of his Works. When these Lectures were read, I know not, there being no date to them; but I judge by the Hand, and some other Circumstances, that they were read some Years before those of Navigation in 1683, *and the following Years; however, the time not being, as to this, material, I hope the Reader will not be displeased with them: They treat of the Sun's Distance, Refraction and Inflection of Rays: Of the Moon's distance: Instruments to take the Diameters of the Planets: To take Angles: To draw a true Meridian, and several other Astronomical Matters.*

R. W.

THe Perfection of Astronomy (a Science that has been cultivated in all Ages, but more highly improv'd in these last Centuries) depends very much upon the knowledge of the distance of those Cælestial Bodies, whose ways we would know, and whose motions and velocities we would calculate. Of which how certain we hitherto are, we need go no farther to be satisfy'd than to examine a few of the most famous Astronomers in their Opinions about the Distance or Parallax of the Sun. We find the noble *Ticho* to make the middle distance of the Sun 1150 Semidiameters. The ingenious *Kepler* in the *Rudolphine Tables* almost thrice as much, namely, 3381. The learned *Bullialdus* 1460; but *Vendelius* ten times more than he, and near fourteen times as much as *Ticho*, *viz.* 14656. with the half of which *Riccioli* is content making it only 7580. And these being deductions from their own several Parallaxes, and perhaps not any one of them from the true Parallax of the Sun, we shall not wonder to see them there also disagree as much *Ticho* making the Parallax of the Sun in its middle distance to be full 3′. 0″. *Kepler* only 1′. 0″. but *Bulliald* 2′. 21″. *Vendeline* 14″. and *Riccioli* 28″. And as *Hercules ex pede*, we may hence guess what is likely to be the Hypotheses of all the other Planets. Nor indeed shall we wonder if we consider, First, The accurateness requir'd both in their Calculations and Observations, and next the uncertainty of the Horizontal Refraction; and 'till this last be brought to a very great degree of accurateness and certainty, it is not to be expected that we shall ever certainly know the true distance of the Planets by the most accurate Calculations and Observations imaginable; for not to stay now on the consideration of what I shall by and by more largely manifest, *viz.* the small and suddain mutations of the internal parts of the Air from Heat and Cold, and Winds and Rains, and the like; we may from the differing Gravitation of the Atmosphere, which has been observ'd from the rising and falling of the Quicksilver in the Torricellian Experiments to be very considerable, namely, almost a fourteenth greater at some times than at others; we may, I say, from hence collect how uncertain the Refractions must be, which are caus'd by so unstable and uncertain a Medium. If therefore we that are thus plac'd this in Atmosphere, have yet a mind to know as much as could be known of those great Works of the Creator that seem to whirle about us and incompass us, we should, for that end, first consider well, and indeavour to acquaint our selves with the Nature of the Air or Medium, through which we look, that lying the first Obstacle in our way towards those Bodies, we would contemplate. And therefore the examination of the Nature of this transparent Medium which thus incompasses us, and through which we are fain to see all the Cælestial Bodies as through a Glass Window, will deserve and require our indeavours in the first place; for being ignorant of the Nature of this ambient pellucid Body, it will be very difficult to determine any thing positively and exactly about the distance and true place of the Planets. And to this end I do not at all like their way of examining it, who first choose an

Of the difference between Astronomers as to the Suns distance.

The cause thereof from the Refraction.

Hypothesis

Hypotheſis of the Planets diſtance, and from that collect the height of the Air and the Refraction of it, and by that means reconcile what Parallax they pleaſe to the Planet they obſerve. Nor yet their way who fancying an imaginary Surface of the Air, at I know not what height, and there giving it an arbitrary refractive Quality, ſtill make the Refraction of the Air as would reconcile all their Theories and Obſervations. Nor theirs who, from the Eclipſe of the Moon and ſhadow of the Earth, collect great matters; for (as I ſhall anon ſhew) all thoſe Phænomena may be explicated, tho' the Diameter of the Sun be no bigger, nay, tho' much leſs than that of the Earth, by means of the Refraction in the Atmoſphere, we being hitherto uncertain how great it may be, and 'till we are aſſur'd of it nothing can be concluded as to the diſtance of the Sun or Moon from the Eclipſes. But I rather therefore ſuppoſe it neceſſary for him that will know the true Nature of the Air as to Refraction, and the true Parallax or Diſtance of the Cæleſtial Bodies, to go quite other ways to work to find each of them a part. And for the examination of the Air it will be requiſite to collect and examine as many Phænomena of that kind as can be met with all. Such as theſe I ſhall now acquaint you with. It has been often obſerv'd, by the naked Eye, that the Sun and Moon, when near the Horizon, appear oval; but ſince the Invention------

The remainder of this Lecture is loſt.

I did the laſt Term indeavour to ſhew, from very many Experiments and Obſervations, that the Air or Atmoſphere, wherewith we are incompaſs'd, had in it two Proprieties not taken notice of before, which, 'till they were well underſtood, examin'd and regulated, would ſo far ſpoil all the moſt accurate Horizontal Obſervations that were not ſomewhat regulated according to them, that there could be no certain deductions from them of the Diſtance or Parallax of any Cæleſtial Body; no, not of the Moon itſelf, which is neareſt to us, and conſequently has the moſt ſenſible Parallax: For I then ſhew'd, that notwithſtanding all the Affirmations, and Theories, and Calculations, and Obſervations of the beſt and moſt accurate Aſtronomers, it was poſſible to ſolve all the Phænomena, tho' the Moon, for inſtance, were ſuppos'd not above a third part of the diſtance, ſhe is commonly by them ſuppos'd to be: For the Inflection of the Rays of Light, which is made in the ſeveral Regions and Spaces of the Air from the differing degrees of Expanſion and Condenſation of the parts of the Air in thoſe places, does ſo uncertainly bend thoſe Rays before they come to the Eye, that 'tis hardly poſſible by the moſt accurate and diligent Obſervations that can be made in any one place, to regulate one already rais'd Hypotheſis, or to found and eſtabliſh a new one; and therefore I ſhew'd, that certainly the beſt way to redreſs this inconvenience, will be to get certain Obſervations made of the way of the Moon among the ſmall or Teleſcopical fixt Stars, by two Perſons very far remov'd from each other in Latitude, tho' as exactly as could be ſeated under one and the ſame Meridian as to Longitude; each of which two Perſons ſhould obſerve exactly with an excellent Teleſcope fitted with a divided Ruler, the way of the Moon among the ſmall fixt Stars; and thereby we ſhould (by firſt regulating the diſtance and knowing certainly her apparent Diameter at that time when ſhe was at that diſtance) be able at all times by a ſingle Obſervation of her Diameter, with a good Teleſcope, without any further Calculation, certainly to obſerve and know her true diſtance at that time, and then it would be eaſy very to know alſo what muſt be her Parallax in all Altitudes above the Horizon, and conſequently it will be extreamly eaſy by the deduction of the Parallax of the Altitude of the Moon, to know, by the Obſervation, what is the then ſenſible Inflection of the Rays.

Of the Inflection of the Atmoſphere.

Two obſervers at a diſtance to obſerve the Moon's place among the fixt Stars.

How to know the Moon's true diſtance; and thence the Inflection of the Rays.

For the performing of which Obſervations, there ſeem to be very many things requiſite, which I ſhall indeavour to explain. And the firſt is a good Teleſcope about ſome ten or twelve Foot long; for this, if it be well fitted into a ſmall and light Tube, is eaſily enough managable by any one ſingle Perſon without much trouble. This Teleſcope is beſt adapted for Cæleſtial Obſervations, if it have only at that end which is next the Eye, one pretty deep

Requiſites for this Obſervation.

deep Convex Crystalline Glass well Polish'd and of clear Mettle; for thereby the Objects will appear much plainer and distincter, tho' there cannot be so much seen at a time, as through a Telescope fitted with two, or more Convex Eye-glasses: Then to fit this Instrument for the Observation of the Diameters of the ☉ ☾ ♄ ♃ ♂ ♀ or ☿, the most convenient and most easy way is to take a small piece of Wire, and to place it so within the Tube, at such a convenient distance from the Eye-glass, that the Eye indeavouring to look through the Tube may see it most distinctly; that is, it must be plac'd within the Tube just in the focus of that Eye-glass; then having by the Eye found the true distance of this Ruler to take it out and divide it into Inches, and Decimal parts of Inches, cutting with the edge of a Knife, or the like, very small cross Strokes or Gutters, in each of those Divisions, and every fifth or tenth Notch, to cut much deeper, so to make it more conspicuous. Having thus divided and mark'd it, this Ruler or Wire should be again put into its place, and the Tube directed against some Star in or near the Æquator, and in that Position so fixt, that the motion of that Star may be plainly observ'd passing along by the divided Ruler. Then having so adapted it, there should be provided a Pendulum made with a Thread and Plummet and adjusted to such a length, as may make it vibrate once every second Minute of Time; having this ready, the next thing to be done, is to place the Tube so, as that the Star may appear just coming into the Glass, then fixing the Tube, and observing 'till the Star be just upon one of the Divisions, let go the Pendulum, and observe the passage of the Star along by the Ruler, 'till by the vibration of the Pendulum you find a minute of Time past, or any other determinate number of Seconds you shall think fit, observing exactly how many Divisions on the Ruler the Star has past by in that time; for by this means it will be exceeding easy to observe how many of those Decimal divisions answer to the Subtense of a Minute of a Degree; for since we know that the motion of those Stars which are in, or very near to the Æquinoctial, is near a Minute of Longitude in four Seconds of Time, or a Degree of Longitude in four Minutes of Time, 'twill be very easy by observing the motion of the Star along the Ruler, and comparing it with the Vibrations of a Pendulum, to find what length of the Ruler does answer to a Minute, or the five Thousand four Hundredth part of a Quadrant; which having found, it will be easy to place several divisions on the other side of the Ruler, that each Minute may be divided into Seconds.

As in the fifth Figure of the eighth Table; suppose ABCD to represent the bright Area of Light appearing through the Telescope; let BD represent the Wire or Ruler, which seems, to one that looks through it, to divide that Area into two equal parts; let the small divisions on the under side be the Inches and Decimals; and let the divisions on the upper side E F G H I K, *&c.* represent the distances, which, by the Vibrations of the Pendulum, have been found to answer to a Minute; for having, by the Pendulum, found the Star to have mov'd from K to E in twenty Seconds of Time, it is manifest, if that distance be divided into five equal parts, each of these must answer to a first Minute of a Degree; each of which first Minutes or Distances EF FG GH HI, *&c.* may be again subdivided into a determinate number of equal parts, each of which will answer to so many second Minutes of a Degree; so that by this means not only the Diameters of the Sun and Moon may be found pretty exactly to Seconds, but the Diameters also of all the other Planets. The distances also of the small Telescopical Stars one from another, may, by this means, be very easily observ'd.

Description of the Instrument. Tab. 8. Fig. 5.

THo' this Instrument may serve very well for many uses, especially for observing the Velocities of the Motions, yet I shall subjoin the description of a much nicer divider for a Telescope, as I found it delineated and described on a loose Paper among the rest of the Author's Manuscripts; it was intitled The divider for Hevelius.

R. W.

The description of an Instrument for measuring the Minute distances of Objects at the focus of the Telescope.

Tab. 10. *Fig.* 1. A aaaa, a Ruler or Frame of Box, or other close Wood, of the form describ'd in the Figure, into which it is let in, a small Plate of Brass bbb upon which the equal divisions are made; there may be also a bended Plate let into the Circular Limb for measuring the Angle at e; ccccc, two Arms of Wood which open on the under side of the Ruler or Frame upon a Joint, whose Center must be plac'd as near the point e, as conveniently as it can without hindring the Prospect. dd a pair of Forceps, with a Screw like a Vice, one of whose sides is fix'd to the Ruler and the other moveable; for the holding the end of the Hair or the Silk-worms-clew ef, ef at the Point e, the other ends thereof being fastned to the ends of the Arms nn. gg, a diagonal Hair or Clew upon which the Divisions are to be measur'd fix'd into the Ruler at gg. eh, the middle Hair or Clew crossing the other at right Angles; kk two Screws, by which the Instrument is fix'd to the Tube of the Telescope. ll, two Arms of Wood fasten'd to the other Arms ccccc at qq, serving for the opening of the Arms equally from the middle Line, and for fixing them in any posture by the help of a Button or Screw, the end of which is m, the said Screw slipping in a small grove or slit oooo. The Line of division bb, I have here plac'd at ten times the distance of gg from the Point e: So that the divisions are made ten times more distinct at bb than they could be at gg; but this distance may be either increas'd or diminish'd, as there is occasion, and the whole Instrument may be made either bigger or less, according to the use thereof. *Thus far the Author's Description of it, the rest of the Contrivance is plain by the Figure.*

A double Telescope for taking Angles, this is afterwards describ'd

Now, because for making a compleat Hoop or Zone of all the fix'd Stars in the Zodiack, the Angle afforded by the help of a single Telescope, is not sufficient for taking the true distance of Stars when many Degrees remov'd from each other; therefore for such kind of Observations there is an Instrument which by the opening or shutting, or the moving of two six Foot Telescopes on a Joint in the manner of a Joint-Ruler, and a small diagonal Scale which measures the Angle they make with each other, when any two Stars, by two Observators, are at the same instant seen through those two Tubes; which Instrument I shall, on some other occasion, describe; for it is indeed one of the best for the observations of the distances and places of the Stars that has been yet thought on, and may serve also for measuring the Diameters of the Sun and Moon, tho' nothing near so exactly as the newly mention'd twelve Foot Telescope; for by the divided Ruler the Diameter of the Planets may be distinguish'd even to Seconds. Wherefore, if by means of Observations made at very far remov'd Stations, we can be assur'd of the distance of any of the Planets, and by this means, at the same time, we have the apparent Diameter of that Body, it will be exceeding easy at any other time, by observing the apparent Diameter with this Tube, to know the then true distance of the Planet at that time also; for the sines of the apparent Angles of the Diameter, and the respective distances will be very near reciprocal; that is, as the sine of the apparent Angle of the Body in the second Observation, to the sine of the apparent Angle in the first, so the distance of the Body in the first Observation, to the distance of the Body of second very near. *Tab.* 8. *Fig.* 6. As in the eighth Table, Fig. 6. Let A represent the Eye on the Earth, BC the Semidiameter of the Moon; for instance, in its the

Perigeum; AB the true diſtance of the Moon at that time from the Eye, BAC the apparent Angle of the Moon's Semidiameter; let DE repreſent the apparent Semidimameter of the Moon in its Apogeum; EAD the Angle under which it appears. Then on A, and the diſtance AC deſcribe the Circle CFG, and from F draw FG Perpendicular to AD; I ſay, as FG the ſine of the apparent Diameter in the ſecond Obſervation to BC the ſine of the apparent Diameter in the firſt; ſo is AC to AE; that is, ſo is the Radius of the leſſer Circle of diſtance to the Radius of the greater, that is, very near as the leſſer diſtance of the Center of the Planet is to the greater diſtance of the Center of the Planet: For DE is very near equal to CB by the ſuppoſition, as being the viſible Diameter of the ſame Body; tho' why 'tis otherwiſe I ſhall by and by ſhew; and AC is equal to AF, as being the Rays of the ſame Circle; therefore by the ſecond of the ſixth Book of *Euclid*, as FG to ED, that is, to CB; ſo is AF, that is AC to AE; which AC and AE give the diſtance of the Center of the Planet from the Eye much more exactly than the Lines AB or AD; tho' neither of them are exact but both ſomewhat leſs than the truth. To demonſtrate which let DEF in the ſeventh Figure repre- *Tab.* 8. *Fig.* 7. ſent the Body of the Sun, Moon, or other Planet, A the Eye, B the Center of that Body, AB the true diſtance of that Center from the Eye, DAB half the apparent Angle of the Body, AD a tangent Ray that touches the Globe DEF in D; from D let fall the Perpendicular DC on AB. I ſay then, that the Line AD ſhall be much nearer an equality to AB than AC; for by the eighteenth of the third of *Euclid*, ADB ſhall be a right Angle, and the Angle ACD is a right Angle by the Conſtruction, and the Angle DAC is common to both Triangles; therefore as AC to AD, ſo AD to AB: AD therefore will be a mean proportional between AC and AB, and conſequently will be nearer to an equality with AB than AC will be. Nor is the viſible Diameter of a Globe exactly the ſame at a nearer and farther diſtance, as I even now hinted: Nor indeed is it at any time exactly the true, but tho' the appearing Diameter be really always leſs than the true Diameter, yet does it always ſubtend a bigger Angle at the Eye. To demonſtrate which, let us ſuppoſe DEH to ſignify a great Circle drawn on the Body of the Moon, or *Tab.* 9. *Fig.* 2. other Globular Body, A the Eye, DC the Semidiameter of the viſible part, BG the true Semidiameter of the Body. I ſay therefore firſt, that DC is really leſs, tho' it appear bigger to the Eye than BG; for drawing the Line BD in the Triangle BCD, the Angle C is a right Angle, and conſequently BD is bigger than DC, therefore DC is leſs than BG which is equal to BD. But Secondly, I ſay, that DC ſubtends a greater Angle at the Eye than BG; for AD being by the ſuppoſition a tangent to the Circle at D, a Line, as AG drawn from any other point of the Semicircle HGE to the point A, muſt neceſſarily divide the Angle DAC into two parts, DAG and GAC; therefore GAC being but a part is leſs than the whole DAC. Further, I ſay, of the apparent Diameters at ſeveral Diſtances, that the ſhorter diſtance has always really the ſhorter apparent Diameter, but that that ſhorter Diameter does ſubtend a bigger Angle at the Eye. That the ſhorter diſtance has really the ſhorter viſible Diameter, is evident, becauſe the Bodies are Globular. To demonſtrate which, ſuppoſe ADFG, in the third Figure, to be a plain paſſing through the *Tab.* 9. *Fig.* 3. Eye and the Center of the Sun. Let A be the Eye farther remov'd, and B the Eye nearer plac'd to C the Center of the Sun. DEFH therefore being the interſection of this Plain, and the Superficies of the Sun or Planet will repreſent a greater Circle on that Body. From the Points A and B draw the Lines AE and AH and BDBJ; which may touch the Circle in EH, D and I, and from theſe two points draw the Lines EH and DI. I ſay therefore firſt, that the Diameter EH of the Disk. of the Sun apparent to the Eye A, is bigger than DJ the Diameter of the Disk. apparent to the Eye B; for drawing the Lines EC and DC, HC and IC, 'tis evident DCJ is leſs than ECH, and conſequently by the fifteenth of the third of *Euclids Elem.* that DI is leſs than EH. Next, I ſay, that the apparent Diameter DJ ſubtends a bigger Angle at B than EH does; for BD and BI being tangents to the Circle DGI, whatſoever Lines are drawn from the point B to any point of the Circle, muſt neceſſarily be drawn between BD and BJ, and conſequently

quently any two of them must make a lesser Angle than DBJ. But to omit these Niceties, which indeed are so inconsiderable in the observation of the Distance or Diameter of the Sun or Moon, and much more of the other smaller Planets, that with the most accurate Instruments that the Art of Man hath hitherto invented, they will hardly be discernable, as not amounting to $\frac{1}{10000}$ part of the Diameter of the Sun or Moon, when biggest, as may be seen by a Table of Natural Sines: It will be therefore sufficiently exact to make the Diameters and Distances Reciprocal. So that if by a good Telescope order'd, as I have directed, the apparent Diameters be heedfully observ'd, we may, supposing any one distance known, by means of two Observators, easily enough know the distance at any time, and consequently the present Parallax, and from that the Refraction, or rather Inflection of the Rays in the Atmosphere: We must therefore rectify our Refractions or Inflections, caus'd by the interpos'd Air, by our certain fore-knowledge of the present Parallax.

How to know the Moens Orbit exactly.

And this Method, tho' it be somewhat præposterous to the ways yet practis'd by the best Astronomers, is certainly the most Natural; for having once the certain Parallax of the Moon, we may very easily, from Observations, collect exactly in what kind of Line or Orbits he is mov'd about the Earth, and with what Velocity in what parts of that Orbit, and consequently from some few Observations, her true motions may be known, which we are hitherto not so sure of; and thence consequently 'twill be no difficult matter to Compose and Constitute a true and real Theory of the motion of the Moon, and to calculate Tables accordingly; which, tho' it has been hitherto pretended by very many, yet 'till some such Course as this be taken for the regulating of Observations, I fear 'twill not be in haste done. From which Tables, and a Hoop, or Zone of all the Telescopical Stars as well as visible, what could be less expected than an easy way for finding of the Longitudes of places? For 'twould be no more difficulty to know the true Longitude of any place then by a six Foot Telescope, which is very easily manageable at Sea to make an Observation of the appulse of the Moon to some fixt Star in that Zone, and from those exact Tables to calculate at what time that should be in the place for whose Meridian they are calculated, and at the same time to what a Clock 'twere in that place where the Observation is made.

To get a true Theory of the Sun and the obliquity of the Ecclíptick, &c.

Having, by this means, got the true Theory of the Moon, it will be so much the easier to find out the true Theory of the Sun; for by that of the Moon we shall be able to know the Inflection of the Rays in the Air, and consequently the Parallax of the Sun, if sensible, will be quickly found, and having its apparent Diameter measur'd with a good Telescope at that time when the Parallax was calculated, it will be very easy from the apparent Diameter of the same at any other time, thro' the same or any other Telescope fitted accordingly, to know the true Parallax of the Sun at the time of the Observation; and consequently both the Obliquity of the Ecclíptick will be exactly known, and the place or Velocity of the Sun in that Ecclíptick (or of the Earth in its Orbit which is all one) will be more easily found, which because the ways hitherto us'd of observing only the Meridian Altitudes, are not so accurate as might be desir'd, I shall propound a way which I think will be very easily practicable, and will afford most certain information of the apparent place of the Sun as to its Positions among the fix'd Stars at all times; and consequently a Year or two's Observations, made after this manner, will very exactly instruct one how to make exact Tables of the Velocity of the Sun or Earth in the Ecclíptick, and consequently to be the better enabl'd to raise a true Theory of the motion of the Sun or Earth; and so to be able more exactly to calculate the Ecclipses of both the Luminaries, and to foretel all the visible Phænomena of the Positions of those two Bodies one to another.

Ways to find the Meridian.

The way I propounded is this, First, To get in a convenient place for Observation, an exactly true Meridian Line drawn. This may be done very many ways, some more easy, others more exact: The most easy and plain way, and which is pretty exact also, if the Sun be near either of the Tropicks, is by procuring a large smooth Plain, which must be exactly level'd Horizontally and fixt in that Position; then finding the middle part and taking

ing there a Point, deſcribe about that Point, at ſeveral diſtances, ſeveral Circles one leſs than another; then erecting a Perpendicular ſtile in the Center, and obſervihg a Morning and Afternoon ſhadow of the Sun, where the ſhadow of the top touches the ſame Circle in two diſtant places, and dividing the interpos'd Arch between thoſe two parts into two equal parts, a Line drawn through that middle Point ſo found, and the Center of the Plain will give the true Meridian or North and South Line of the place.

And this ſuppoſing the Sun near the Tropick of *Cancer* or *Capricorn* will be pretty near the true Meridian. But in this Obſervation care ſhould be had, that the Sun be pretty much elevated above the Horizon, before the ſhadow be obſerv'd, becauſe of the varying Refractions at ſeveral times of the ſame Day. The Meridian likewiſe may be found when the Sun is in either of the Æquinoxes, by obſerving any two ſhadows of the Stile, and drawing a Line through them, and then to that Line from the Center, drawing another Line at right Angles; for this Perpendicular Line ſhall be in or very near the Meridian of the place.

A third way, but not ſo certain as either, may be, by a pretty large Magnetical Needle, ſuffer'd to play or move upon a very ſharp Point; for in many places, as at the preſent, here in *London*, the Needle will, by the Magnetiſm of the Earth, be directed very near the North and South Line of the place. But none of all theſe being exact, the two firſt being uncertain, by reaſon of the annual motion of the Sun or Earth; and this laſt by reaſon of the variation of the Magnetical direction of the Needle, 't will be requiſite to make uſe of ſome other that is more accurate.

And among theſe may be reckon'd the way by taking the Altitude and Azymuth of any known Star, which will require the calculation of a Triangle or two; or to obſerve the Azymuths of any Star when it is in the ſame Eaſtern and Weſtern height; or, which is beſt of all, to obſerve Azymuths of the moſt Eaſtern and Weſtern excurſions of a Star within or near the Artick Circle, which, how it may beſt be done, I ſhall ſhew in my next Diſcourſe, as likewiſe deſcribe ſome uſeful Inſtruments for Aſtronomical Obſervations. *The moſt exact way.*

I did, the laſt Day, propound three things that were requiſite for the Perfection of Aſtronomical Theories by Obſervations; and they are ſuch as, without which, we ſhall have but little certainty of any Hypotheſis whatſoever. And indeed they were ſuch as ſhould never be ſeperate; for either of them being wanting, the other would be imperfect: And therefore whenſoever any Obſervation is made of the one without taking notice of the other, that Obſervation muſt need be imperfect and inſignificant. The things to be obſerv'd, I ſhew'd, were three; the firſt was the true diſtance of the Body, whoſe way and motion was to be obſerv'd from the Center of the Earth; the only accurate way of doing which, I ſhew'd, was by means of two Obſervators very far remov'd from each other on the Surface of the Earth. I ſhew'd alſo, that the moſt convenient places, for ſuch ſtations, would be ſome two places as far remov'd from each other in point of Latitude, as could be conveniently found, and as near under the ſame Meridian or Degree of Longitude. That their beſt method of Obſervation would be to begin with the Moon, and to find her true diſtance; and next with the Sun, obſerving at the ſame time their apparent Diameters; for by that means I ſhew'd how the apparent Diameter of any one known diſtance being given, the true diſtance, at any other times, would be eaſily found from the apparent Diameters, and that therefore there needed no more trouble but only to obſerve the apparent Diameters by means of a good Teleſcope; and the true diſtance might, by Calculation, be preſently known; for I then ſhew'd, that the apparent Magnitude of the Diameter, and the diſtances were Reciprocal. I ſhew'd likewiſe by what means a Teleſcope might be ſo prepar'd as to be fit for ſuch Obſervations.

And therefore it were extreamly deſirable, that ſome, whoſe leiſure would permit them, would ſet upon this Work, and if they were not able to go through with the whole, to indeavour to do as much as were requiſite for

the Obſervations to be afterwards made, of the ways and motions of the Planets.

The fixt Stars in the Zodiack to be obſerv'd.

And for this end, if they did only regulate exactly all the places of the Stars within, or pretty near the Zodiack, that were either of the firſt, ſecond, or third Magnitude; it would be ſufficient for any Obſervations that were to be made of the Planets, eſpecially if the Obſervator were furniſh'd with an Inſtrument which I the laſt Day mention'd, and promis'd then more fully to deſcribe; and that is with a double Teleſcope, as I may ſo call it, or an Inſtrument, which, by means only of two Teleſcopes, mov'd on a Joint, and a Ruler divided by a Line of Chords anſwerable to the length of the Teleſcopes, does, by the help of two Obſervators, eaſily and moſt exactly determine the Angle of diſtance of any two Objects. This Inſtrument was invented by Sir *Chriſt. Wren*, a Perſon ſo eminent in all kind of Knowledge, and moſt eſpecially in Mathematical and Mechanical, that the naming him the Author will be a ſufficient commendation of the Inſtrument itſelf. Omitting therefore any further Praiſes of it, I ſhall indeavour, in as few words as may be to deſcribe the Inſtrument itſelf, and the ſeveral parts of it, the manner of rectifying it and uſing it for any Cæleſtial Obſervations.

Deſcription of the double Teleſcope. Tab. II. Fig. I.

The Inſtrument conſiſts of two ſquare Tubes or Boxes AB, and CD, which are each of them at B and D furniſh'd with a good Object-glaſs of ſix Foot, and at the other ends A and C are likewiſe furniſh'd with a very deep Lens or Eye-glaſs M N; each of them alſo have a ſmall Cell to keep the Eye at a due diſtance from the Glaſs; and at a convenient diſtance within thoſe Eye-glaſſes, as about O and P, are plac'd two ſmall Plates of Braſs, out of which a round hole is cut in the manner of the Figure R, only leaving a ſmall Triangle, whoſe Point juſt comes to the Center or middle of this Circle at S; this I call the Sight, the uſe of which I ſhall by and by deſcribe. Theſe two Tubes, thus fitted, are join'd together by a very firm Joint at E; which Joint is made ſo ſtrong and ſo exact, that the Tubes always, whether open or ſhut, keep in the ſame Plain: Theſe Tubes, being thus join'd, are firſt rectify'd to an exact Parallelifm one with another, by being directed ſo againſt ſome Star, and mov'd to and fro 'till the Star be ſeen through both of them at the ſame time to touch the Apex or Corner of the Triangle in the Sight; at which time, by means of a contrivance at the other end, they are fix'd in that Parallelifm; ſo that againſt whatſoever Star one of them be directed, the other will, in the ſame manner, be directed alſo; the conetrivance for fixing theſe Tubes at the ends A and C, is this: On the Tube CD is faſten'd a peice of Braſs JK, at the end J, of which, is made a Center or Hole L, at the ſame diſtance from the Tube that the Center E is of at the other end; and on to the Tube AB is likewiſe plac'd a correſponding piece of Braſs FG, which is not ſo fixt to the Tube as the other, but is made to ſlide a little, as occaſion ſhall require, between two pieces of Braſs T and V, but ſo as by means of a ſmall Screw H to be ſuddainly fix'd in any poſture; this piece of Braſs has likewiſe a ſmall Center or Hole L, at the ſame diſtance as near as may be, that the Center E is remov'd from the Tube AB; theſe two Centers are both join'd together by means of a ſmall Screw which paſſes through both of them; which being done the Screw H is looſn'd, and the Tubes are, by being both directed againſt the ſame Star, reduc'd to an exact Parallelifm; which being done, by the turning of the Screw H, the Plate FG is firmly fixt in that poſture to the Tube AB, and the Inſtrument is rectify'd for Obſervation.

This being done, the exact diſtance of the Centers E and L is meaſur'd, and by that diſtance as Radius a Ruler YY is divided, either into a Line of Chords, or, which is better, into ſuch equal parts whereof ten Thouſand make the whole Radius; then the Screw being remov'd that held the two Centers together at L, and two ſmall Sockets xz ſcrew'd on, through which this divided Ruler may ſlide, the one on the Center of the Plate FG, the other on that of IK. And the one end of the Ruler being fix'd in one of theſe Sockets, ſo as the beginning of the diviſions lies juſt over the Center of it; and the other part ſliding in the other Socket, according as the Tubes are more or leſs open'd from each other on the Center E; the two Obſervators

are

are to direct each of them his own Tube to the Star, which they have agreed upon to obſerve; ſo that at the ſame time one directs his Tube to one of thoſe Stars, the other directs his to the other Star, and when each of them has at the ſame inſtant rectify'd his Tube to the Star, he obſerves ſo that the Apex or Point of the Triangle in the ſight does juſt touch the Star, then he that has the Tube through whoſe Socket the divided Ruler ſlides by turning a ſmall Screw YZ, fixes thoſe Tubes in that poſture, and by the number of the equal diviſions of the Ruler, which meaſures the diſtance of the two Centers, the apparent Angle or diſtance of thoſe two Stars, is moſt exactly found to Minutes. And indeed, by means of a ſmall additional contrivance, which I ſhall elſewhere ſhew, it may not only be made to diſtinguiſh Angles to Minutes but to Seconds alſo. Now this Inſtrument, beſides this great exactneſs, has many other conveniences which may render it very conſiderable; for it may be made very light, and is alſo exceeding eaſily manageable, and by being clos'd together takes up but a little room, and may be eaſily tranſported from place to place, and made uſe of almoſt in any Chamber; and indeed all Particulars conſider'd, it is a worthy Product of its excellent Inventor: By this, not only the places of the fixt Stars may be regulated, but even the places of the Planets may moſt exactly be found.

I Shall here add the Deſcription of an Inſtrument for taking Angles at one Proſpect, as I found it deſcrib'd upon a looſe Paper. ee, ff, two long Rulers or Arms opening upon a Joint or Center g, hh a Ruler divided into a thouſand parts, meaſuring the Angle at g by a Table of Chords; ab, a Teleſcope fixt on the Ruler ff, ſo as that the middle of it may lie Perpendicular over the inner edge of the Ruler; a the place of the Croſs-ſight, b the Object-glaſs, i the Eye-glaſs, cc the Reflex-glaſs whoſe edge juſt touches the Center g, and whoſe Surface cc is in the ſame plain with that of the inner edge of the Ruler ee: On the backſide of which Glaſs is a Braſs Plate with two Ears dd, at right Angles, by which it is ſcrewed to the Ruler ee. Tab. 11. Fig. 2.

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If therefore by the Inſtrument deſcrib'd Page 502, all the Stars within or near the Zodiack were regulated and aſſertain'd, it would then be much more ſecure, taking the true diſtance of the Planets to be obſerv'd from them, and much more eaſy to find their true place in the Zodiack; and conſequently a much leſs number of ſuch kind of Obſervations would ſuffice to determine their true Ways, Motions and Velocities. Now, tho' that eminent Aſtronomer *Hevelius* has promis'd ſhortly to publiſh to the World a perfect Catalogue, not only of all the fix'd Stars already taken notice of in other Catalogues, but even of multitudes of others ſufficiently manifeſt to the naked Eye, yet we think that Expectation ſhould no ways diſcourage any from making Obſervations himſelf, ſince, at beſt, no Man can be ſo ſure of anothers Obſervations as of his own. And next, ſince it would not be a labour of very great difficulty to regulate the places of all the Stars of the firſt, ſecond and third Magnitude within or near the Zodiack, becauſe their number is not very great.

And, Thirdly, It cannot but be a great ſatisfaction to any ſuch Obſervator to find when thoſe others, promis'd by *Hevelius*, ſhall be Publiſh'd, that his own Obſervations do concur with thoſe of the other, or that he is aſſur'd that his own are more exact than thoſe.

But, Fourthly, And, moſt eſpecially, he ſhould not be deter'd, but much rather excited, ſince without ſuch Corrections of the places of the fixt Stars nothing can be done in any other Cæleſtial Obſervation, and conſequently ſuch a part of a Man's time, as to this deſign, will be wholly loſt. But to proceed with what I was ſaying concerning the Obſervations requiſite for the regulation of the Theories of the Planets; I ſay, ſuppoſing the true places of the fixt Stars, as to their Longitude and Latitude, were known, and ſuppoſing we had, from diſtant Obſervations, the Moons true diſtance from the Center of the Earth, and her apparent Diameter at that time, we might eaſily, by the Teleſcope, find her diſtance at all other times, and by her

Obſervations in order to regulate the Planets motions.

her appulſe to certain Stars, or diſtance from them, together with the time of the Obſervation and her apparent Diameter, we might eaſily know her true Poſition among the fixt Stars, in reſpect of the Center of the Earth; and if ſuch Obſervations were continu'd every Day for ſome Months, or rather ſome Years, we might expect another kind of Theory than any we have hitherto had of the Moon. Now the beſt time for making all theſe Obſervations of the Moon, ſhould be when it can, with convenience, be perform'd when the Moon comes juſt to the Meridian; at that time the Moon being leaſt incumbr'd with Refraction and Parallax; and as for the reducing of her Orbit to the Eccliptick, that will be eaſily enough done afterwards, when her paſſage among the fixt Stars is once well known; and, by the way, methinks it would be the beſt way for any ſuch Obſervator not to puzzle or prepoſſeſs himſelf with many Notions, Suppoſitions, Theories and Hypotheſes, but rather to lay aſide for a while, at leaſt, all thoſe Opinions of determinate Orbs, and Epicycles and Excentricks, and Circles and Elipſes, or any other pre-conceiv'd Notion, and only to make and regulate the Obſervations ſo (the manner of which I have already ſhewn) that the true Place or Poſition of the Moon, among the fixt Stars of the Zodiack, in reſpect of the Center of the Earth; and her true diſtance from the Center of the Earth in that Poſition, might be accurately found out and Regiſter'd; for by a good number of ſuch Obſervations and Collections, we ſhould not only be able to examine more narrowly all the already famous Hypotheſes, and to overthrow them perhaps, but to raiſe and excogitate divers others, ſuch as would at leaſt reſt upon a more ſure Foundation, and if carefully and conſiderately built be of a more ſound and ſubſtantial Structure.

Nor ſhould theſe kinds of Obſervations be made of the Moon only, but of the Sun. *Mercury*, ♀, ♂, ♃, and ♄; for tho' indeed their true diſtances from the Center of the Earth are not ſo eaſily known (tho' indeed we know not yet neither to how great a certainty Induſtry may bring us even in this particular alſo) tho', I ſay, the true diſtances of theſe Bodies from us be very difficult to be found, yet their comparative diſtances may much more eaſily; for, by the help of a very good Teleſcope, we may at all times obſerve their apparent Diameters moſt exactly, and conſequently ſince, as I have ſhew'd the laſt Day, the apparent Diameters and Diſtances are Reciprocal, we might have their comparative diſtances, and perhaps alſo from comparing ſeveral Circumſtances we might come by their true ones alſo. For ſuppoſing we had the diſtance of the Sun and Earth (the moſt likely way for finding which I ſhall anon explain) we might poſſibly find thoſe of the other Planets by ſome ſuch way as this, namely, by the accurate Obſervation of their apparent Diameters with an excellent Teleſcope of forty or rather threeſcore Foot long, when they are neareſt approaching their being hid by the Beams, and when they are in their oppoſition to the Sun; for by the comparing of theſe two we might be inform'd of the proportion between their diſtances at thoſe times, and conſequently the difference of thoſe two, ſeeming, for the moſt part, to be aſcribable to the great Orb of the Earth. It will not be difficult, from many of theſe Obſervations, to determine the proportion of the Diameter of the great Orb of the Earth to the Diameters of the Orb of *Saturn*, of the Orb of *Jupiter*, and of that of *Mars*; the Diameters alſo of *Venus* in her retrograde Conjunction with the Sun, and in her direct; that is, when ſhe is in her neareſt and fartheſt diſtance from the Earth, will very much help towards the finding the proportion of the Orb of *Mercury* about the Sun to that of the Earth.

As for the finding the true diſtance of the Sun, the beſt way would be by means of two Obſervators, plac'd as far aſunder as they could be conveniently; which two ſhould either at certain times of the Year (namely, when the Sun is in or very near either of the Solſtices) obſerve by the help of a Quadrant (which I ſhall another time more fully deſcribe) by which the Altitude of any Cæleſtial Body may be obſerv'd to ſecond Minutes; they ſhould, I ſay, with ſuch a Quadrant obſerve moſt exactly the Meridian heights of the Sun when in the Solſtice, being each of them moſt exactly aſſur'd of the true height of the Pole by obſerving the greateſt and leaſt height of ſome

notable

notable Star within the Artick Circle by means of this Inſtrument. And 'tis not unlikely but that by this means, theſe two Obſervators, comparing their Obſervations, may be able to deduce the Parallax of the Sun. But ſuppoſing that be exceeding difficult and ſcarce feaſable, yet ſome Ecclipſe of the Sun may ſo fall out as to be diſcernable by both; and then from the comparing of ſuch Obſervations made by each, 'twill be no difficult matter, ſuppoſing the diſtance of the Moon known, to know that of the Sun alſo: And having its true diſtance once given, together with its apparent Diameter at that time, its diſtance at any other time will be eaſily enough found, ſuppoſing its Diameter only obſerv'd.

Having found this, it will be eaſy, by Obſervations, to find out the Orbit of the Sun or Earth, and the Velocity of either of them in any part of it; and this will be by accurately obſerving and comparing the Appulſe of the Sun and any notable fixt Star, whoſe Longitude and Latitude is certainly known to the Meridian; obſerving likewiſe the exact Meridian Altitude of the Sun, together with its apparent Diameter. For performing of theſe Obſervations as they ſhould be, there will be three things requiſite beſides what I have already deſcrib'd, which was the Teleſcope; and thoſe three things are, Firſt, An exact Meridian Line or Inſtrument for Azymuths. Secondly, A moſt exact and manageable Quadrant for obſerving Altitudes. And, Thirdly, A moſt accurate Time-keeper, Watch, or Clock, each of which I ſhall deſcribe in their order.

of finding the Earth's Orbit.

Three things neceſſary.

I did, the laſt Day, ſhew the neceſſity of regulating the places of the fixt Stars before they could be made uſe of for finding the true place of any of the Planets, for I then hinted how much many of them had been found to deviate from the places aſſign'd them by *Ticho*. But becauſe it would be very difficult to rectify all the Conſtellations I then hinted; that it would be ſufficient for moſt Obſervations, if only thoſe Stars were regulated, which were the moſt conſpicuous or notable in or near the Zodiack; and for this purpoſe I did likewiſe then delineate and deſcribe a new and moſt exact Inſtrument, which I judg'd the moſt convenient for that purpoſe, of any that has yet been made uſe of, it being an Inſtrument very eaſily manageable, very little ſubject to Error from the make, and if diligence be us'd, ſuch as will eaſily enough diſtinguiſh every four Seconds. I did indeavour likewiſe to ſhew the manner of rectifying it, and uſing it for thoſe Obſervations. And indeed, if only a Cæleſtial Globe of all the fixt Stars were to be made, wherein only the Reſpect and Poſition of the Stars one to another were to be noted, there needed no other Inſtrument; but becauſe their particular Reſpects alſo, both to the Poles of the World, and to the Poles of the Eccliptick, that is, to the Poles of the diurnal and annual motion of the Earth, or rather indeed the places of thoſe Poles among them are to be taken notice of, therefore other Inſtruments alſo will be requiſite. Thoſe I mention'd the laſt Day would be three, and thoſe were, Firſt, An exact Meridian Line. Secondly, A moſt exact Quadrant for taking Altitudes. And, Thirdly, An exact Watch or Time-keeper. As for a Meridian Line the moſt exact way of obtaining it (to omit now ſeveral more common which I before hinted) is by obſerving by the help of certain Perpendiculars, the moſt Eaſtern and Weſtern Excurſions of ſome Star not far remov'd from the Pole at leaſt ſomewhere plac'd within the Artick Circle. The manner of doing which may, in ſhort, be this, Fix to ſome convenient Beam a very long Perpendicular or Plumb-line, whoſe ſuſpending String ſhould be of Braſs-wire of a ſmaller ſize, to the end of which ſhould be hung a Plummet of Lead, almoſt as big as the Wire will conviniently bear; this Plummet ſhould be ſo inclos'd within a Box, that it may conveniently move, ſo as to draw the Line Perpendicular, and yet be ſheltered from the motions and diſturbances of the outward Air. To the North of this, at a good diſtance, the farther the better, from a convenient Beam ſuſpend two other Perpendicular Lines carefully prepar'd and fitted according to the directions I gave for the former, and fix them ſo, that by looking by the firſt, and one of theſe, you may be able to ſee the moſt Eaſtern Excurſion, and by the firſt and the other of them, the moſt Weſtern Excurſion of the Pole-ſtar, or any other within the Artick Circle. And having theſe

To draw a true Meridian.

three Perpendiculars thus exactly regulated, it will not be difficult to suspend a fourth, so as that by looking by the first and fourth, the Angle made by the second, first and third, may be divided into two equal parts: Between the tops of these two Perpendiculars, extend also another small Wire which shall lie most exactly in the Meridian Line. And this I judge to be the most accurate way of any I have yet met with for finding the Meridian Line, and the most convenient for the uses hereafter to be mention'd. This Line will denote out the imaginary Circle which passes through the Pole of the World or of the diurnal Motion of the Earth, or the Pole of the Horizon or the Zenith of the place: And this being found it will be exceeding easy to find the exact place of the Pole in it. Not by the Meridian Altitudes of the Sun; which is to suppose that already most exactly known, which we shall afterward examine and find out; but by taking most exactly the height of any Star within the Artick Circle, when by these Perpendiculars it be found to be in the Meridian; for if by an exact Quadrant its height be observ'd when it crosses the Meridian below and above the Pole; and half the difference of those two heights be added to the least elevation or height found, it will give the exact Point among the fixt Stars, to which the Poles of the Earth do at that time tend: I say at that time, because it has been found that the Poles of the diurnal Motion of the Earth do in time change and alter their places among the fixt Stars, so as to describe a kind of Circle about a Point, in or very near the Poles of the Eccliptick or Annual motion of the Earth. I say, in or very near, because it has not been yet certainly determin'd what the variation of the Poles of the Eccliptick or the annual motion of the Earth is; and tho' various Astronomers have excogitated several Hypotheses, whereby they indeavour to make the variation of the Obliquity of the Eccliptick regular, and tho' some have ascrib'd that variation of that Obliquity to proceed from a motion of the fixt Stars, others from the variation of the very Orb of the Sun or Earth, others to the variation of the Æquinoctial; yet I cannot find by all the Observations that have hitherto been recorded, that the matter can be accurately determin'd; for since the places of the Stars, set down by the Antients, have been found by the noble *Ticho* to be in many particulars very false; and since that even of those exact and diligent Observations of *Ticho*, there are lately found, by the excellent *Hevelius*, as I hinted the last Day, so many of them most egregiously differing from those Places and Positions they are plac'd in by *Ticho*, what hope is there of bringing that to any certainty where the Ground-work or Foundation of Observations on which the Theories are to be built, are so unstable and uncertain? For either there can be no certain credit given to any Observations to be met with in Authors; or if there be, I see, no reason why we may not affirm even the very apparent distance of the fixt Stars one from another, or their Positions or Respects among themselves to be alter'd, and this or that Star to be really in an other Position to the Circumambient fixt Stars; that is, really to appear in an other place of the Heaven at this Day, than it did in the times of the Antient Astronomers. Now if this be so, it will be yet a further dispute, whether this has been caus'd by some slow motions of those Stars one among another; or whether by the alteration of the very Systeme of the Sun in respect of them; and tho' the first seem the more probable, there having of late Years been observ'd very strange variations and alterations as to Magnitude even among those fixt Stars; witness those several new Stars which have appear'd and disappear'd, and vary'd their Magnitudes to all degrees almost [witness also those Comets which have been by the latest and best Astronomers judg'd to be above the Orbs of the Planets, and to be equal'd with the Region of the fixt Stars;] [as to instance in no other than that new Star which has so many times appear'd and disappear'd in the Neck of *Cetus* which was observ'd by *Hevelius* in the Year 1660, and does not, that I can find, appear at this time, no not through a Telescope.] Tho', I say, these particulars might make it most probable, that those transpositions have been made even in the Regions of Stars; yet 'tis not impossible but that some variations even in the Systeme of the Sun, may make some sensible difference. And this, by the way, minds me of a thing which I have several Years since propounded

To find the Pole.

Of the Earths annual motion and Poles of the Eccliptick.

pounded as a thing worthy examination and experiment, and that is to be, by fixing a long and good Telescope directly against that Star of the Dragon, which is little more than three Degrees distant from the Pole of the Ecclip-tick, when in the Meridian, and to observe whether by that means there cannot be found a manifest difference between the Elevation or Altitude of it at two distant times of the Year; that is, supposing those two Observa-tions to be made at half a Years distance; for to me it seems not unlikely but that the annual Orb of the Earth (if such a motion it have) may, by this means, be perceiv'd to describe a small Circle about the Pole of the Eccliptick.

To examine that motion.

For since by a thirty six Foot Telescope it is exceeding easy to distinguish the Seconds of a Degree, nay, almost Thirds, 'tis uot improbable but that the annual Orb of the Earth may describe a Circle about the Pole of the Eccliptick, whose apparent Diameter may at least amount to some Seconds if not Minutes. And there seems not any more likely way in the World of determining the Truth or Falsity of the Copernican Systeme than by this means. Now, tho' these Stars which lie nearest the Pole of the Eccliptick, if other particulars be answerable, were the best for this kind of Observation, yet the Observation of the Pole-star may perhaps be sufficient; for if the difference of the Meridian Altitudes of those Stars that are near the Poles of the Eccliptick be considerable, those Stars also which are very near the Poles of the World, cannot chuse but have a sensible variation; and conse-quently also the Pole of the diurnal motion of the Earth will describe a small Ellipse near the Pole-star, which 'tis not unlikely but some such way as this may, by several Circumstances, detect. But to return to what I was saying a-bout the manner of examining the places of the fixt Stars. I say, it were extreamly desirable that a Cælestial Globe were so made, that the exact Place and Positions of all the Stars, in respect of one another, were most acturate-ly determin'd and delineated, without any regard at all to the Eccliptick or Æquator; that is, that the distances of the Stars from one another might, by accurate Observations to be made with the double Telescope, be defin'd, after which, from a sufficient number of accurate Observations to be made, as I shall by and by direct, the true Eccliptick or way of the Sun or Earth a-mong these Stars should be exactly found out and delineated: For it is sufficiently evident from the various Theories and Hypotheses, and Tables of Astronomers, and by the variations of them all from Observations, how much they are all of them hitherto to seek in many particulars, not only in a great measure of the true Motion or Velocity of the Sun or Earth in the Eccliptick Line, but somewhat also of the very Position of the Eccliptick-line itself, and consequently all the Æquations of times which are deduc'd from these, are somewhat uncertain also. Now for finding out the Ec-cliptick, the best way would be, First, To find out the true Point or Pole of the World, which may with care be most accurately done. Next the Æqua-tor or Æquinoctial Circle should be found, and for the Time and Year when the Observations are to be made, the Declination and right Ascension of some of the most notable Stars near the Æquator; that is, taking for the time the Longitude and Latitude of the Stars to be reckon'd after the same manner as the Longitude and Latitude of places on the Earth are, namely, by tak-ing a Meridian or great Circle passing through the Pole of the World, and any notable fixt Star, and for the present placing that as the first Meridian, as 'twere; then taking notice of the right ascension of the most notable Stars in respect of that Point where that great Circle cuts the Æquator, making some allowance in all the following Observation for the procession of the Æquinoxes, according as I shall by and by direct; and instead of the true Latitude of the Stars from the Eccliptick, which we will suppose yet to be sought, at least which we design hereby to examine, to take their Declina-tion *pro tempore*, from the Æquinoctial Circle. But because neither these nor the following Observations can be well made without the two other Instru-ments I formerly hinted; therefore in the next place I shall indeavour to de-scribe those and the manner of using them.

This was wrote before the Authors dttempt for the Earth's motion.

And,

The description of the Quadrant. Tab. 10. Fig. 2.

And First, For a Quadrant to observe the Altitudes and Angles of the fixt Stars or Planets, which shall be exceeding light, small and easily manageable, and yet shall be adapted so as to distinguish an Angle as exactly as a Quadrant made the usual way, shall be capable of performing, tho' it be twenty times bigger in Diameter, I shall add this following Description.

Prepare a Quadrant of Brass or Wood, or any other convenient Substance, that will neither warp nor shrink, such as ABC in the Figure, whose Radius PB may be about sixteen or eighteen Inches long, more or less; let, to one side of it, be fastned a long, square, hollow piece, as AD, of the same substance, and about a Foot longer than the Radius of the Quadrant having a perforation through the whole length of it, of about an Inch over, to serve for the Tube of a three Foot Telescope on the out side of the piece; suspended a Perpendicular or Plumb-line FE, whose Plummet F may be large and heavy; then prepare a small long Index, shaped in the manner of that in the Figure IHG, which should be of some matter that is exceeding light and stiff, such as the outside of a Cane, or the like; and so order'd, that the short end GH may counterpoise the longer HJ; which longer HJ should be taper'd into a very small and slender Stem, and point towards I: Into the part H of this should be let in a small piece of Brass k, into which should be drill'd an exceeding small and fine Hole or Center, the smaller the better, so that it will indure the finest Steel Wire tho' as small as the Hair of a Man's Head to pass through it, and no more; for the more curious and exact this contrivance be made, by so much the more exact will the Instrument itself prove: At the bigger end of this slender Index G, fix a small piece of Brass which may stand above the Plain about a quarter of an Inch, as X, and in the midst of it cut a very small slit only just big enough for the Plumb-line FE, to slide or be thrust between it. Having thus prepar'd this Index, by means of a small Steel Wire coming out of a hole in the middle Line of the Tube AD, at a convenient place of it, put on this Index, so that the small top of it, I, may reach and point to the small cross at F; the other end of this Wire passes through the hole of a small bended Arm of Brass NH, and is there fastned. Having thus fitted on this Index and hung on the Plumb-line EF, making it pass through the small slit of the Brass X, that is erected upon the bigger end of the Index GHI, set the piece AD Perpendicular, which you will be able to do to the greatest exactness imaginable; for by means of this small Index, if the piece AD be never so little out of its Perpendicularity, the top of the Index I, will make it most visible; so that by this means you may come to as great an exactness as if the piece AD, and the Plumb-line, were above sixty Foot long; for the end of the Index HI being near thirty Inches, and the Plumb-line being somewhat longer, and the shorter end of this Index being but one Inch, or the thirtieth part of the length, it will follow, that whatsoever motion is impress'd on the shorter end of the Index G, will be thirty times more sensible at the smaller end of the Index F, and consequently that the same exactness of Perpendicularity will be found, as if the length of the Perpendicular or Plumb-line were thirty times increas'd or lengthen'd, which would amount to more than threescore Foot. But thus far I have only explicated the way of setting the Quadrant most exactly Perpendicular. The next thing I am to shew is, how it will be able to determine Altitudes, not only to Minutes, but even to Seconds. The contrivance for performing which effect, for measuring, is this, Let the edge of the Quadrant BC be made of Brass, tho' the rest of the Quadrant be of Wood; let this edge be an Inch thick at least, and rounded most exactly and truly to the Center P; upon which Center P, make a Ruler PR to move, and on this fix a small Telescope MO of the same length with AD, namely, about three Foot long, having a very good Object-glass at M, and a very deep Eye-glass at O, and by this Glass the Position of an Object may more nicely be distinguish'd than it can be by any common sights, tho' they be plac'd more than sixty Foot asunder: And for the exact determination of the Angle that this visual Ray makes with the Perpendicular I, cause to be plac'd upon this Tube and Ruler a flat Circular Plate VXY, of about two Foot Diameter, the Limb of which I divide into three equal Parts, and each of

those

those I subdivide again into sixty Parts, and each of those sixty I again subdivide into sixty more; so that the whole Circumference, which will be about six Foot and a quarter, will be divided into ten Thousand eight Hundred parts; for thrice sixty will be one Hundred and Eighty, and sixty times one Hundred and Eighty will make one Thousand eight Hundred; which number of divisions it will easily enough bear, by means of Diagonals. This Circle is so fixt on the Ruler, that the Center of it Q may be distant from the edge or limb of the Quadrant BC, exactly one One Hundred and twentieth part of that Diameter; then prepare a small Cylinder of Brass, whose Diameter may be exactly the sixtieth part of the Radius PB, and whose length may be equal to the thickness of the edge or reim of the Quadrant; let this, by means of two small Centers or Pins, be mov'd in the hole, on the end of which Axis is put a small light Index ST; these things being so prepar'd, by means of a small String which is stretch'd on the broad edge of the Quadrant BC, and at the same time rould about and fix'd to the Cylinder Q; this Cylinder Q is so held by it, that, by the moving the Ruler PR three Degrees on the edge of the Quadrant, the small Cylinder Q makes a perfect Revolution, and consequently also the Index ST will make a compleat Revolution also: So that the Hand making a Revolution every three Degrees, and every of those three Degrees having a space or length of above twenty five Inches, it will not be difficult, as I shew'd before, to divide each of those Spaces into sixty Minutes, and each of those sixty Minutes into sixty Seconds. And this is that Instrument, which, if great Care and Art be us'd in the making of it, and in the manner of observing will be found as exact as a Quadrant of thirty or forty times that Radius, if not more, and for its lightness and smallness will be easily manageable and portable. I shall not now stay to shew the manner of rectifying and using it, but shall refer it to some other opportunity.

NB. *I do not find any thing more relating to this Quadrant nor the description of the Time-keeper here mention'd.*

R. W

The CONTENTS.

THE following Lectures were read in the Year 1685. *and contain Discourses relating to the knowledge of the Longitude, with several Methods that have been or may be made use of for that end; of which seven are here enumerated, and the first and second farther enlarged upon,* viz. *the* Astronomical *and* Hodometrical; *by the way, some curious Subjects are touch'd upon, in relation to observing* Ecclipses *of the* Moon, *the* Satellites *of* Jupiter, *&c. and afterwards proceeding to treat of the* Hodometrical *method, the Author discourses of the Nature of the* Rumb-line *and its Proprieties: In order to which he treats of some matters relating to Practical Geometry, as of a Point, Line, Circle,* &c. *and of the difficulty of drawing either a strait Line or Circle, of any considerable length, or Radius true; and having shewn some methods of dividing a Line given into all its* aliquot *parts, he concludes with some Reflections on the Nature and Properties of the* Logarithmick *and* Rumb-*line, but leaves the Subject unfinished.*

To these are added a way of drawing Arches of great Circles, and an account out of the French *Memoires, and another of Senr.* Cossini's, *touching the alteration of the Latitudes of Places, with the Author's Remarks thereon.*

R. W.

June 25. 1685. I have, in my former Lectures, explain'd those imaginary Lines upon the Surface of the Earth, which are of use in Navigation, and are found by the help of Cælestial Observations, *viz.* First, Meridians, being great Circles which pass through the two Poles of the Earth. And, Secondly, Parallels; namely, lesser Circles which are parallel to the Æquator, that great Circle which divides the Surface of the Earth into the Northern and Southern Hemispheres: And have shewn you, that all indeavours in the Art of Navigation, is to be able to find out the proper Circle of both kinds, which is peculiar to the place of the Ship. How the Parallel Circle is found I have also shew'd, *viz.* how the Latitude of a place, or the distance of it from the Æquinoctial Line, is to be found by Cælestial Observations, either of the Sun in the Day time, or of the fix'd Stars in the Night; the methods of which are very easy, and commonly known and practis'd, tho' not without considerable defects both in the Instruments and the common practise of Observation, as I shall explain more at large when I treat concerning the Nautical Instruments, and their use at Sea.

I have likewise explain'd the ways of finding the Position of the Meridian, or the North and South Line of a place, by the help of Cælestial Observations, and of the Magnetical Needle, and at the same time of finding how much that Magnetical Needle or Compass doth vary there-from either towards the East, or towards the West. But this is only the finding of the Meridian consider'd as an Azymuth Circle, and not the finding of the Meridian peculiar to the place in respect of any other Meridian which passeth through some other place; which is that which is requir'd to the determination of the Position of a place upon the Surface of the Earth in respect of the Parallel and Meridian, which is the main end of Geography and Navigation.

What the Longitude is.

The finding then of the Meridian of a place, which I here intend, is the finding which of all the infinite Meridian Circles which pass through the two Poles and cut the Æquinoctial at right Angles, is the Meridian that passes through the place where, or for which the inquiry is made; that is, what Angle that Meridian maketh at the Pole with any other known or determin'd Meridian that passes through any other known and assign'd place, or what part or parts of the Æquinoctial Circle are intercepted between the two Points where the said Meridians cut the said Circle. This is that Ploblem which

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is call'd the finding of the Longitude of a Place, and which hath for ſo long a time puzzl'd all the Geographers, Aſtronomers, and Geometricians to find out a demonſtrative and practical way to reſolve; and which, nothwithſtanding the multitude of ingenious attempts that have been made for that purpoſe, doth hitherto remain an unſolvable Problem, eſpecially at all times and at Sea, where the moſt uſe of it would be. Not but that much hath been done towards it, by various inventions, which, tho' not compleat and perfect in their kind, are yet of very great uſe in Geography and Navigation, as I ſhall by and by ſhew. But the perfecting of this Art is, yet as a thing wanting in the World, and very much ſought for. And this the more, becauſe Geography and Navigation are lame without it, having but one of its two Leggs good and ſound, the other being but a Stilt or Prop; however it hath hitherto ſerv'd to carry on the practice of Navigation, by which the greateſt part of the World hath been not only diſcover'd but Traded to, and by means hereof every one part almoſt of the Earth, eſpecially of Maritine Parts hath Communication with every other. It will therefore deſerve to be inquir'd into and deſcrib'd as to that ſtate of Perfection and Practice which it hath now attain'd; that from the knowledge from what ſtate it is in at preſent, we may be the better able to diſcover its Defects, and what it further wants to make it compleat and perfect.

The helps then that have been propounded or made uſe of hitherto for finding the difference of Longitude between two places, or the Angle that their reſpective Meridians make at the Pole, may be reduc'd to theſe ſeven general Heads.

Seven methods for finding the Longitude.

Firſt, Aſtronomical, ſuch as depend only upon Cæleſtial Motions and Obſervations.

Secondly, Hodometrical; ſuch as depend upon the Menſuration and Computation of Courſe and Diſtance.

Thirdly, Magnetical; ſuch a depend wholly upon Magnetical Proprieties and Inſtruments.

Fourthly, Chronometrical; ſuch as depend upon an exact Menſuration and Computation of Time.

Fifthly, Mechanical; ſuch as depend upon ſome Mechanical Inventions, and have no relation to any of the former.

Sixthly, Phyſical; ſuch as depend wholly upon ſome Phyſical Proprieties of the Body of the Earth.

Seventhly, Mixed or Compounded ways, making uſe of two, or more, of the former ſix principal Heads.

The Aſtronomical methods.

Firſt, Then, for the Aſtronomical Methods, or ſuch as depend wholy upon Cæleſtial Motions and Obſervations; there have been divers ways thought of, all which may be reduc'd to two Heads.

Firſt, Such as depend only upon ſome Cæleſtial appearance made for the effecting of this Inquiry in ſeveral parts of the ſame Hemiſphere, without reſpect to Aſtronomical Tables. Or,

Secondly, Such as depend upon the truth of Aſtronomical Tables, calculated for ſome known Meridian, to which ſuch Obſervations may be referr'd, and the Longitude of any place, where ſuch an Obſervation is made, may be preſently deduc'd. Now, tho' no Aſtronomical Tables have been ſo perfect and compleat as to perform what is neceſſary, yet they have notwithſtanding been founded upon a true Ground and Principle, and have failed only upon the account of the Imperfection of the Theories yet known of Cæleſtial motions, a help for which I intend ſhortly to publiſh.

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Six of them. The first way is by the Ecclipses of the Moon, observ'd either at several places, or at one place only.

The second way is by observing the place of the Moon crossing or reduc'd to the Ecclipticck.

The third way is by observing the true place of the Moon in any part of her Orb or Dragon, which is various ways perform'd, either by taking her distance from one or more fix'd Stars, or from Altitudes taken in known Azymuths.

The fourth way is by observing, with a good Telescope, the progress of the Light and Darkness over the spots and marks in the Face of the Moon. These four last ways suppose a perfect Theory, and Tables of the Lunar motions, both which are yet wanting.

The fifth way is by the Satellites of *Jupiter*, or by the fix'd spot in one of the Belts of *Jupiter*; and this either observ'd at divers places, or at one only. This last supposeth a perfect Theory and Tables of the motion of *Jupiter*'s Satellites, which are yet wanted.

The sixth is by the Satellites of *Saturn*. These two last ways are to be observ'd by the help of long Telescopes, without which, the motions and appearances requisite for this purpose, cannot be observ'd; and therefore 'till better Telescopes be found than those we have at present (such as, tho' of but a short and manageable length, as of three or four Foot, will yet make the appearances as plain as one of those we now use of thirty or thirty six Foot long) these ways will be of little or no use upon the Sea, tho' they may be of very considerable use upon the Land in those Towns or parts where the Ship has occasion to stay. First, Because they happen very often in comparison of Lunar Ecclipses: And, Secondly, Because by Observations of these kinds made on the Land at such places, compar'd with Observations made at any other known place, the difference of Longtitude between those places will be rectify'd, and consequently they will much help to the rectifying Mapps or Chards, which is one very necessary Instrument to be made use of in Navigation.

Some things premised. Now for the better understanding of all these Astronomical ways of inquiring the Longitude of a place, it is necessary to premise some præcognita which are necessary to be known, in order to a better comprehension of them.

It is to be observ'd then, that every place upon the Surface of the Earth hath a Cælestial as well as a Terrestrial Meridian, that is, the imaginary plain of the Meridian of each place suppos'd extended to the Orb of the fix'd Stars, doth design an imaginary Line among them; which, as the imaginary Meridians upon the Earth are suppos'd to pas through the *Arctick* and *Autarctick* Poles or Points upon the Surface of the Earth, so the imaginary Meridians answering to them in the Heavens, are suppos'd to pass through the two Poles of the Æquinoctial in the Heavens, upon which is made the diurnal motions of the Heavens in the Ptolomaick Hypothesis. When therefore the Sun is seen in any place to be in the Meridian of that place it is twelve of the Clock at that place, but at no other place whatsoever but such as lie under the same Meridian, for to all other places it is either before or after Noon. So that as many Degrees as a place lies Eastward of the place in which the Sun is at that present in the Meridian, by so many Degrees doth the Sun there appear to have past it, and by how many it lies more West, by so many doth the Sun want of coming to its Meridian; and because the Sun passeth three hundred and sixty Degrees in twenty four Hours, and consequently fifteen Degrees in an Hour, and fifteen Minutes in a Minute, and fifteen Seconds in a Second of Time, therefore it is easy to reduce the Degrees and Minutes of the difference of Longitude to Hours and Minutes of Time, and contrary wise, to reduce Hours, Minutes and Seconds of Time to Degrees, Minutes and Seconds of Longitude.

This being premis'd, I come next to the Explication of the Astronomical methods

The first method by Ecclipses of the Moon. The First then, and principal, which hath been often practic'd, and which hath been of very good use for discovering the Longitude of Places, is that by an Ecclipse of the Moon, observ'd first in differing places at the same

ſame moments of univerſal time, but at different Local times: This Eclipſe of the Moon being an accidental darkning of the whole or ſome part of the Moon's Face, by reaſon of the Moon's paſſage through ſome part of the conical ſhadow of the Body of the Earth, becomes viſible to more than a Hemiſphere of the Surface of the Earth. So that if the ſame were obſerv'd accurately in as many places as it could be ſeen at, this alone would ſhew the true Longitude of all thoſe places in reſpect of one another, and would be a means to rectify the Mapps for all ſuch parts. By Local time, I mean that denomination of one and the ſame inſtant of univerſal time which it receives in ſeveral places, from the reſpect that the Cæleſtial Bodies have at that inſtant to the Horizons and Meridians of thoſe ſeveral places; becauſe the ſame inſtant that is call'd twelve a Clock in one place where the Sun appears in the Meridian, is in other places call'd, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, a Clock, and all other denominations of Minutes, Seconds, *&c.* that can be in the twenty four Hours of the Day. Now the beginning and end of an Eclipſe of the Moon being made in leſs than a Minute of time (for it is eaſy, by the naked Eye, to diſcover, within leſs than a Minute, when the real ſhadow juſt touches the Limb of the Moon, and by the Teleſcopes to diſcover to leſs than a quarter of a Minute) if thoſe times be diligently obſerv'd in ſeveral places, and adjuſted exactly to the Local times of thoſe places, the different Local times being compar'd will give the different Longitude of thoſe places in reſpect of one another; for every Hours difference of time gives fifteen Degrees difference, and every minute of time gives fifteen minutes of a Degree of Longitude: And by ſo much the ſooner or earlier in the Local time of the Natural Day of each place it appears, by ſo much the more Weſtwardly is the place ſituated; and by ſo much the later the ſame appearances are ſeen in each place, by ſo much the more Eaſtwardly is the ſituation of that place. 'Tis true, that in ſuch places where the Eclipſe appeareth near the Horizon, reſpect ought to be had of the Refraction and Parallax of the Moon, in giving the viſible Poſition of the Moon in reſpect of the fix'd Stars that may paſs under or very near to it, when ſo Eclipſed; but if we only regard the Local time, that may be exactly found by the fix'd Stars, either by taking their Altitudes or obſerving their Tranſits by the Meridian, without having any regard at all to either of them.

Local time what.

The whole uncertainty that happens to Obſervations of this kind, is only from the difficulty of diſcovering the very moments of the beginning and end of the Ecclipſe, becauſe of a certain penumbra or leſſer ſhadow which incompaſſeth this Conical ſhadow of the Earth; inſomuch, that I have often obſerv'd this Penumbra to dusk that Limb of the Moon which is next the Cone for near half an Hour before the real ſhadow toucheth it, and for as long after the real ſhadow is gone off from it, after the end of an Eclipſe. But generally the Umbra is ſo much differing from the Penumbra, that one may, with eaſe, be certain; to leſs than a minute of time, when it toucheth the Limb, eſpecially in Immerſions and Emerſions out of the total darkneſs in total Eclipſes. Thoſe that have the convenience of Teleſcopes may have the particular intermediate times when the Umbra doth cover or paſs through the middle of ſome remarkable ſpots in the Face of the Moon as the ſhadow comes on or goes off; becauſe the Limb of the Umbra is much more defin'd upon the Face of the Moon, when both the light and the dark parts can be ſeen together; and 'twill not be difficult this way to be certain to leſs than fifteen Seconds of Time, and conſequently to be ſure of the difference of Meridians to leſs than four minutes of a Degree; which is as near to exactneſs as need be, for moſt Geographical or Nautical Uſes. For the uſefulneſs and practicableneſs of this way I could produce you multitudes of inſtances of the Rectification of the Longitudes of places from one another, and conſequently of the true ground of making or rectifying of Mapps; but I ſhall only inſtance in one or two: The firſt ſhall be that which was made by Captain *Thomas James* at *Charlton* in *Hudſon's Bay*, *October* the 29th 1631, and by Mr. *Henry Gellibrand* profeſſor of Aſtronomy in this Houſe, where he, with ſeveral other Friends, made the Obſervation of the ſame Eclipſes. Now, after the return of the ſaid Captain *James*, Mr. *Gellibrand* comparing

The difficulty in obſerving Eclipſes of the Moon and how to obviate it.

the two Obſervations together, found that the Meridian of *Charlton* was Weſtward of the Meridian of *London* five hours eighteen minutes in Time; or in Degrees of Latitude, 79°. 30′. This he verify'd alſo by another method, of which I ſhall have occaſion to ſpeak hereafter, and found the difference of Meridians of thoſe two places to be in time 5h. 14m. or in Degrees of Longitude 78°. 30′. which differs from the former account but four minutes of Time, or one Degree of Longitude. Now what difference did thus ariſe between the account of the former, and the latter way is certainly to be aſcrib'd to the latter method, which was more complicated and depended upon the truth of Tables, there being no Obſervation made here at this place to correſpond with Captain *James*'s made at *Charlton:* However, Mr. *Gellibrand* in his appology thinks it may be the better born withal, ſince it could come ſo near the truth in the finding the difference of Longitude of Places ſo far remov'd; ſince very famous Authors, who have ſought the Longitude of Places by other methods, have differ'd from one another, and from the truth ſo much more; for giving an inſtance of the ſituation of two eminent Cities here in *Europe*, not very far from one another, and which have each of them had very eminent Mathematicians and Aſtronomers, *viz. Rome* and *Norimberg: Regiomontanus* makes their difference of Longitude 36; *Werner* 32; *Appian* 34; *Meſtline* and *Origanus* 33; *Stofler* 18; *Maginus* 26; *Schonerus* 12; *Mercator* and *Hondiuso* 12. *Stadius* 13; *Janſonius* 10; *Longomontanus* 16; *Lausbergius* 10; but *Kepler* by two Obſervations of two Lunar Ecclipſes, made according to this method, deſtroys them all, and proves them to be different but only four minutes of Time.

So that we may plainly perceive that this method, if it be duly obſerv'd, and the Obſervations accurately and judiciouſly made, is much to be preferr'd before divers others. And therefore I do very much wonder why the Learn'd Dr. *Voſſius* in his late Treatiſe, that he hath publiſh'd concerning the rectification of the Longitudes of places, ſhould reject this way as fallacious and uncertain, whereas 'tis moſt undeniably certain that 'tis infinitely to be preferr'd before the other ways which he there mentions: And indeed conſidering the facility and obviouſneſs of it to any ones underſtanding, and thence the practicableneſs of it by any of the moſt ordinary Capacity, and with the leaſt apparatus of Inſtruments, and without a ſuppoſition of the perfection of Aſtronomical Tables; I think I may pronounce it the moſt generally practicable way yet known; not but that ſeveral of the other Aſtronomical ways which I am to explain, will, with great Care and Circumſpection, and convenient Inſtruments, together with intelligent Aſtronomers to perform the Obſervations and Calculation, bring us to a much greater preciſeneſs. But ſince thoſe Requiſites are not at all times and places to be procur'd, there is more of real good to be expected from this one method, than from any other yet known; and to hint that only by the bye, I find that this Obſervation of Captain *James* and Mr. *Gellibrand* doth prove, that the moſt part of the *Dutch* Mapps have made that place in *Hudſons-Bay* above ten Degrees of Longitude too much to the Weſtward.

There are other inſtances of this Nature might be produc'd to ſhew that ſeveral parts of the Eaſt Indies are, in the Mapps, plac'd too far to the Eaſtward, contrary to the ſuppoſition of Dr. *Voſſius* in his late Treatiſe. But I ſhall not now inſiſt upon further proof of that which will be ſo eaſily underſtood by any one, who ſhall well conſider of its Principles.

The ſecond method by the Satellites of Jupiter.

Next to this way I ſhall annex that of obſerving the *Satellites* of *Jupiter*, because they are of the ſame Nature, and proceed upon the ſame Grounds. And ſuppoſing the uſe of Teleſcopes to be practicable at Sea, would be there of very great uſe, which I do not deſpare to ſee effected in a ſhort time: But for determining the Longitudes of places upon the Land, Obſervations may be made twenty times more exact, if a convenient apparatus of Inſtruments be procur'd, and diligent and knowing obſervers be made uſe of, and this by reaſon of the almoſt momentary continuance of the appearance, that is to be obſerv'd, which will thence be ſeen by all the obſervers at the ſame inſtant almoſt of time; whereas there is a greater Latitude of uncertainty in Eclipſes of the Moon by reaſon of the Penumbra.

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This way then by the *Satellites* of *Jupiter* to knowing and diligent Aſtronomers is much to be preferr'd before that of *Eclipſes of the Moon*, upon three accounts. Firſt, By reaſon of the frequency of appearances ſufficient for determining this Inquiry. *This way preferrable.*

Secondly, Upon the account of the diſtinctneſs, exactneſs and preciſeneſs of the time of the appearance.

Thirdly, Upon the account of the eaſineſs and facility of making the Tables, and of calculating the time; there being little elſe to be conſider'd, but only the middle motions of them; at leaſt, what inequalities ſoever it be in their Anomaly, it is hardly ſenſible or worth taking notice of them.

Firſt, For the frequency of appearances ſufficient for this purpoſe; whereas of Lunar Eclipſes we ſeldom have above one or two in a Year, of thoſe may be had one, two, or more almoſt every Night; and theſe for ſo long as *Jupiter* is more than a Sextant from the Sun, are very conſpicuous by the help of a large Teleſcope; nay, within half that diſtance if the Poſition of the Ecliptick do favour the appearance either in the Morning before the Sun Riſing, or in the Evening after the Sun Set: But the *Satellites* are moſt conſpicuous, when *Jupiter* is more than a Quadrant from the Sun. Now, that this may be the better underſtood, it will be neceſſary to explain, in ſhort, the *Mundus Jovialis:* We are to know then, that *Jupiter* being the higheſt Planet but one, namely, *Saturn*, being view'd through a Teleſcope, is diſcover'd to have a round Body in Diameter, when acronical about 50″.. This Body is obſerv'd to have ſeveral darker or dusky Belts which croſs the Face of it parallel to the Eccliptick, and by a conſpicuous ſpot, which I firſt diſcover'd, this Body is found to move round upon its Axis in about ten Hours time; beſides this, *Galileo* firſt diſcover'd that it had four ſmaller Planets, which he call'd *Satellites*, which continually mov'd round about it; theſe, by later Obſervations, compar'd with former, have been reduc'd to ſuch a Perfection, as that by Tables, made of their periodick Revolutions, the Poſitions and Affections of them, for any certain time, can be pretty near aſcertain'd.. The firſt and innermoſt of theſe is diſtant about three Semidiameters, and performs its Revolution in about $42\frac{1}{2}$ Hours: The ſecond is diſtant about five Semidiameters, and performs its Revolution in eighty five hours and twenty minutes: The third is diſtant about $8\frac{1}{2}$ Semidiameters, and performs its Revolution in about one hundred ſeventy two Hours. The fourth and outermoſt is diſtant about fourteen Semidiameters, and performs its Revolution in near ſixteen Days, eighteen Hours and a Quarter; or $402\frac{1}{4}$ Hours. *Satellites firſt obſerv'd by* Galileo.

THo' the diſtances and Revolutions of theſe ſecundary Planets differ very conſiderably from what the Learned Dr. Gregory *in his late accurate* Aſtronomiæ, Phyſicæ & Geometricæ, Elementa, *yet I have not preſumed to alter them, but have Printed them as the Author has left them: They are placed by Dr.* Gregory *as follows. The innermoſt* Satellite *of* Jupiter *makes its Revolution in one Day* $\frac{3}{4}$, *and is diſtant* $5\frac{2}{3}$ *Semidiameters from the Center of* Jupiter. *The ſecond ſurrounds him in* $3\frac{3}{5}$ *Days, and is diſtant nine Semidiameters. The third in the ſpace of* $7\frac{1}{6}$ *Days, whoſe diſtance is* $14\frac{1}{3}$ *Semidiameters. The fourth and laſt in* $16\frac{3}{4}$ *Days, and is diſtant* $25\frac{1}{3}$ *Semidiameters. The diſtances are almoſt double, whence the miſtake of our Author proceeded, I know not, but I thought beſt to give the intelligent this ſhort Advertiſement of it.*

R. W.

Every one of theſe four in every Revolution, have at leaſt two remarkable Poſitions fit for this purpoſe; ſome have four, ſome may make ſix remarkable Signals. The Signals fit for this purpoſe, are, Firſt, Their touching the Limb of the Body of *Jupiter*, either at their ingreſs or egreſs, and that is alſo in every Revolution double: Firſt, When they are in their ſuperior half of their Epicycle, and ſo move direct, they have their Ingreſs and Egreſs behind the Body of *Jupiter*. *The Satellites may ſerve for finding the Longitude in ſix Poſitions.*

Secondly,

Secondly, When they are in the lower half of their Epicycle and appear Retrograde, they have their Ingreſs likewiſe, and their Egreſs from the Face of *Jupiter*. Next when the outermoſt of them does not touch, but either move above to the Northwards, or below to the Southwards, their Orbit or Epicycle then appearing an Ellipſis, then there are at leaſt two remarkable Poſitions of them which will be fit for this purpoſe; that is, their direct Conjunction and their Retrograde Conjunction. Beſides theſe, there are two ſorts of Eclipſes; the firſt ſort are thoſe of the *Satellites*, that is, when the *Satillites* enter into the dark Cone of the ſhadow of the Body of *Jupiter*, or when they emerge or get out of it, both which may be ſometimes plainly diſcover'd in the ſame Revolution of the *Satellite*, at other times only one of them, that is, either the Immerſion or Emerſion.

Secondly, There is an Eclipſe alſo caus'd upon the Body of *Jupiter* by the ſhadow of the *Satellite*, by which means one may, with a good Glaſs, plainly perceive a dark ſpot or ſhadow entring the Eaſt Limb of *Jupiter*, and paſſing over ſome part of its Face, to leave the Body of *Jupiter* at its Weſt Limb: Each of theſe Tranſits of the ſhadow will afford three remarkable Inſtants or Times fit for this purpoſe, namely, Firſt, The Ingreſs of the Shadow or Spot into the Face. Secondly, Its Poſition in the middle of the Line of its Tranſit, which by reaſon of either of the Belts upon the Face of *Jupiter*, or the lateral Poſition of ſome of the other *Satellites*, may be eaſily diſcover'd. And, Thirdly, The Inſtant when it goes off or leaves the Limb of *Jupiter*, which are plainly enough diſcover'd by good Teleſcopes and diligent Obſervers. So that ſince there are ſo many remarkable Accidents obſervable, ſcarce any Night can paſs without affording ſome one or more of thoſe opportunities. Hence it will be ſufficiently evident, that there will be above a hundred convenient times to make ſuch Obſervations more than can poſſibly happen by means of Ecclipſes of the Moon.

Beſides theſe, there are other remarkable Conjunctions of the *Satellites* themſelves one with another, which will ſerve for proper Remarks, eſpecially at ſuch times as *Jupiter* is in or very near the Eccliptick; for then the plains of the Orbs of the *Satellites* are very near in the plain of the Ecliptick, and the apparent motion of the *Satellites* is very near in a ſtraight Line, and ſo the Conjunction of one of them Retrograde in the lower part of its Epicycle with another of them direct in the upper part of its Epicycle, is very ſhort and momentary, and ſo becomes a fit mark for ſuch an Obſervation. The like may alſo be obſerv'd when *Jupiter* having a conſiderable Latitude the way of the *Satellites* appears Elliptical; for then the Conjuction of two *Satellites*, may, with ſufficient accurateneſs, be obſerv'd.

Now any one of theſe remarkable appearances being view'd and exactly obſerv'd by two Perſons at differing places, if the times of ſuch appearances be exactly taken at both places, they will certainly give the difference of the Longitude of thoſe two places in the ſame manner, as I before ſhew'd, might be done by Eclipſes of the Moon; and conſequently if the ſame appearance were obſerv'd with the ſame care in a hundred places, the Longitudes of all thoſe places would be thereby aſcertain'd, and that in the next place to a much greater preciſeneſs than 'tis poſſible to do by the help of Eclipſes of the Moon; becauſe ſome of theſe may be diſtinguiſh'd almoſt as eaſily to a Second of Time, as thoſe of the Moon may be to a Minute, which appears yet farther, Firſt, By reaſon of the ſmallneſs of the Body of the *Satellites*. Secondly, By reaſon of the great Velocity of all and much more of the innermoſt or firſt, which is next the Body of *Jupiter*. Thirdly, By reaſon of the ſmall diſtances of them, and eſpecially of the two innermoſt from the Body of *Jupiter*, and conſequently of the ſmall Penumbra the ſhadow of the Body there affords, which is alſo ſo much the more diſtinguiſh'd by reaſon of the vaſt diſtance of the Sun, and thence of the great Dimination of its Diameter, when view'd from the Body of *Jupiter*, and thence the ſmallneſs of the Angle of the Penumbra; for whereas the Angle of the Penumbra at the Earth is about half a Degree, the Angle of the Penumbra at *Jupiter* will not be more than $\frac{1}{9}$ part of a Degree, the diſtance of the Earth from the Sun to that of *Jupiter* being but as 10 to 45, or as 2 to 9. All which Particulars do

do contribute to the quickness and short duration of the appearance: So that the Time is very precise and seen by a whole Hemisphere of the Earth, as it were, in a moment; and there is no regard to be had of Parallax, and nothing else to be taken notice of but the very precise time of the appearance; for this only gives the true difference of Longitude between all those places where it shall be so observ'd by the same method, as I mention'd before in Eclipses of the Moon.

The Difficulties that occur in this method, are, First, That pretty long Telescopes are requisite for making the Observations and accurate Pendulum Clocks, both which are as yet not practicable at Sea. But, as I said before, notwithstanding this it may be made useful in Harbours and on Shore in such places where Ships may reside, which will be of great use for rectifying the Longitudes of Charts and Mapps. *The difficulties in this method.*

A second Difficulty in this way, is the distinguishing of one of the *Satellites* from the other: But for this the Theory of them is so far brought to perfection, and was above twenty five Years since much advanc'd by my Predecessor the ingenious Mr. *Laurence Rook*, that the Positions and appearances of the *Satellites* can be certainly Predicted and Calculated for any certain time; and 'tis not difficult to make an Automaton or piece of Watch-work which shall, at all times, give the Positions and appearances accurate enough for such Observations, at least to direct an Observer at what time he is to expect or watch for such an Appearance; and I have verify'd very many of Mr. *Rook*'s Predictions and Ephemerides for those Appearances, and found them pretty exact, even to less than a minute of Time. By which method if Ephemerides be made for one, two, three or more Years, and sent abroad into the East and West *Indies*, and other parts of the World, 'tis not unlikely but many such Observations might be procur'd from several parts of the World, which would be of great use, especially if at the same time there were some in *England* that should constantly make the like Observations here with equal care. And I have good reason to hope, that by this means we may obtain the Longitudes of several places in the *East-Indies*, since I understand that the *French* King hath sent several very able Astronomers into the *East-Indies* with an apparatus of fit Instruments, almost on purpose to make these and such other curious and useful Observations.

Besides this I am certainly inform'd, that it hath been of late much practised in *France*, whereby they have fix'd the Longitudes of the principal Towns in *France*, and also that of *Uraniburge* in *Denmark*, and of *Cayen* in *Iceland*, in the Possession of the *French* upon the Coast of *Guiana* in *America*. But this only by the bye.

But to proceed, the same thing may be done by the *Satellites* of *Saturn*; but they being discover'd but of late, and so not yet brought to so perfect a Theory, and besides requiring much longer and better Telescopes to observe the Appearances; I shall forbear to discourse farther of them 'till those *Desiderata* are procur'd; but whatever Invention will serve to detect their Appearances, will be much more useful for observing the same of *Jupiter*, which are much more near, and so much more vivid and conspicious.

The same thing may be done by observing the Appulses of the Moon to any fix'd Star that lies in its way, when observ'd at several places of the Earth, wherein the Appearance is so very short and precise, that even in the space of a single Second of Time, a Star is seen and quite disappears behind the Body of the Moon; but then by reason that both Refraction and Parallax are to be accounted for, which are differing to every place where the Observation shall be made, it is not fit for common use, but requires some better skill in Astronomy than most Observers are furnish'd with, which I shall therefore pretermit for the present, because I shall have occasion to treat more largely of it when I explain those ways that do necessarily require a knowledge of both those.

But still all these methods are useless as to the main design for which the knowledge of the Longitude is desir'd; which is from Observations made upon the place wherever it be, whether at Sea or on Land, and to determine presently what is the Longitude of that place from any known Meridi-

an. This is that Invention which has hitherto puzzl'd all the Learned Men, whether Mechanicks, Navigators, Geographers, Astronomers, Geometers and Philosophers; among which, tho' there have been many pretenders, yet no one has perform'd it, or shewn the way how to do it: 'Tis true, there have been enough have shewn what things are requisite to do it, but no one has produc'd those Requisites. 'Tis certain, that an exact Theory and Tables of the motion of the Moon, or of the motion of *Jupiter*, and his *Satellites* would perform it; but those Theories and those Tables are hitherto wanting, as are also exact Clocks that will move exactly upon the Sea, and such Telescopes as tho' but of three Foot length, and so might be made use of at Sea, would yet do as much as those we now have of thirty Foot; 'till which be procur'd, these ways, that I have hitherto nam'd, will be of little use for this purpose.

November 12. 1685. I explain'd to you the last Term, several præcognita necessary to be known, in order to the finding the Longitude of any place upon the globous Body of the Earth; that is, of finding the Angle that the Meridian of that place maketh with any other determinate Meridian, whether it be the prime Meridian generally agreed upon, or any other particular Meridian of some notable place from which the Ship departs; whose respect to the prime Meridian, or the Meridians in the Chart made use of, is known. In order to which I enumerated the several general ways that have been hitherto thought of for effecting this end, namely, Astronomical, Hodometrical, Magnetical, Chronometrical, Mechanical, Physical, and Mixt. Each of these ways I did more fully explain the last Term, and shew'd the several bounds of them, as also the several Objections, Difficulties and Imperfections each of them was subject to, and what they wanted to make them compleat and useful; which I shall not now trouble you with the repetition thereof, but rather proceed to the second method or general way of finding the Longitude of places, or difference of Meridians. Namely, The

The several ways for finding the Longitude.

Hodometrical, or by the observation or computation of the way of the Ship between place and place; that is, of observing the several Rumbs or Lines in which the Ship saileth, and what way it hath made in every of those Rumbs; that is, how many Leagues or parts of a League the Ship hath pass'd in every Rumb it hath sail'd upon, and how to compute the same, and thence to deduce the true place of the Ship at any time, in respect of the place from whence the departure is made, or the difference of the Meridians of the Ship, and that place, which is the Longitude desir'd. In order to the better explication of which it will be necessary to explain the several parts that are necessary Ingredients in every such Inquiry or Operation, that so it may be perform'd the more knowingly and scientifically, and not by wrote and ignorantly as it is now perform'd, for the most part, by practical Navigators; and to that end it will be necessary to explain, First, What kind of Line it is a Ship describes upon the Surface of the Earth or Sea in its passing or sayling through it, when steer'd upon a certain Point of the Compass. Secondly, How that Line is found and distinguish'd from all other Lines that may be describ'd upon the Surface of the Earth, for that it is a Line not only differing from all other Lines upon the Surface, but because every one of those Lines differ from every other of the same kind; and not only so, but every part of each Line differs from every other part thereof in many respects; as First, In its flexure or bending: Secondly, In respect of its proportion to the Meridians and Parallels, namely, as to the mensuration of Latitude and Longitude: And, Thirdly, In respect of any other great or lesser Circles that may be drawn, or suppos'd drawn upon the Surface of the Earth; such as lesser Circles of distance from any one Point or Place; or greater Circles, such as Lines of Position or great Azymuthal Circles. Nor have I hitherto met with any Globe whereon the said Lines have been truly describ'd, or any other that has prescrib'd a Scientifical or practical way of describing the same.

The Hodometrical way.

What the Rumb or Line of a Ships way is.

How it differs from all other Lines.

The chief propriety then of this *Rumb-line*, upon the Surface of the Globe, is, that it always makes the same Angle with all the Meridional Lines or Circles that it cuts or crosseth, and consequently that it is a *Spherical-Spiral* or

The chief Propriety of the Rumb Line.

Helix

Helix which incompaſſeth the ſame with infinite Revolutions which will never bring it to the two Polar Points which are the Centers, towards which it tends both towards the North and towards the South; notwithſtanding the infinite Revolutions, yet it is a finite Line which beareth a certain proportion to the length of a Meridian, and may be defin'd, determin'd and divided as exactly as any other Line or Circle drawn upon the Face of the Globe, and alſo the reſpect or proportion that any part of the whole Line beareth to the Meridian or Parallel that it croſſeth.

Of its length and proportion to a great Circle.

Firſt, As to the length of any Rumb-line; I ſay, that it beareth the ſame proportion to the length of a great Circle, that the Secant of that Rumb Angle from the North or South, hath to the Diameter of the Globe; ſo that tho' it maketh Infinite Revolutions about each Polar Point, and will never arrive at it, yet are all theſe infinite Revolutions equal to a finite and determinable length of a ſtraight Line, and that to as great an exactneſs as the proportion is or can be determin'd between the Radius or Diameter of a Circle and the Circumference thereof. Both which Proprieties, and ſeveral other tending to the menſuration and computation of the parts thereof, and for manifeſting the reſpect they bear to the Meridians or Parallels, or for determining of the reſpective Variation of the Longitude and Latitude which it maketh in its Progreſs either way towards the North or South Poles, I ſhall, in ſome following Lectures, demonſtrate; whereby all ſuch Diſputes, as have ariſen about that Subject, will be remov'd, and the Nature and Proprieties thereof will be manifeſted by a much eaſier method of Demonſtration than what hath been hitherto by any one us'd or produc'd for that purpoſe. I ſhall alſo ſhew ſome other ſorts of Projections of the Sphære in *Plano*, than have hitherto been produc'd, very apt and pertinent for this purpoſe, whereby the Navigator may more eaſily, with his Ruler and Compaſſes, meaſure the Rumb-line, and reſolve all Queſtions that concern the ſailing by the ſaid Line with as great certainty and exactneſs as is neceſſary to work withal from any Obſervations or Menſurations that can be made at Sea by the Logline and Compaſs.

But before I can well proceed with the explication of this Head, it will be neceſſary to premiſe ſome Præcognita of practical Geometry, which will be uſeful for the knowledge and more eaſy deſcription of the Rumb-lines, and for the meaſuring of the parts of them; eſpecially by reaſon that the Rumb-line as it is, or ought to be, deſcrib'd upon the Globe, as it is very difficult and almoſt impracticable to be made uſe of at Sea; ſo do I not find that the ſaid Lines are hitherto truly laid down upon any Globes yet extant, or any certain way preſcrib'd for the true drawing or laying down of the ſame upon the Surface thereof, but they are ſet off by ſome Points from Tables calculated for that purpoſe, and the interjacent parts of the Lines are fitted up by hand and by gueſs, which is very imperfect and inartificial.

But by an Inſtrument that I have invented, it may be moſt exactly drawn, not only upon the Surface of the Globe itſelf, but alſo upon ſeveral projections of the Globe in *Plano* or upon a Plain, whereby not only the ſeveral Proprieties of the ſaid Line may be expreſs'd, but alſo the menſuration of it by the help of Ruler and Compaſs, will be more facile, expedite and tractable for uſe, and the true Nature of this perplex'd Line more eaſily comprehended and conceiv'd: And this I do the rather, becauſe I judge, that by means of this way the true Courſe of the Ship may be more ſpeedily, eaſily, and with leſs ſubjection to miſtake, be computed and protracted, than by reſolving of Triangles or Arithmetical Calculationt; for if by the Inſtrument can be diſcover'd as ſmall a part as one can be aſſur'd by the Log-line in Sailing one Watch, then all nicety beyond that is loſs of Labour and Time.

What is here meant by practical Geometry.

By Practical Geometry then I underſtand that part of Geometry, which teaches an eaſy way of performing that by Operation, which is requir'd to be done by Theory, in order to put it into effect and practiſe. The buſineſs then of this Practical Geometry, is principally to deſcribe, deſign and lay down all thoſe Things or Lines exactly, according to the Theory which are requir'd to be done, and to determine and meaſure the quantities of the parts deſir'd by, or from that Deſcription.

I know

I know that into Practical Geometry, is uſually alſo taken all the Buſineſs of Obſervation, ſuch as the taking or meaſuring of Angles, of Altitudes of the Cæleſtial Bodies or Terreſtrial, as Mountains, Clouds, and the like, and the meaſuring of Sides or Angles upon the Earth in ſurveying; and the meaſuring of the Contents of ſolid Bodies, as Timber, Stones, *&c.* and the meaſuring of Liquors, or the capacity of containing Veſſels, as is done in Gauging, and other practical parts of Mathematicks; but theſe as not at all pertinent to my preſent purpoſe, I ſhall now omit, and only confine my ſelf to ſpeak of ſo much of Practical Geometry as ſerves to teach the true deſcribing and dividing of ſuch Lines, Surfaces or Bodies as are, or may be uſeful for this part of Mathematicks upon which I am diſcourſing, which is of the Art of Navigation; namely, how any Probleme that is requir'd, or is neceſſary for this Art, may, by the help of Ruler and Compaſſes, be truly protracted and meaſur'd upon a Plain, with as great exactneſs as 'tis poſſible, by the help of the Inſtruments and Methods that are hitherto us'd to make Obſervation on which to ground the Calculation.

In this then I have four things to be conſider'd, which makes up the Pythagorick Tetractys, namely, Point, Line, Superficies and Solid; of each of which I ſhall diſcourſe.

What is here meant by a Point.

By Point then I do not here underſtand an imaginary nothing, which, in ſpeculative Geometry, is defin'd to be a Negation of Quantity, or an Entity that hath no Part or Quantity; but I underſtand ſuch a Point as hath Quantity and Extention, but yet ſo ſmall and minute, as that the ſenſe cannot diſtinguiſh that it hath any Parts; ſuch as the Point of a very ſharp Needle, or the Point of a very curious pair of Compaſſes; or ſuch a mark with Ink as is made with a very ſharp nibb'd Pen upon fine ſmooth Paper, which tho' it may be eaſily enough prov'd, either by Microſcopes and other Glaſſes and by Reaſons too to have breadth, and ſo both Longitude and Latitude, nay, and Profundity too or thickneſs, yet as to the uſe, for which it is here deſign'd, it is ſufficient, and may paſs for a true Mathematical Point, if at leaſt we will but ſuppoſe the middle of it to be that which is aimed at in our Operation.

A Point is determin'd or given or found when the reſpects it hath to ſome other Point or Points, Line or Lines that are alſo given and known, and are ſufficient to determine its true place., as if it be deſir'd to find or place a Point upon a plain Superficies that ſhall have the ſame diſtance from each of the two other Points given that they have one from another: The Proprieties can but agree with two Points in all that Plain, which two Points are one on the one ſide, and the other on the oppoſite ſide of a Line drawn between the two firſt Points given, and therefore the place of the Point is not determin'd unleſs the ſaid reſpect be alſo given.

But if a Circular Line be given, and it be deſir'd to find or make a Point which ſhall be equally diſtant from every part of that round Line, then is the Poſition of that Point truely defin'd, and can be plac'd but in one place to have that Reſpect or Propriety.

But further, if two Points be given in a Plain, and it be requir'd to find or place another Point in that Plain that ſhall have this Propriety, that the ſtraight Lines drawn from the third Point to be found, ſhall make a right Angle, or any other Angle at that third Point, then are the Data not ſufficient to determine the Point, becauſe there may be infinite of ſuch Points found, which will all fall in ſome part of a Circle which paſſes through thoſe two firſt Points; and to determine ſuch Point it will be neceſſary either to give the determinate diſtance from one of thoſe two firſt Points, or the Angle that is made at one of them. Again, if from two ſuch Points it be requir'd to find or place a third Point, whoſe diſtances from the firſt two ſhall be to each other of any known or determin'd Proportion, as 2, to 3, or the like; the Data are not ſufficient to determine the third Point, becauſe there may be infinite of ſuch Points, all which will fall either in a Circle or a ſtraight Line; and therefore there is ſome other Propriety requiſite to determine the third Point to a certain Poſition. In the like manner I could inſtance a hundred other Caſes, to ſhew the neceſſity there is of giving Proprieties

prieties sufficient to determine the Position of any Point which is to be plac'd, otherwise the Practise or performance thereof cannot be done. But I shall not here further insist upon it, because that I shall discourse of it more fully in the consideration of Lines, Superficies and Solids; and the only thing to be observ'd in the placing of a Point, is to set it exactly in the crossing of two Lines which are to determine its Position.

Of Lines.

The next we are to consider is Lines; that is, not a length without bredth, as in pure and speculative Geometry, but a length that hath the least sensible bredth that can be describ'd, such as a Line drawn with the point of a very sharp Needle, or point of a Compass, or fine nibb'd Pen, which may pass for a length without bredth at least, if we consider the middle of it.

The difficulty of drawing a strait Line.

Now Lines may be either straight or bent; a straight Line is that which is the shortest that can be drawn between two Points given, and consequently there can be but one such drawn, and therefore that Line is perfectly given, which is so determin'd by two given Points, and therefore in speculative Geometry, 'tis put for a *Postulatum*, that such a Line may be suppos'd drawn, or is easy to be drawn; but in practical Geometry we must consider of the means how to draw it actually, which in some cases is not so easily perform'd, if extraordinary truth and exactness be requir'd: For, First, if the Line be to be drawn upon a plain, a straight Ruler being laid so as that the straight edge of it just passes over the two Points, then moving along by that edge a fine pointed Needle or sharp nibb'd Pen, we draw a line from the one Point to the other, and for common use the thing is done; but if any thing of Niceness or Curiosity be requir'd, we shall find it very difficult to lay the Ruler so as that it equally respects the two Points, but that it will lie a little nearer one Point than the other. Again, 'tis difficult to carry the Needle or Pen along with the Hand, as always to keep the same respect to the side of the Ruler. And, Thirdly, 'Twill be very difficult to find or provide a Ruler that is perfectly straight, but that it will have some bending in it one way or other, be it shot never so true with a Plain; for tho' the Plain be true that shooteth it, yet if the Ruler be not secur'd from warping it will bend under the Plain; besides, there are very few Plains that are so true, but that, if they are of Wood, will, in a short time, have some little warping or bending; and I know an ingenious Workman that assur'd me he could never shoot any thing true 'till he had made a Plain of Steel, which he had ground down to a truth of smoothness and plainess by rubbing and polishing it upon another Plain, and to have a true Plain to rub it upon, it is no easy matter to procure as I have been sufficiently satisfy'd by such as have indeavour'd to have them for grinding of Optick or Perspective Glasses; for I could never yet meet with any one but that, by a way I had to examine them, I have found them either a little Concave, or a little Convex, tho' that were so little, as not, by the common ways of examination, to be easily found. But it may be said, that streigning a fine Wire, or Hair, or fine Silken Clew between two Points, will describe or draw a straight Line between two Points; to which I answer, that if the Plain on which such a Line be to be drawn be exactly plain, and that plain lie exactly Horizontal, then such a Wire or Hair will perform it; but if the Plain be inclin'd or stand Perpendicular, and the two Points are not Perpendicular one over the other, then such a Line can never be streign'd strait whatever strength it be streign'd withal; for its own weight shall make it bend down in the middle, as has been sufficiently demonstrated by the ingenious *Galileo*, and *Mersennus*, and divers others; especially if there be any considerable distance between the two Points. These things I mention to shew, that tho' it be taken for granted, that this which seems the easiest of all things in practical Geometry to be done, yet is not performable without great difficulties where niceness and great exactness is requir'd: And possibly this might be the reason why Geometricians will not allow such Lines to be Geometrical, whose way of describing requires the sliding of a point along by the straight side of such a Ruler as the Ellipse, and several other Curve Lines, whose Proprieties are as exactly known and calculable as that of the Circle, and this only granted may be as easily describ'd, and therefore may as reasonably be suppos'd describable as the Circle or a straight Line.

Since from what I have alledg'd 'tis evident, that it cannot be done exactly without conſiderable difficulties; but if the two Points be very far diſtant, it is almoſt impoſſible by any way to exhibit or draw ſuch a Line; for not again to mention the bending of Rulers or Line, which 'tis impoſſible to prevent, even the ſight itſelf, that is the Ray of Light, paſſing from Point to Point through the Air, is not a ſtrait Line as to its Poſition, by reaſon of the differing Refraction which is in the *Medium* of the Air, which I my ſelf have very often prov'd by Obſervation, finding the ſame three Points which appear at one time in a ſtraight Line, at another time, ſometime within half an hour, have appear'd out of it very conſiderably, which I have very often diligently remark'd.

I have been the more large and particular in ſhewing you the difficulties that occur in the actual or practical performance of that which ſeemeth, and is ſo ſuppos'd, the eaſieſt ſort of Line that can be drawn, that you may not think it ſtrange if hereafter when I ſhew you the way of drawing Rhomb-lines of ſeveral ſorts, and ſome other Curve-lines uſeful in Navigation, you meet with ſome kind of Difficulties and Obſtructions in the methods and ways of deſcribing and meaſuring of them, which yet I ſhall ſhew you as to the true uſe that is to be made of them in Navigation, will be as ſufficient as the Circle or ſtraight Line; but upon this I ſhall not now further inſiſt, but proceed in the next place to ſhew how on a given Line about a Point given, a Circle may be deſcrib'd; this, in Speculative Geometry, is a *Poſtulatum* and ſuppos'd as eaſy and obvious to be done, and in ſmall Circles on a Plain or Table, it is ſo by opening the Compaſſes to the length of the Line having ſet one Point of the Compaſſes in the Point given, and with the other ſtriking round the Circumference 'till it return to the place where it began, by which means a Circular Line may be deſcrib'd much eaſier and more exact than a ſtraight Line, or any other can be drawn. But for the deſcribing greater Circles the thing to be done is not ſo eaſy, nay, ſo difficult, that 'tis almoſt impoſſible, eſpecially where exactneſs is requir'd, as I was ſufficiently ſatisfy'd by the difficulties that occurr'd in ſtriking a part of the Arch of a Circle of ſixty Foot Radius for the gage of a Tool for grinding Teleſcope Glaſſes of that length; whereby it was found that a Beam Compaſs made with all Care and Circumſpection imaginable, and us'd with as great Care, would not perform the Operation nor the way by an Angular Compaſs, ſuch as is deſcrib'd by *Guido Ubaldus* in his deſcription of the Planiſphere, and alſo by *Blagrave* in his Mathematical Jewel, and ſeveral other Authors, there being found ſo great a difficulty in making the edges of Rulers exactly ſmooth and ſtraight, as I did formerly mention, there being indeed no other practical way of making ſuch edges but the gaging of three ſuch edges all true to one another by rubbing and grinding, as there is hardly any other practical way of making the edge of a Ruler to be a part of a very large Arch fit to be a gage for a Tool for grinding Teleſcope Glaſſes, then by grinding and rubbing the edges of two ſuch Rules together, the one whereof is Convex and the other Concave. The difficulties in this kind I do the more inſiſt upon here, becauſe of the uſe of ſuch parts of large Arches in the drawing of the Projections of the Sphere, which the Work-men uſually perform by the help of a Steel Bow, which is bent leſs or more, as is deſir'd, by means of a Screw againſt the middle of it, the two ends of the ſaid Bow being held by the frame of the Inſtrument in which the Screw is alſo mov'd. But this Inſtrument as it is much more eaſy and applicable to this purpoſe, ſo is it far leſs true and exact than the Angular Inſtruments. The true Figure of ſuch a Steel Lath for bending Circularly being not yet known, which I affirm notwithſtanding what *Marchetty* in his Treatiſe *de Reſiſtentia Solidorum*, has demonſtrated ſeemingly to the contrary; and if it were, and were exactly made, yet thoſe that have been converſant or experienc'd in the Nature and Uſe of Steel for Springs or bending, will quickly be ſatisfy'd how difficult a matter it is to procure ſuch a uniform peice of Steel, and how much harder it is to temper it equally. But I ſhall not inſiſt further on this Matter at preſent, having only mention'd what I have here alledg'd, to ſhew, that tho' theſe two Lines which are the ſimpleſt and moſt eaſy to be drawn and

The difficulty of drawing Arches of great Circles.

deſcrib'd

deſcrib'd are yet not of ſo eaſy performance in ſome Caſes where great exactneſs is requiſite, but that there is great care neceſſary in the preparing and uſing Inſtruments fit for that purpoſe; and likewiſe to ſhew that if the ſame care be taken in the providing and uſing of Inſtruments for deſcribing the Rhomb-lines, they may alſo be deſcrib'd and drawn with the like certainty and exactneſs, and be every way as fit for uſe and practiſe in buſineſs of Navigation.

Nov. 19. 1685. I begun the laſt day to explain ſome part of Practical Geometry, in order to reduce Mathematical Theories about Navigation into Uſe and Practiſe, and explain'd the ways and the difficulties alſo of drawing the ſimpleſt and plaineſt of all Lines, *viz.* the ſtraight and the Circular Lines whith are taken for granted in Speculative Geometry to be ſo eaſy to be done, which notwithſtanding, when there is requir'd great exactneſs in the performance, are not ſo eaſy actually to be effected. It may therefore be inquir'd, why then are they put as *Poſtulata* as if performable by any? To which I anſwer, That the buſineſs of Speculative Geometry being only to demonſtrate the propriety of ſuch quantities, as Lines, Superficies and Solids from their Definitions or Deſcriptions; it is ſufficient to have only a right Conception of what is to be underſtood by thoſe Appellations, and that they are things poſſible to be done, or conceiv'd ſo to be, for grounding the Demonſtrations thereupon, and that the actual drawing and delineating of them there, is only to help the Imagination to conceive the notion of them aright. But when we conſider them in reference to Practical Geometry, we are to conſider, not only that the things to be done are poſſible, but to teach the Ways, Inſtruments and Operations how they may be actually perform'd; and therefore 'tis not here enough to conceive, that there may be a right Line drawn between two Points, or there may be a Circle deſcrib'd about a Point or Center at a diſtance given or determin'd, and then to demonſtrate by reaſon that thoſe Lines muſt have ſuch and ſuch Proprieties; but we are to draw them actually, and to ſhew by practiſe and actually doing, the thing requir'd, and thereby to exhibit the thing done to Senſe, which is one of the ends and uſes of Speculation. But it may be Objected by ſome, or at leaſt thought ſo; but what need is there of all this Curioſity, Preciſeneſs and Care of placing Points aright, and drawing Lines ſo curiouſly ſtraight, and of Circles ſo exactly round and true? To which I anſwer, that this is not a needleſs Curioſity, nor ſo ſlight and inſignificant a Matter as not to be regarded, but a matter of great Uſe, nay, a thing of abſolute Neceſſity; and without which, all the real uſe of Practical Geometry, eſpecially in Geography, Navigation and Aſtronomy, will be lame and imperfect: for all our deductions and concluſions in theſe Arts are founded upon proper and true Obſervations made; and all our Obſervations are made by the help of Inſtruments; and thence it will follow, that if our Inſtruments, us'd for ſuch Obſervations, be not exactly made and divided, our Obſervations cannot be true, and if our Obſervations are not true, our Deductions from them will not be true neither, but erroneous and falſe, and conſequently all the reſt of our Labour and Care and Skill will be needleſs and inſignificant: And that this is ſo any one will eaſily grant, when he conſiders, that in moſt Inſtruments that are us'd for the Sea, which ſeldom exceed two Foot Radius, the ſmalleſt Point almoſt that is ſenſible is the repreſentation of a Minute; and that Minute upon the Surface of the Earth, is no leſs than $6086\frac{17}{30}$ *Engliſh* Feet, there being found 365184 Feet in one Degree of the Earth, which amounteth to ſixty nine Miles, and eight hundred ſixty four Feet, or about $\frac{1}{6}$ part, the Statute Mile containing 1760 Yards, or 880 Fathoms; ſo that in the make of an Inſtrument of ſuch a Radius, the error of the bredth of a Needles Point in the placing the diviſions of the Limb or the drawing the Diagonal Lines or Circles, or the other parts of it, will eaſily make an error of a Mile in Latitude upon the Face of the Earth, and much more in Longitude.

Why ſpeculative Geometry puts ſome things as Poſtulata that cannot be performed.

And indeed conſidering the careleſſneſs that is at preſent in the make of the ordinary Sea Inſtruments made for Sale, and ſeveral other Imperfections, it is well if they can be certain to ten or twelve Minutes, that is, twelve or fourteen

The defect of the common Sea Inſtruments.

fourteen Miles. Now what ſignifies the reſolving and calculating of Triangles to ſingle minutes or leſſer parts, when you are not ſure by Obſervations to ten. If therefore by the help of Inſtruments, ſuch as a Planiſphere, a Sector and Compaſſes all Problems may be truly protracted and reſolv'd more exactly than the Obſervations can be made, on which they are grounded, what need will there be of more curious Calculations? But that this may be done, I ſhall prove by the ſequel of this Diſcourſe, if at leaſt due care be taken in the materials making and dividing the Inſtruments, whereby I ſhall ſhew that it will not only be ſufficiently accurate for all ſuch uſes; but it will have this of advantage alſo, that whereas the other method by reſolving Triangles Arithmetically is done blindly and by wrought, and without a true Conception of the reaſon of thoſe Operations; this will be done more knowingly by protracting; ſince that alone will be ſufficient to ſhew the reaſon of the Operation, and to prevent a World of miſtakes of one thing for another very uſual in the other way, ſince this way things are plac'd and and meaſured in their proper places. This I thought neceſſary to acquaint you with, that you might thereby ſee the great neceſſity and ſignificant uſe of ſuch Niceneſs and Curioſity, as I mention'd to you the laſt Day, in finding and making the Points and drawing both the ſtraight and circular Lines true, and that ſuch as may have occaſion to make uſe of ſuch Inſtruments, or to make them themſelves, as I hope ſome here may do, would be very careful to ſee that they are made with ſufficient exactneſs, and that the Materials be ſuch as may continue and preſerve their form without warping or ſhrinking. But on this Subject I ſhall ſay more hereafter when I treat of the ſeveral Inſtruments themſelves: I ſhall therefore at preſent proceed to the other parts of Practical Geometry, and in the next place explain what is underſtood by the reſpects that two right Lines drawn upon the ſame Plain, bear to one another: This will fall under two general Heads; Firſt, Such as are equally diſtant from one another, and ſo call'd Parallels: Or, Secondly, Such as ſome ways croſs each other, and ſo form an Angle between them; for an Angle is nothing elſe but the Reſpect, Tendency, or Inclination of two Lines in the Point wherein they cut or croſs each other.

This Inclination of two right Lines in the Point of Interſection is computed by the part of the Arch of a Circle drawn about the Point of interſection as a Center intercepted between thoſe two Lines, and computed or compared with the whole Circumference of that Circle; as if AB and DG cut each other
Fig.3.Tab.10. in the Point C, and upon the Point be deſcribed the Circle FHKI; FE meaſures the Angle FCE, for what part FE is of FHKIF, FCE is of four Right Angles.

If the intercepted part be one quarter of the whole Circumference, then that Angle meaſured by it is call'd a Right Angle, and the Lines are call'd Perpendiculars to each other; as if AB and HI croſſing each other in the Point C, FH be $\frac{1}{4}$ of the whole Circumference, then is HI Perpendicular to AB and AB to HI.

If the intercepted part be leſs than a quarter of the whole, 'tis call'd an Acute, as the Angle ECF or BCG, becauſe FE or KG are each of them leſs than a quarter of the Circumference, FCE and ECH making one quarter of the Circle.

If the intercepted Arch be more than a quarter 'tis call'd an obtuſe Angle, as ECB or FCG, which are compounded of a Right Angle and an Acute, *viz.* ECH and HCB, or FCI and ICG.

Hence 'tis obvious that Perpendiculars make four equal or right Angles about a Point as FCH, HCB, BCI, ICF.

And that all other croſſing Lines make two Acute and two Obtuſe, which four are equal to four right; and any two adjoining are equal to two Right Angles as FCE and ECB are equal to FCH and HCB. So,

From hence proceeds the neceſſity of dividing and meaſuring the parts of a Circle, and finding the proportion they bear to the whole Circumference; which is various ways performed, the moſt uſual and uſeful of which are perform'd by the help and meaſure of ſtraight Lines, which have certain reſpects both as to lengths and poſition to ſome Diameter or Radius of the ſaid Circle,

cle, of which I ſhall afterwards ſpeak; ſuch as are Chords, Sines, Tangents, verſed Sines or Darts.

A Diameter of a Circle is any ſtraight line drawn through the Center, and terminated at each end by the Circumference, as FB, HI, or EG.

And a Semidiameter, which is alſo call'd a Radius, is equal to half the former, being any ſtraight line drawn from the Center to the Circumference, and terminated by them; as the half of any of the former lines terminated at one end by the Center C, as FC or CB, HC, or CI, *&c.*

All Diameters of the ſame Circle are equal to one another, as are alſo all Semidiameters or Radij, becauſe every part of the ſame Circumference is equally diſtant from the Center.

If a ſtraight line be drawn within the Circle cutting the Circumference thereof in two Points, the part of the line intercepted between thoſe two Points is call'd a Chord or Subtenſe in ſimilitude to the String of a Bow, ſubtended or ſtretched from the ends thereof, as HG is the Chord of the Arch HKG being extended between the ends of it H and G, and 'tis call'd the Subtenſe or Chord of both thoſe Arches or parts of the Circumference which it divides or under which it is drawn; as of HKG, and of HFG. So a Diameter is always the Chord of a Semicircle.

All Chords that are equal ſubtend equal Arches of the ſame Circle, becauſe a Circle is a bent or curve Line, whoſe bending or curviture is every where equal and uniform, every part thereof therefore which is equal in length muſt have the ſame curviture, and conſequently the ſame length of a ſtraight line extended or ſubtended from its ends.

Theſe Definitions or Deſcriptions will be enough for my preſent Uſe and Diſcourſe, I ſhall therefore proceed.

In Practical Geometry, as every regular line is drawn or deſcribed by ſome proper Inſtrument; ſo every length is meaſured and every diviſion alſo made by ſome proper or known meaſure, by which the ſenſible truth thereof is experimentally verify'd and exhibited; I do not ſay demonſtrated, as ſome I perceive are very apt to do both in their Writings and Diſcourſe, who ſuppoſe the ſhewing a thing drawn upon Paper to be that which is underſtood by Demonſtration; but that, I conceive, may proceed from a common, tho' falſe Acceptation of that Word, ſince the ſtrict and proper ſenſe thereof is much an other Notion, of which I formerly more largely diſcourſed: And therefore I now take it for granted, that the Principles of Speculative Geometry are already known, and as ſuch I ſhall refer to them where I have occaſion to make uſe of Demonſtration; and ſhall not oblige my ſelf to follow the method of *Euclid*, but only treat of ſuch parts of Practical Geometry as relate to the Subject I have in hand.

Now becauſe I ſhall only diſcourſe of ſtraight Lines and Circular, I have no need at preſent to mention any other Inſtrument than a ſtraight Rule and Compaſſes, which are the moſt plain Inſtruments uſed, and ſo are ſufficiently known ſo as not to need any thing more to be ſaid of them than what I have already premiſed.

I need not alſo, I ſuppoſe, now mention the ſeveral ways how to draw or let fall a Perpendicular from a Point given to a line given, nor how to raiſe a Perpendicular from a Point in a line given to that line; nor how to divide a line into two equal parts, theſe being ſufficiently obvious and commonly enough known. And therefore taking theſe for granted as already known, I proceed to other ways of dividing a line given into ſuch a number, or ſuch ſorts of parts as ſhall be required.

And Firſt for dividing a given Line into any number of equal parts, the way of proceeding is as followeth. Let AB be a line given to be divided into nine equal parts, Firſt, Open your Compaſſes to the length of the line, and having one point of them in A, deſcribe the part of an Arch CB, then from the Center B deſcribe the Arch AD, then taking with your Compaſſes the diſtance of any point in AD as D from the point A; ſet off the ſame diſtance from B in the Arch BC to C: Then draw the lines ACE and BDF, through the points AC and BD: Then opening your Compaſſes as near as you can judge to the length of a ninth part of the Line AB, the *of dividing a given Line.* *Tab.* 10. *Fig.* 4.

nearer you gueſs the better; and beginning at A, ſet off that length on AE eight times, as 1, 2, 3, 4, 5, 6, 7, 8, then with the ſame opening of your Compaſſes, beginning at B, ſet off the ſame length eight times on BF, as g, h, i, k, l, m, n, o, laſtly, laying the Rule on i and o, 2 and n, draw the ſeveral lines j o, 2 n, 3 m, *&c*, Theſe parallel Lines ſhall divide the line AB into nine equal parts as was deſired in the Points p, q, r, s, t, *&c*. the demonſtration of which is ſo eaſy that I ſhall not ſtay to inſiſt upon it.

To divide a line into all its aliquot parts. Next let it be required to divide a line given into all its aliquot parts, or to give a ſeries of parts which ſhall be reprocal to a ſeries in Arithmetical proportion, as, 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{7}$, *&c* in infinitum. The method of doing it practically may be either of theſe three following ways.

Tab. 11. *Fig.*4. Let AB be a line given to be divided into all its aliquot parts, as $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, at one of its ends, as B; croſs it with the Perpendicular KI, and produce it towards I, as far as there ſhall be occaſion. Then taking any Point in the line BK at pleaſure as D, draw DC equal and parallel to AB and compleat the Parallelogram AKDB. Then with your Compaſſes taking the length BD ſet it off from B towards I, as many times as you deſire aliquot parts, as BE, EF, FG, GH, *&c*. then laying the Rule on the Point C, and thoſe other Points E, F, G, H, ſucceſſively draw ſtraight lines which ſhall cut the line AB in the points 2, 3, 4, 5, *&c*. then ſhall the line AB be thereby divided in as many aliquot Sections as ſhall be deſir'd; for A2 ſhall be half of AB, A3 $\frac{1}{3}$, A4 $\frac{1}{4}$, A5 $\frac{1}{5}$, and ſo onward ſo far as you will proceed; for ſince DC is parallel to AB, and equal to it the Triangles DEC, and BE2 ſhall be ſimilar, and DFC and BF3 are alſo ſimilar; and DGC likewiſe to BG4, and ſo onward in infinitum. It follows therefore that as ED, 2, is to EB, 1, ſo CD = to AB, 1, to B2, = to $\frac{1}{2}$, = A, 2, in like manner as FD, 3 to FB2; ſo CD, 1, to B, 3, $\frac{1}{3}$, which taken from AB leaves A3 = to $\frac{1}{3}$, and ſo for all the reſt, which is obvious enough.

The ſame might have been thus demonſtrated; AC being made equal and parallel to BE, EF, FG, GH, the Angle CAB will be equal to ABE, therefore the Triangle CA2 will be ſimilar to EB2; and therefore as CA is to A2 in the Triangle CA2; ſo EB will be to B2 in the Triangle EB2; but CA is put equal to EB, therefore A2 is equal to B2, therefore A2 = $\frac{1}{2}$ AB. Again, for the ſame Reaſons, CA3 will be ſimilar to FB3, and conſequently CA. A3 : : FB. B3; but FB is double CA, therefore B3 is double A3, therefore A3 = $\frac{1}{3}$ AB, and the ſame for all the reſt.

Here in the practical performance of this Problem will appear the neceſſity of that nicety and exactneſs I preſcrib'd in drawing of ſtraight lines curious and true, and placing of the points preciſely in the middle of the line and of laying the exactly ſtraight edge of the Rule over the very middle of the points, through which the lines, are to paſs, and of carrying the Needle or Point with which you draw very equally and uniformly; for if all theſe particulars be not carefully obſerv'd, and accordingly practis'd and perform'd, tho' the Problem be true in the Theory, yet the diviſions made upon the line AB, will be but imperfect and lame, eſpecially if the line BJ be far produced, and the repetitions of the equal parts be made ſome ſcores or ſome hundreds of times, becauſe the lines drawn from the point C through theſe Diviſions on the line BI produced, will be ſo oblique that a very little error in any of thoſe obſervables, will be apt to make an error of a whole diviſion, and ſo 'twill be difficult to diſtinguiſh for inſtance between a 99th part and a 100th part, moreover becauſe the effecting of the Problem this way, if the Reciprocals run far, will require the line BJ, to be drawn out to a great length, and requireth as much room as the performing it by the Hyperbola, which in many occaſions cannot be ſo conveniently done, therefore the ſame Problem may be effected by another way in a much leſs room and with ſhorter Inſtruments, which therefore will be the leſs ſubject to warping, and may be more carefully perfected.

Tab. 11. *Fig.*4. The ſecond way then of effecting this Problem is this: Let AB be a line given, all whoſe aliquot parts are deſir'd, as its $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, *&c*. which are reciprocals to a rank of numbers in Arithmetical progreſſion, as 1, 2, 3, 4, 5, 6, *&c*. Upon the line AB make a Parallelogram Square or Rhombus ABCD, then

then draw the Diagonal AC. Now for finding the half, draw the Diagonal DB croſſing AC in E; through E draw FEG parallel to AD or CB, cutting the line AB in G: Through D and G draw DHG cutting the Diagonal AC in H; and through H draw IHK parallel to AD; then through D and K draw DLK croſſing the Diagonal AC in L; and through the Point L draw MLN parallel to AD, and ſo proceeding ſo far as ſhall be needful or deſir'd, you ſhall find as many aliquot parts of AB as you ſhall deſire; for as AB is the whole, ſo AG is the half, AK the third, AN the fourth, and ſo you may find the fifth, ſixth, ſeventh, eighth, ninth, and ſo onward as far as you pleaſe. For Firſt, the oppoſite ſides of the Figure ABCD being equal and parallel, the Diagonals muſt interſect each other in the middle, becauſe AED is ſimilar to CEB, and therefore as AD is $=$ CB, ſo AE $=$ CE and DE $=$ BE. Next becauſe the Triangles ABC and AGE are ſimilar, as AE is half AC, ſo AG $= \frac{AB}{2}$.

Secondly, AK is $\frac{1}{3}$ of AB; for the Triangles AHG and DHC are ſimilar, becauſe the oppoſite Angles at H are equal, and the alternate Angles at A and C are equal, as alſo the other alternate Angles at D and G; therefore as DC is to AG, which is as 2 to 1, ſo CH to AH; AH therefore is $\frac{1}{3}$ of AC, and becauſe ABC and AKH are ſimilar, therefore as AH is $= \frac{AC}{3}$, ſo AK $= \frac{AB}{3}$

The like Demonſtration will ſerve for all the reſt how far ſoever continued.

This Problem I have been the more particular in explaining for that I ſhall have ſeveral occaſions to make uſe of both in projections, and likewiſe in the contrivances of ſeveral uſeful Inſtruments for Navigation, as particularly in a way of ſounding the depths of the Sea in ſuch places as Lines will not reach, and in computing the way of a Ship through the Water, and ſeveral other inventions, of which I ſhall ſpeak hereafter.

Now becauſe the drawing of parallel Lines ſo often as there are Diviſions made, may ſeem ſomewhat troubleſome, therefore I ſhall ſhew another way how to effect this Problem without drawing parallel Lines; which is thus. Let AB be a line given to be divided into all its aliquot parts. Through the Points A and B draw right Lines parallel to each other, as CD and FE, whether at Right Angles or not with the line AB it matters not. Set off on each ſide of each of the Points A and B in the lines ſo drawn parallel a Point, as C, D, E, F, of equal diſtance from the reſpective Points A and B. Then draw CE, which ſhall cut AB in the Point G in half; the draw AE and DB, which likewiſe interſect each other in half in H; then draw CH and Dg, which ſhall interſect AB at I, making AI $\frac{1}{3}$ of AB, and AE at K, making AK $\frac{1}{3}$ of AE; draw CK and DI, theſe ſhall interſect the lines AB and AE at L and m, making AL $\frac{1}{4}$ of AB and Am $\frac{1}{4}$ of AE, and ſo proceed in infinitum: This will alſo give you all the aliquot parts of AB or AE. Or a Series decreaſing in reciprocal proportion to any Arithmetically increaſing Series, as 1, 2, 3, 4, 5, 6, 7, *&c.* in infinitum. The Demonſtration of which Problem is much the ſame with that in the preceding Problem, and therefore I ſhall not ſpend time in the repetition thereof. *Tab.* 11. *Fig.* 5.

And thus far I have proceeded to ſhew how any line given may be divided into an infinite Series of Reciprocals to a Series in Arithmetical Progreſſion, of which ſort I have only inſtanced in that Reciprocal to 1, 2, 3, 4, 5, 6, *&c.* but the ſame method will ſerve to give the Reciprocal to the Series that expreſſes the differences between ſquare numbers of the prime Arithmetical Series, as 1, 3, 5, 7, 9, or any other ſuch Arithmetical Progreſſion, whatſoever the common exceſs or difference be, as I could plainly demonſtrate if it were material to my preſent deſign, and may hereafter more at large upon another Subject; but I ſhall now rather proceed to ſhew how any line given may be divided into an infinite ſeries of Parts in Geometrical Proportion continually decreaſing or increaſing, according to any proportion whatever aſſign'd, as 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, and ſo onward in infinitum: Or, 1, $\frac{1}{3}$, $\frac{1}{9}$, $\frac{1}{27}$, $\frac{1}{81}$, $\frac{1}{243}$, and ſo onward to any proportional leſs then can be aſſign'd, and how

to

to find the ſum of ſuch an infinite decreaſing Series or a line equal to them, all added together.

Tab. 11.*Fig.*6. To effect which, let AB be a Line given to be divided into an infinite ſeries of Geometrical proportionals, according to any Ratio given; as ſuppoſe of 1000 to 999, or any other Ratio whatever; for inſtance, let it be of 8. to 7 croſs the line AB at the point or end A with another ſtraight line, as CAD, which may be drawn at Right Angles, or any other Angle pretty near it, for the ſame effect will follow; then opening your Compaſſes to any diſtance, but as near as you can gueſs to an eighth part of the length of the Line CD, *viz.* according to the conveniences you may have of drawing or producing the ſaid Line on the Plain or Table you are delineating upon and ſetting one Foot in A, ſet off the ſame eighth part from A to C on one ſide of the Point A: Then on the other ſide ſet off the ſaid diſtance AC ſeven times, *viz.* to D. Then draw from the Point C the Line CE parrallel to AB, and from the Point B to draw BE parallel to AC, ſo as to compleat the Parallellogram or Rhombus ABEC; then through the Points D and E, draw the Line DE, cutting the Line AB in F; through F draw FG parallel to AC or BE; and through D and G draw DG cutting the Line AB in H; through H draw HJ parallel to AC or BE, and draw DJ, cutting AB in K; and through K draw KL parallel to AC, and ſo proceed to draw DL. Mn, Dn, op, *&c.* as far as you pleaſe. Theſe Points F, H, K, M, o, *&c.* ſhall divide the Line AB into a ſeries of Geometrical continued proportionals in the Ratio of 8 to 7, as was deſcrib'd or requir'd to be done: For AB ſhall be to AF, as 8 to 7, and AF. AI, :: 8. 7, and AH. AK :: 8. 7, and ſo onward in infinitum, or as far as ſhall be requir'd; and not only ſo, but the whole line AB ſhall be made up or compounded of an infinite ſeries of continual proportionals, in proportion as 8 to 7, all which infinity of proportionals being joined or added together into one line will be equal to the line AB, and neither exceed it, nor be ſhorter than it.

Now that this diviſion will be rightly done, will appear by the following Demonſtration, AB and CE being parallells to each other, and equals as by the Conſtruction is requir'd to be done; DC alſo being a ſtraight Line touching the Line AB in A; and DE being a ſtraight Line cutting the Line AB in F; the two Triangles DCE and DAF will be ſimilar; and conſequently as DC to DA, which, by the conſtruction, is made, is as 8 to 7, as was requir'd; ſo CE (which was put equal to AB) to AF. In the ſame manner FG being drawn parallel to AC, CG and AF are equal, and the Line DG being drawn cutting the remainder AF in H; he two Triangles DCG and DAH are alſo ſimilar, and conſequently as DC to DA; ſo is CG (which is equal to AF) to AH. Now DC to DA is put as 8 to 7, therefore alſo AF to AH is as 8 to 7, as was requir'd: By the ſame Ratiocination, may all the reſt of the infinite proportionals be proved to be to one another, as 8 to 7, and conſequently they will be all an infinite ſeries of continued proportionals, decreaſing infinitely in proportion as 8 to 7' which was the thing requir'd.

Now ſince the whole Line AB, and the Ablata AF, AH, AK, AM, are in continual proportion, as 8 to 7, as is prov'd, the Reliqua BF, FH, HK, KM, *&c.* will be alſo in the ſame Geometrical continu'd proportion one to another, as 8 to 7, as is evident by the 17th of the 5th of *Euclid*, &c.

To expreſs theſe Proportionals in Numbers is very difficult, but if this Series be expreſs'd Algebraical it will be eaſily perform'd; for putting the firſt difference a, and the ſecond b, it will be this, a, b, $\frac{bb}{a}$ $\frac{b3}{a2}$ $\frac{b4}{a3}$ $\frac{b5}{a4}$, *&c.*

This method of finding and eaſily deſcribing a Rank or Series of continual proportionals, I have the rather choſen to explain and demonſtrate by this Problem, becauſe by means hereof the true Nature of Logarithms and the Logarithmick Line will the more plainly be underſtood and comprehended, which by reaſon of the reſervedneſs and deſign'd obſcurity of moſt of thoſe who have written concerning the method of compounding and forming the Logarithmick Tables, are not ſo obvious to every Reader; for in this preſent

Problem

Problem, if the continual Proportionals BF, FH, HK, KM, MO, and all the rest be put for the absolute Numbers: Then B[illegible], BE+FG, BE+FG, +HI. BE+FG+HI+KL, will be the Logarithms to those Numbers, that is 1, 2, 3, 4, 5, 6, *&c.* for Logarithms are nothing else but the Numbers of the proportionals that are in the Series pitch'd upon, or made choice of between any two absolute Numbers (or because a unite is the first and root of all other Numbers) between one and any other absolute Number whatsoever. And to that end in the making of Logarithms, because if the proportional difference between the antecedent and the consequent be very great, it will hardly fall out, that any of the proportional Sections will either fall in the equal Section of the absolute Number exactly, or so near the same as will be sufficient to make the number of the proportional differences exact enough to serve for the Logarithm; therefore the greater the number of those proportionals are between the unite and the other absolute number, the nearer will the equal divisions of the interjacent space approach the proportional Sections of the same; and by the increasing the numbers of the intermediate proportionals, if the equal divisions do not *coincidere* with the proportionate exactly, yet the approach may be made within any difference whatsoever required, which is all that the nature of the thing, in some cases, will bear, they being infinite and incommensurate; for the making of which Logarithmick Numbers or Tables various ways have been made use of by several Authors, some more easy in the Invention than others, yet they are all to the same effect, tho' some of the Progressions are more accommodated for use than others; as that of Mr. *Briggs*, where the Logarithm of one is, put 0, and the Logaritthm of 10, 1 of 100. 2 of 1000. 3 of 10000. 4 with a certain number of Cyphers after them, as Mr. *Briggs* puts 14. So that he supposeth One hundred Millions of Millions of proportional parts between one and ten, and between 10 and 100, and between 100 and 1000, and so onward in the Decimal progression; or between 1 and $\frac{1}{10}$, and $\frac{1}{100}$, and $\frac{1}{100}$, and $\frac{1}{1000}$, of which in 100 Millions of Millions, there are thirty Millions of Millions, One Hundred and Two Thousands, 999 Millions, 566 Thousands, 368 continual proportionals between one and two; and because it would be impossible ever to enumerate and calculate all these, therefore there have been various Expedients found to facilite this *tædium* of working proportionals by Multiplications and Divisions, and extractions of the Roots, and to perform the same thing for finding the Logarithms or the number of proportionals in the series pitch'd upon, answering to each absolute number, by little more trouble than bare addition, which doth save an infinite of trouble; and considering the great Use and Benefit of them in solving many difficult and almost insolvable Questions of Geometry by any other way, is a part of Geometry extreamly desirable to be thoroughly known and understood, nevertheless it being not so much to my present purpose, and belonging more particularly to the business of Arithmetick, I shall not further proceed in the explication thereof at present.

But rather proceed to the Explication of the Logarithmick Line, and shew how it depends upon the Problem I have now explained, of dividing a Line given into any infinite series of continual proportionals, because, as I shall after prove, the same is the true Line of the Rumb in those projections which I design to describe.

Let AB then in the second Figure represent the Radius, BC a line at right Angles with it, and equal to it the tangent of forty five Degrees, which is to be divided into an infinite series of continual proportionals; so that BC to BG shall be as any one number to any other number assigned. For instance, as 100000 to 99999, make B d equal to $\frac{1}{100000}$, part of AB, and draw d e parallel to BC; then make ds, st, tv, vx, *&c.* each equal to dB, and draw the Lines s, 1. t, 2. v, 3. x 4. *&c.* parallel to BC. Then proceed to divide the Line BC into the series of proportionals cg, gi, jl, ln, np, *&c.* as I shew'd in the preceeding Problem; and through the Points g, i, l, n, p, draw the Lines gf, i 1. l 2. N 3. P 4, *&c.* parallel to the Line AB meeting or cutting the fore-said Parallels de s 1. f 2. V 3. X 4. in the Points f, 1, 2, 3, 4, *&c.* the Curve Line drawn through the Points C, f 1, 2, 3, 4, will represent *Tab.* 12. *Fig.* 1.

the Logarithmick broken Line being composed of the Diagonal Lines fC, hg, ki, ml, on, *&c.* in which BC, df, S i, f 2, v 3, x 4, the ordinates to the Line AB, shall represent the absolute numbers which are here a rank of continual proportionals answering to the numbers 1, 2, 3, 4, 5, B or nought, and Bd, Bs, Bt, Bv, Bx. The respective Logarithms to them increasing as the absolute do decrease, according to *Neiper*'s method, or else BX, DX, SX, TX, VX, X, or o, will represent the Logarithms decreasing as the absolute decrease, according to Mr. *Briggs* and most others.

This Line which I have here described is not a true Curve Line, but a Line compos'd of fragments or short pieces of straight Lines, *viz.* of the straight Lines of cf, gh, ik, lm, no, pq, *&c.* which are all Secants to the Radius db of the continual proportionals put as tangents, because fg, hi, kl, *&c.* are all equal and parallel to it; and as AC the Secant of 45 is to AB; so fc to fg = dB as Radius; so fi = gh, 12 = ik, *&c.* so cfi 2, 3, 4, 5, is equal to the several Secants Cf; gh, ik, lm, no, pq, *&c.* and supposing dB one infinite part of AB, these fractures will be infinitely small, and so the Logarithmick Line or Rhumb-line will be a true Curve Line compos'd of infinite of these infinitely small Secants.

From which Generation of this Curve Logarithmick or Rhumb-line, may be deduc'd, First, That the Line AB being infinitely continu'd towards A, shall be the Asymptot Line to the Logarithmick Curve cf, 1, 2, 3, 4, *&c.* nearer and nearer, to which it shall always approach, but never touch it.

Secondly, That if from any Point of this Line infinitely continued either way a perpendicular or ordinate to AB be drawn, and also a tangent, the distance between the ordinate and tangent intersection of the Asymptot shall always be equal to the distance AB; from which propriety the mechanical Description thereof, with great exactness and certainty, I shall prove to be easy.

But because this Line may be various other ways describ'd also, which will also give light to the Nature of it; it may be conceived to be generated by the composition of two differing kinds of motions crossing each other at right Angles with differing tendency and velocities.

As supposing a Point or Atom at C, actuated by two equal tendencies or velocities, the other towards W. Supposing the velocity towards C to remain always the same, and uniform the motion or velocity towards W will continually increase so that when the Atom has past, for instance, $\frac{1}{10}$ of the distance between CW and AB, the velocity from BC towards AW will be as $\frac{10}{9}$, and at the end of the second space of time, as $\frac{10}{8}$, of the third, as $\frac{10}{7}$, of the fourth, as $\frac{10}{6}$, and so $\frac{10}{5}$, $\frac{10}{4}$, $\frac{10}{3}$, $\frac{10}{2}$, and 10, and so onwards in infinitum.

If on the other side we suppose the tendency, velocity or motion from BC towards AW, to be always equal and uniform, that is, in a certain space of time, to move a space equal to one tenth of the length CB, then the motion or velocity from CW towards AB, will decrease continually by an infinite series of continual Proportionals, according to the differing velocities of the two tendencies. These Proprieties I have not now time to demonstrate fully as they ought, but I shall reserve them to another opportunity.

Tab. 12. Fig. 2. *THere being mention made at Page 524. above, of an Instrument for drawing Spirals or Rhumbs but not described I have here added a short description of an Instrument I remember he shewed the model of to the Royal Society with its performance. Let there be made a thin flat Ruler a b c, having a slit through the middle of it c d to slip freely upon a Center Pin fixt perpendicular in a plain, upon which the Line is to be drawn: At the end of this Ruler c there must be cut a round hole with a Ring of Brass exactly fitted to it, and in this Ring a small Truckle Wheel with its Axis well fixt at right Angles: Then by moving this Ring in its Socket in the Ruler, the plain of the Wheel may be set to any Angle with the slit in the Ruler; which done, by moving the Ruler upon the Plain round the Center, the edge of the said Truckle-wheel will describe, upon the Plain, the Spiral with the Angle required at every revolution proportionally approaching the fixt Center. E is the Truckle-wheel and Ring taken out of its Socket in the Ruler.*

The

THe Author having mentioned the great difficulty of drawing the Arches of very large Circles at Page 523 Supra, and finding a Lecture of his proposing several methods of performing it, I thought best to insert it here, the ways being, as I judge, new and ingenious.

R. W.

MAy 8th 1685. It is a Postulatum in Geometry, that 'tis possible or practicable to draw or describe a Circle to any given Radius, and also from a Point given to any other Point to draw a straight Line; but tho' in Speculative Geometry it be only to be understood, that a Circle of any bigness may be conceived as drawn about a Center given, or a straight Line may be conceived to be drawn between any two Points given; yet in Practical Geometry where the *Postulata* are to be produc'd to effect and to be actually executed, if either of them are very large, the difficulties are greater than every one will easily imagine, and neither the one nor the other can, with any tolerable exactness, be perform'd. 'Tis true that a Line may be extended and streined between two Points at a considerable distance, and so that Line may be said to be a straight Line as to its swarving laterally; but as to its straightness in the Perpendicular Plain that passes through those two Points, 'tis not in the power of Art to make it; for that the power of gravity acting on it will bend it into a Curve (which has of late Years much excercised the Speculative Geometers to contemplate, and they have given it the name of the *catenaria*) but none have found any ways of describing it otherwise than by Points, which are very troublesome and tedious, and at best but imperfect (which yet I shall shew how to do some other time) but I at present only mention it by the by, to shew, that tho' a Line may be strained between two Points, yet gravity will bend it from its straightness; and tho' 'tis Possible in great part to take off that gravity by a fluid, in which the said Line shall be immers'd, yet that for a great length will not obviate the Objective. 'Tis true, if the Points be plac'd perpendicular one over another, a Line may be extended straight without any impediment from gravity, but then any motion of the Air, through which it passes, is apt to bend it some ways or other, so that even that way is not free from Objections. And I found in my Observation of the Parallax of the Earth, that there was very much trouble and difficulty to find the true Perpendicular Point under the Center of the Object-glass, which yet with perseverance, I conceive, I did at last attain. However some have propounded ways of performing that Observation which have ten times the difficulty to execute it to any tolerable satisfaction that was found in mine.

The difficulty of drawing a strait Line.

Now as this first *Postulatum* of actually drawing a straight Line between any two Points has its dfficulties, so the next of drawing a Circle to a Center and Radius given, has many more, especially when the Radius is large. 'Tis almost impossible to make a Beam for the Compass that is to describe it that shall not bend and warp, and shrink and stretch in the using of it; and I remember when Mr. *Reeve* was to make a Gage for a Tool to grind an Object-glass for a Telescope of sixty Foot, after much Charge and Labour to perform it, tho' all possible care and caution was imploy'd to effect it, yet after all he was near a Month in Gaging his Tool before he could bring it to any tolerable perfection, and even then he found it not to be of a Sphere of its due length, but considerably less; which caus'd me to contrive a way how to do it true at once with a much less aparatus, and that of as great a Sphere as should be requir'd, as of six hundred as well as of sixty Foot, which I publish'd in my Micographia in the Year 1664; but one *Campani* an *Italian* above ten Years after publish'd the same thing as his own Invention, not taking any notice of what I had done. I know Mr. *Auzout* Objected, that there were some difficulties in adjusting the Machin, but I soon satisfy'd him that they were all insignificant.

Or the Arch of a large Circle.

So

So that we see, that tho' Science can easily suppose and conceive things as possible to be done, yet Art doth find many difficulties in the actual performance of them, and both ought to be call'd in for assistants in the prosecution of experimental Philosophy: Wherefore there ought to be as much care taken for the improving and perfecting of Art, as there is requir'd Sagacity and Perspicacity in observing the effects and methods of Nature.

Now Nature in its Operations, is, for the most part, Regular, Constant, Exact, Potent and Effective, and whatsoever is thereby design'd, it accommodates all things necessary to the performance thereof; it not only makes the Materials of a proper Substance, but it shapes the parts of their due Figure, and joins them in their due order, and actuates or moves them with proper motions. But Art, which at best does but mimick Nature, must search for materials where it can find them, and make use of such as can be procur'd. These it must shape and fit for its purposes as the Matter will indure, and as the Tools and Instruments, made use of, will perform, and they must be join'd and compos'd together as other circumstances will permit, and actuated by uncertain, irregular and insufficient Powers. So that at best the productions of Art in respect of those of Nature, are very much inferior in perfection.

The benefits of Art.

And yet they are of great significancy for the accommodating the productions of Nature to the use of Mankind. Thus Art doth form a Ship to pass the Seas as big as the largest Fish, which it animates and directs with Men, and makes the Wind to move and convey from Port to Port. Art doth often also help and promote Natures Operations; as it improves the Sight by Spectacles, Microscopes and Telescopes. It divides and measures the parts and intervals of Time by Watches: It converts Corn into Bread by separating the Husks and Bran by the Sive and Searce, kneading the more nutritive part into Dough, and last of all baking it in the Oven. And the Fruit of the Vine it improves to a most pleasant Spirituous Liquour for drink. We owe almost all our Accommodations of our Life to the productions of Art. Nature puts us into the World more naked than most other of our fellow Creatures; but Art has abundantly supply'd that Defect, by accommodating the teguments of other Animals and Vegetables for that purpose. Nay, Minerals also and Metals have been made subservient. I might instance also in infinite other accommodations and conveniences of Life. So that tho' Art be far short of Nature in perfection of acting, yet since the power of it is placed in Man, it seems to be of as great a concern to him to be knowing and potent therein; for every new discovery therein gives him a new Power which he had not before. Thus the discovery of the Magnetical Needle inabl'd him to cross the Ocean and discover a New World; and to incompass the Earth and converse with the remotest Inhabitants. Thus the discovery of Telescopes inabled him to discover Cælestial Bodies never so much as dreamt of before; and the Miscroscope has discover'd a New World which was before wholly invisible. The discovery of the Pendulum has actually proved the inequality of the length of Days, and divided the intervals of Time more exactly than the Sun.

The discovery of Gun-powder and Guns has chang'd the whole method of offence, and defence both by Land and Sea. I might instance in many other effects of Art to shew how much the Power of Man is increased by them: but these are sufficient, and by these we may be inabled to judge of their significancy when they are made use of as they ought.

By these also we may be sufficiently inform'd how much a new Discovery or Observation may be considerable when duly apply'd, tho' in itself it seems never so obvious, slight and common, as to instance in the Pendulum, or in Printing, the grounds of which were sufficiently obvious to all, and therefore slighted, whereas the due application of them has perform'd almost miracles. And there are other things as obvious as them, which being duly apply'd, will be as effective tho' in another kind. An Experiment or Discovery is not therefore to be slighted, because, when it is shewn, it seems easy, and obvious, and trivial, and because the consequences or uses thereof are not presently detected.

What

What I ſome Weeks ſince propounded concerning the drawing of a Circle true to a large Radius, I do very much doubt whether the beſt Mechanick, it ſhould be propounded to, would preſently be able to effect it; which I am the more inclin'd to believe from the Experimets I have ſeen try'd to that effect, by the moſt accompliſh'd Perſons both for Science and Art; and yet when diſcover'd, I doubt not but almoſt every one will be apt to ſay, he knew as much; and yet I do not find that any one has mention'd it in their Writings. *Guidus Ubaldus* and *Stoffler* have ſhewn a way of drawing a part of a Circle of a large Radius by the help of two Rulers fix'd at a proper Angle, and ſliding againſt two Pinns at the extreamities of the Arch to be deſcrib'd, which is founded on a propoſition of *Euclid*; but our Mathematical-Inſtrument-makers ſeldom or never make uſe thereof, becauſe of the difficulty of its uſe, and imperfection of its performance; and tho' Mr. *Reeve* had procur'd one made with great exactneſs, yet it did not perform its effects; but he made a Beam compaſs of ſixty Foot Radius, which did it not much better, by reaſon of the warping at ſo great a length, which I conceive alſo Sir *Chr. Wren* complain'd of in ſtriking the Circle for the Dome at St. *Paul*'s, tho', for that effect, it were accurate enough. The Mathematical-Inſtrument-makers inſtead of the Angular Rule make uſe of a Steel Bow, which they can, by a Screw, bend more or leſs as they have occaſion, and ſo can ſtrike a ſmall Arch of a Curve, which, tho' not exact, is yet near enough to the Arch of a Circle they have occaſion to make upon their Inſtrument, and ſerves well enough for common uſe in ſmall Inſtruments; but where the Inſtruments are large and the Arches great, the irregularity may be diſcover'd; and if a Planiſpherical projection of a Sphere of twenty or thirty Foot Diameter were to be drawn, both theſe Inventions would be inſignificant.

The method for drawing large Circles.

The contrivance which I ſhall at preſent deſcribe is ſuch as will perform what is neceſſary for the deſcribing a Circle of two hundred or three hundred Foot of Diameter; which for moſt uſes in making Inſtruments or Mapps of the Planiſpherical Projection as large as any I have yet ſeen, or for ſtriking Gages for Glaſs Tools or Diſhes larger than any have been yet made; tho' for ſuch Tools indeed, the method I have deſcrib'd in my Micrography is much better, becauſe it doth at once, gage the Mould for caſting, or the Tool for working of the true Spherical Surface requir'd, whereas this only making or deſcribing a Line, the Mould and the Tool muſt be turn'd by that Gage to make the Surface thereof, of the Sphere requir'd. But there are other conſiderable uſes of it as I ſhall ſhortly have occaſion to ſhew.

Thurſday, May 16. The Royal Society met, I diſcours'd of my Inſtrument to draw a great Circle, and produc'd an Inſtrument I had provided for that purpoſe, and therewith, by the direction of a Wire about a hundred Foot long, I ſhew'd how to draw a Circle of that Radius; which gave ſatisfaction; the way was by a ſmall Truckle-wheel fix'd in a thin Ruler, ſo that the Axis of the Truckle kept parallel to the extended Wire Radius. Which Ruler had two ſmall Staples fix'd in it, through which the Wire could eaſily ſlip to and fro. I explain'd alſo to them the other way of fixing the Truckle at the end of a ſmall long Pipe of Braſs that had a hole at the Center of each end, through which holes that Wire was to paſs that was extended from the Center, and the ſame Truckle being always at right Angles with the Radiant Wire, and the Wire being free to ſlip to and fro in the holes, the edge of the Truckle would deſcribe the Arch of the Circle exact.

Wedneſday May 22. 1695. I have the laſt Meetings indeavour'd to explain the difficulties there are in making conſiderable diſcoveries either in Nature or Art; and yet when they are diſcover'd they often ſeem ſo obvious and plain to be underſtood or to be diſcover'd, that it ſeems to be more difficult to give a ſatisfactory Reaſon why they were not ſooner diſcover'd than how they came to be detected now. How eaſy it was (we now think) to find out a method of Printing of Letters, *&c.* and yet except what may have happen'd in *China*, there is no Specimen or Hiſtory of any thing of that kind done in this part of the World. How obvious was the vibration of Pendulous Bodies? And yet we do not find that it was made uſe of to divide the ſpaces of time, 'till *Galileo* diſcover'd the Iſochroneſs of its motions, and

thought of that proper uſe for it. What I ſhew'd an Experiment of and explain'd the laſt Meeting, may poſſibly be thought obvious and eaſy enough to have been ſooner thought of, by ſuch as may have had occaſion for its uſe, and yet I never found the leaſt mention made of it in any Author I have yet met with. That contrivance will ſerve very well for deſcribing a Circle of two, three or four hundred Foot Diameter, and will deſcribe it as exactly and curiouſly as any ſmall Beam Compaſs will do a Circle of two, three or four Foot. But when it doth exceed a certain length, even that alſo will begin to fail, and the difficulties will much increaſe; for that a Wire will be too weak to bear a weight ſufficient to ſtrain it near enough to a ſtraight; ſo that there is in this way alſo a *a non plus ultra*, but *eſt aliquid Prodire tenus*; this is much farther than could be done any other way; and by this way, if a true plain be given, any part, or even a whole Circle may be deſcrib'd of as great a Diameter as I have already mention'd.

But if a greater be yet neceſſary, Mechanicks do hitherto fail us, and Nature alſo gives us none greater nor leſs than the Circumference of the Earth, and that in the Surface of the Water, when the Air is Stagnant, or without Wind, or in the Surface of ſuch Water frozen into Ice. But this is ſo great a Spherical Surface, that it can be of no Mechanical uſe that I yet know of, unleſs it be to afford us a Plain large enough to deſcribe a large Circle upon, which is otherwiſe difficult enough to be procur'd. But when we have procur'd ſuch a Plain by the help of Nature in this manner by freezing, yet to deſcribe a Circle of a thouſand or two thouſand Foot Diameter, will be impoſſible by any way I have yet met with; and yet I think it not beyond the power of Art, nay, tho' one of twice that magnitude were it neceſſary.

And tho' it may be difficult enough to find a way before it be ſhewn, yet when diſcover'd, every one will be ready enough to ſay, 'tis eaſy to do, and that it was obvious to be thought of and invented; for that indeed every one ſees the Experiment of it daily, and yet no one has thought of applying it to this purpoſe, as in the inſtance I juſt now mention'd of the Pendulum: And that I may the more plainly evidence this, I have prepar'd an apparatus for the effecting thereof experimentally; which, tho' it be not a compleat Inſtrument, ſuch as I deſign to have made (when I can procure a proper Workman at leiſure) yet by this, and the demonſtration of the truth of the Grounds and Reaſons thereof, it will be put out of doubt. This Apparatus, and the demonſtration, I will preſently produce.

THe Author not having given any farther deſcription of his way, and the Apparatus of performing it, I thought it might be acceptable to tranſcribe the account of it as I found it enter'd in the Journal of the Royal Society as follows. May 22. 1695. *Dr.* Hook *produced and read an account of an Inſtrument for deſcribing a very great Circle, being, by the help of two rouling Circles or Truckles in the two ends of a Rule, made ſo as to be turn'd in their Sockets to any aſſigned Angle, thereby to become the two Tangents of any great Circle to be deſcribed; the inclination of the plains of the two little rouling Circles being always equal to the Angle, the length of the Ruler ſubtends to the Radius of the Circle propoſed.*

This is all I find concerning it; it were to be wiſht there had been ſome draught thereof preſerved; but this way may be better apprehended by the next following.

R. W.

June 20. 1695. I have in my former Diſcourſes or Lectures ſhewn ſome new methods of deſcribing the Arches of very large Circles, ſuch as are very hardly poſſible to be deſcrib'd by any other way, at leaſt not to that exactneſs, nor without almoſt infinitely more trouble and labour; and theſe by Inſtruments eaſy enough to be made and uſed, and as eaſy to be underſtood and demonſtrated, and thoſe founded on Experiments and Practices ſo univerſally known, that one would wonder how ſuch an application as this

ſhould

should not be thought of by any one that had occasion for the use of it; and this the rather, because we know it to be the reason on which is founded the practice not ony of turning the Waggons, Coaches, and such other four Wheel'd Carriages, but also of Boats, Lighters, Ships, and other Vessels; as also Fishes for moving upon and through the Water, and of Hawks, Kites, and other Birds which move through the Air. But we need not much wonder neither, when we consider at the same time how obvious the grounds of the Art of Printing were by the use of Seales, and of rectifying Clocks by the use of Pendulums, and yet how long the World was without those Arts before they were thought of for those purposes and reduc'd to practice. The true cause of which is the unwillingness that Men generally have to be at the trouble of thinking and meditating, especially when they observe that those that are so, do generally reap nothing for all their Labour, but either Contempt, and the nicknames of Madmen and Projectors, or the Emulations of others, which creates them continual troubles. Nor is there less difficulty in procuring the Instruments or Apparatus necessary to put a new Invention into use and practice, than to invent and contrive the same; for Workmen are generally very unwilling to be put out of their common Road of working, and make a hundred Objections before they will undertake, and very often make as many mistakes in the performing, before they will rightly execute what is desir'd; and the inventer must be content not only to afford them his patience, but his Purse also, otherwise no further progress is to be expected, and often also, tho' both are supply'd, yet nothing will procure any further trials; and new hands must be sought, where possibly the inventor speeds little better; but supposing him at last to have executed his design and made his purchase, what has he got but some *Difficiles Nugæ*, some new *Swing Swangs*, which were the names that the Barometer for the Weather, and the Pendulums for Clocks did a long time bear; but when Truth at length doth prevail, and the usefulness of an Invention appears, then every one claims it for his own, tho' possibly he never had the thought of it, 'till all the World knew it. These may be some of the reasons why inventions have come so thin and seldom into the World: And why many parts of useful Knowledge do yet remain undiscover'd; nor can we well expect that they should be more frequent, 'till the allurements that should prompt the Inquiry have another appearance. However, whether from the Genius of these later Ages, or from the increase of Literature by the propagation and communication of Knowledge by Printing, or from some other happy influence from above; we have found that the present Age has been much more fruitful in that kind than many preceeding, and we may hope that the approaching may be yet more, if at least *invenire discamus invienendo, ut Scribendo discimus scribere*; *Nam Res dat lumina Rebus.* This was one cause why I contriv'd the following addition to what I have already explain'd concerning the methods of describing very large Circles. The first of which was how to describe such a Circle about a Center given, and the length of the Radius, and that of so great a length, that it is almost impossible for to make any Beam Compass long enough to perform it without warping and bending, or any string strong enough to do it without stretching and shrinking; all which inconveniences I have thereby shew'd how to obviate most easily by making use of one small Truckle put upon a Wire strain'd from such a Center to its Circumference. The second way was how to describe a Circle, or any part of it be the Radius almost never so great, and that without knowing or making any use of the Center, but only upon knowing the length of the Radius or the desir'd Magnitude of such a Circle, or the Magnitude of the Subtense of the Arch of a Degree, Minute or Second, *&c.* of such a Circle. Now because there may be yet another condition desirable for some occasions, which cannot be well perform'd by either of those methods, and yet may be of necessary use for the solving of some Problems, or the actual execution of some Designs; upon further contemplating this Subject I have contriv'd this present Addition; and that is to draw the Arch of a Circle to a Center at a considerable distance, where the Center cannot well be approach'd, or where, by reason of incumbrances interjacent, a Wire cannot be extended; as from the

the top of a Pole set up in the midst of a Wood, or from the spindle of a Vane at the top of a Tower in a City, or from a point on the other side of a River, or in a Lake or Morass; in all which the Center cannot conveniently be approach'd or come at otherwise than by the Sight. This Requisite then I perform by the help of two Telescopes, so plac'd at the Truckles as thereby to see through both of them the same Point which is propos'd for the said Center, and, by thus directing of them to such a Center, to set the Truckles in their due posture, so as to describe by their motion any part of such a Circle as shall be desir'd, whose Center shall be the point of the Pole or Spindle mention'd. The qualifications of the Instrument necessary for this Effect are, First, That the Centers of the Truckles be exactly equi-distant from the Center of the Compass; that is, that the Arms of the Compass be of equal length. Secondly, That the plains of the edges of the Truckles do exactly intersect in the Center of the Compass. Thirdly, That the two Telescope Sights be exactly Perpendicular to those two Plains at two Points, as near as may be over the Centers of the Truckles.

Tab. 12.*Fig.*3. This will be more plain by a delineation, where ab, ab are the two Telescopes directed to the inaccessible Center E. c, c the two Truckles plac'd at right Angles to the Telescopes. c d, c d, two Rulers jointed at the Center d, b b a Ruler upon which the two Telescopes slide, so as to be fixt upon occasion after being directed to the distant Center.

An Extract out of the Parisian *Academies' Memoires relating to the alteration of the Axis of the Earths motion, Read to the R. S.* July *the third* 1695.

As there are some Inventions that are the Products of Design and Ratiocination, such as are acquir'd by the use of known Principles by the way of reasoning, Application or Contrivance; so there are others found out by meer chance upon Trials made for other purposes, as Gun-powder, the Magnetical Vertue, Telescopes, *&c.* But there is also a third sort of Inventions which may be ascrib'd partly to the one, partly to the other, partly to Design and Ratiocination, and partly also to Chance and Observation: Of this kind was that of the cause of the Cælestial motions and of the Spheroidical form of the Earth; of which I have long since discours'd, as also of the Parallax of the fixt Stars, and likewise of the alteration of the Poles of the Earths diurnal motion. Now tho' this Doctrine has hitherto met with great opposition on the one Hand and contempt on the other, because the later part of the invention has not been compleated by some lucky chance to prove it positively, by finding out some instances among the many Observations that are recorded that might put it beyond dispute, nor by hitting upon a *medium*, by which that might be verify'd in a short time; which, according to the known methods of Observations, require a very long one, yet I hope that a little time will produce some such proof as will put it out of doubt; and if that does not succeed according to my expectation, yet I hope I shall in some little time be able to shew a way how to effect it. I am not displeas'd that Monsieur *Cassini* thinks it worth his inquiry, and I am apt to believe is conscious of the truth of it, and that he begins to think of expedients how to solve the Phænomena when they shall be certainly found to concur with this Hypothesis, if he be not already convinc'd of it, and to be able to loose the inventer of it by finding a great number of old pretenders to it. 'Tis true that many have mention'd such a suspicion, and have indeavour'd to prove it, but they seem to have grounded their Conjectures only upon Experiments or Observations made at several times in the same place, but not upon the Theory of the causes of such a variation, whereas my Conjectures concerning it were deduc'd from a Theory, which I conceive may be consonant to the processes of Nature; I know, indeed, that 'tis a very difficult matter to find out such a Theory, and almost impossible to make it so evident as the Principles of Geometry; for that the Nature, Composition, and internal Operations and Powers of mixt Bodies are far beyond the reach of the Senses; nor will

the

Tab: XII.

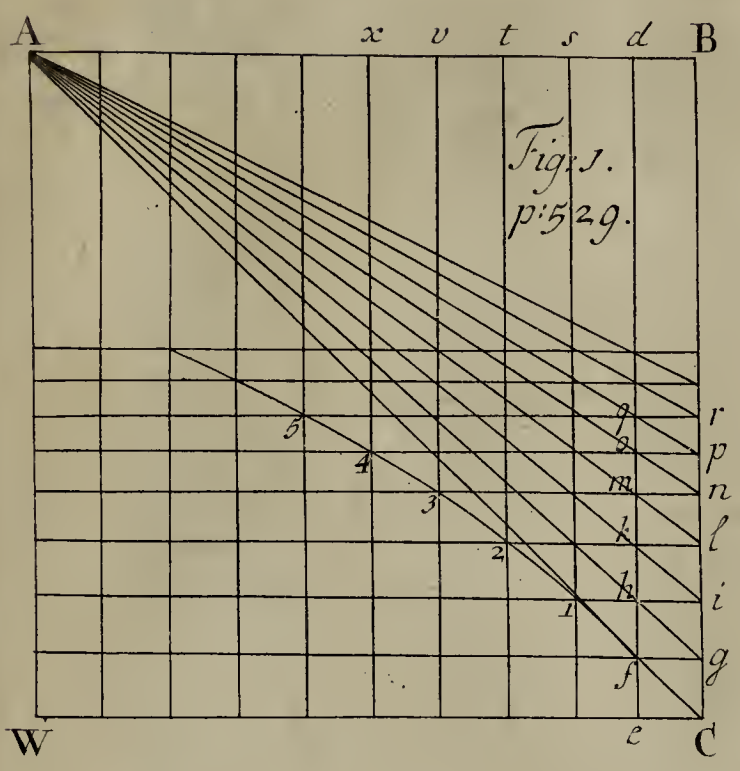
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Fig: 1.
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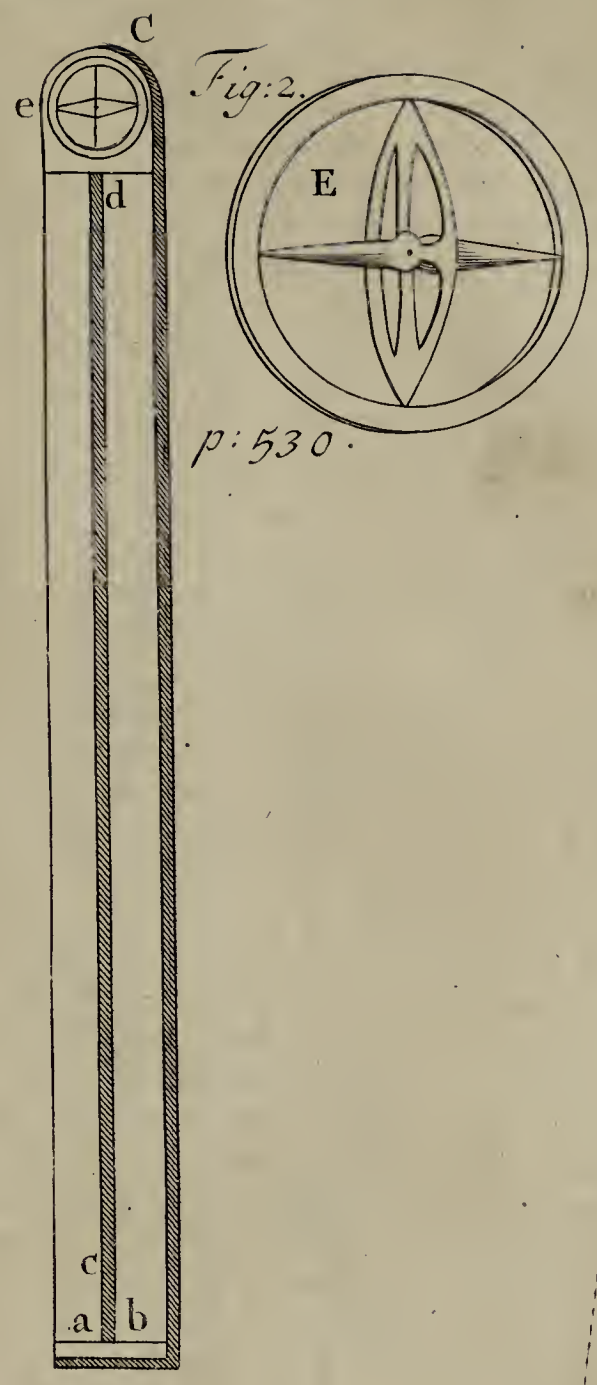
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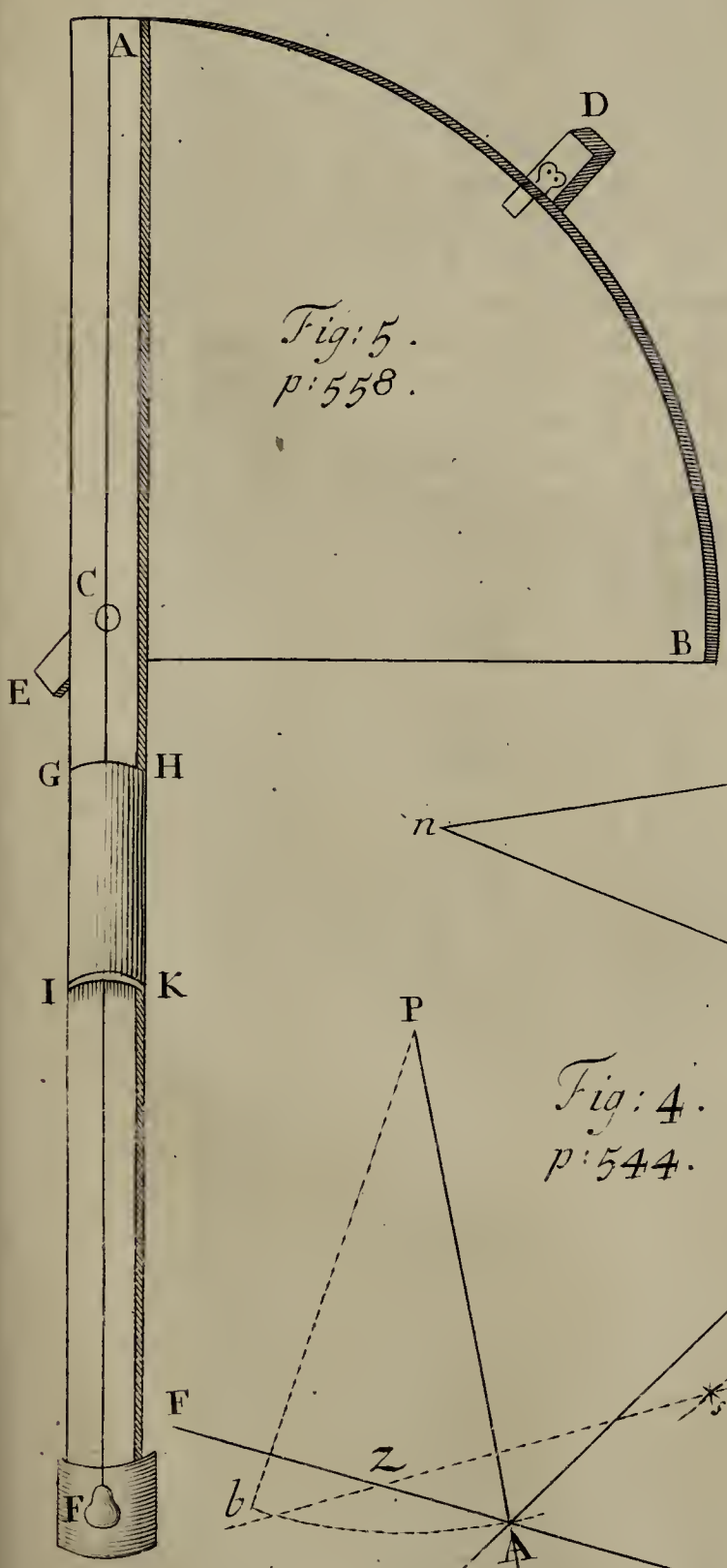
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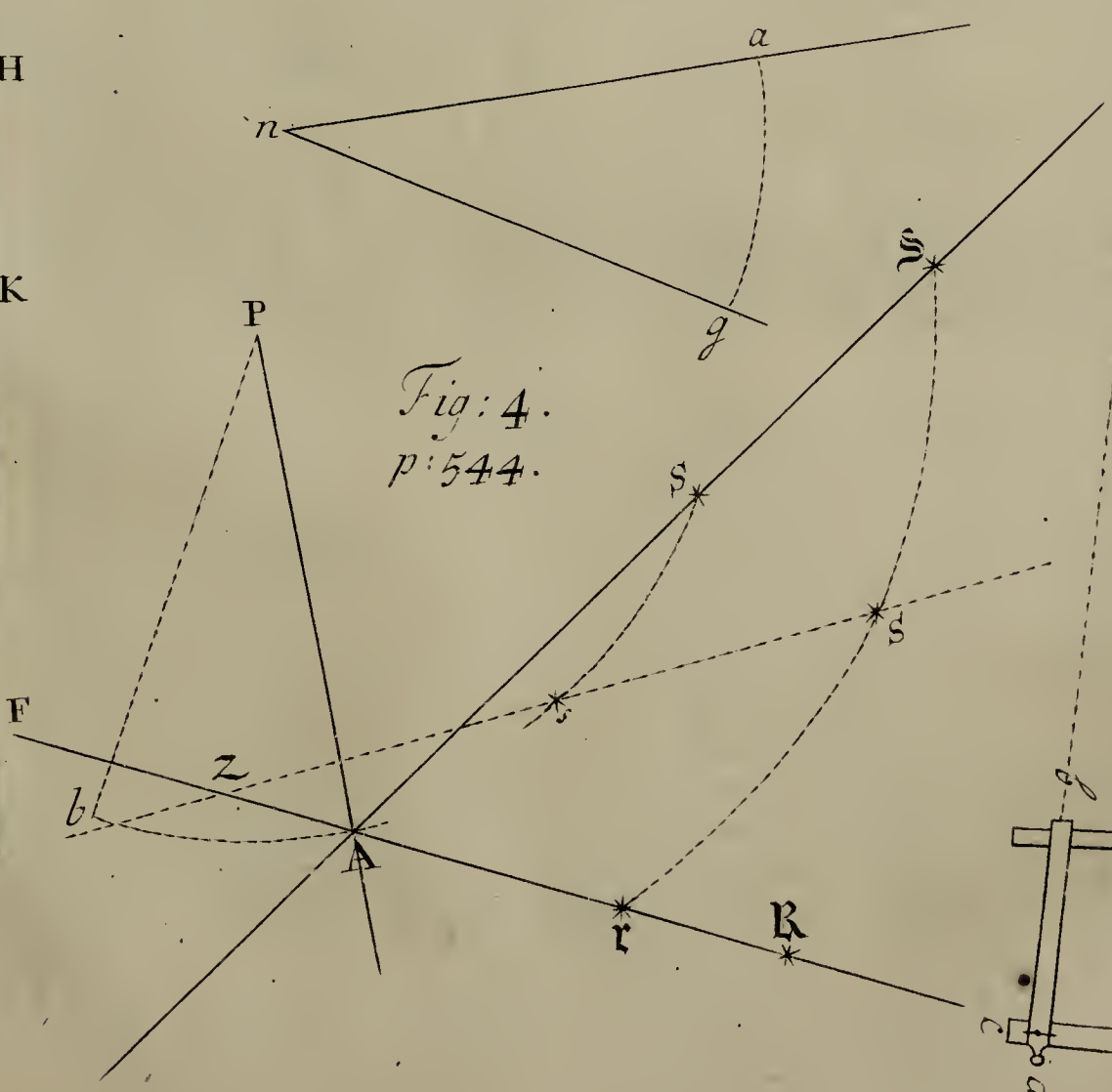
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p: 544.

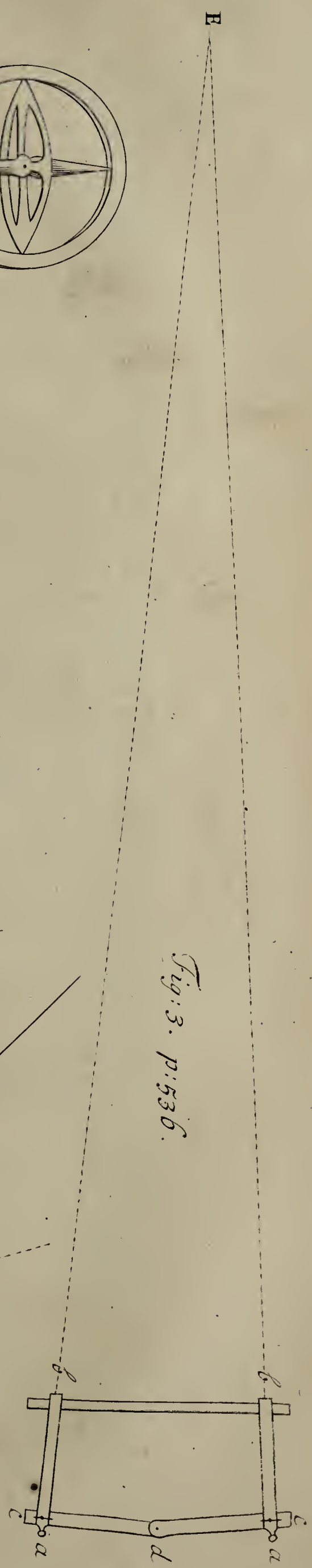
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Fig: 3. p: 536.

the Analogy hold between the motion of gross and sensible Bodies and those of minute and insensible, as can plainly enough be prov'd. And upon that account the *Data*, upon which the Ratiocination is founded, being uncertain and only conjectural, the Conclusions or Deductions therefrom can at best be no other than probable; but still they become more and more probable, as the Consequences deduc'd from them appear upon examinations by Trials and design'd Observations to be confirm'd by Fact or Effect. So that the Effect is that which consummates the demonstration of the Invention itself; and the Theory is only an assistant to direct such an Inquisition, and by what means to procure the demonstration of the Existence or non-existence thereof. Thus by my Theory I was led to believe that the body of *Jupiter* had a motion upon its *Axis*, and thereupon I had a long time indeavour'd to discover by my sight, whether it were really so as I suppos'd; but I could not perceive it 'till I procur'd and made use of a very good Telescope, and there was a Concurrence of a due position of the permanent Spot in *Jupiter*, and a clearness of the Air, and possibly of my Eyes that assisted me in the Observation; however therefore, tho' the Observation were the Demonstration, yet the Theory was the occasion of seeking after it: And the same was that discovery of the Parallax of the Earth, and of the Cælestial Motions, which I have mention'd in my Discourse, Printed on that Subject. Now, tho' I do not find that any have given themselves the trouble to repeat the Experiments and Observations necessary for that purpose; and tho' I think there is no one that can find a real Objection against the way and method of verifying it, which I made use of, yet there have not been wanting divers who have so far taken notice of it as to suggest other ways of doing it, tho', I conceive, much more troublesome, and abundantly more liable to Objection than that which I contriv'd. But let every one take his own method (for there may be many, but I believe it will be hard to find a better or so good) provided they do actually make the discovery of the reality thereof; and I am very apt to believe that the same has been verify'd in *France* and elsewhere also by my way, tho' they seem unwilling to own it, and have not publish'd the Fact; and that possibly may be, because they (that have made it) are unwilling to be thought to learn from others; and because I fear they cannot find another way of their own that will be so good as mine. And this I am inclin'd to think from a late Discourse Publish'd in the *Memoires of the Parisian Academy* and elsewhere, by which they would have it be believ'd, that the Well in the Observatory of *Paris* was made for that purpose before the publication of my attempt, tho' 'twas two Years after I had made those Observations, and read them to the Royal Society; and that Monsieur *Cassini* has purposely made Observations of the Latitudes of Places to find whether they do alter or not, and that thereupon he had detected such a variation of the height of the Polar Star, which might serve to make him the discoverer of the annual Parallax. The mode of the whole Discourse is somewhat singular, which I have therefore extracted, to shew what methods are us'd by some to raise Arguments against a truth they are unwilling to have known; and the rather, because it is also somewhat akin to Discourses for the same purpose of our own *English* Manufacture.

The use of Theories.

" The irregularity of the Seasons of some late Years, and the frequent " *Earthquakes* which have happen'd in divers places has made some suspect a " change in the *œconomy* of the World, and there have been some Astrono- " mers who believ'd that there has been of late some considerable changes " of the height of the Pole. Mon. *Cassini* having been consulted on this affair " from divers places, has computed the present posture of the Heavens, " with the Observations he has made for above thirty Years, as also with " those of the most antient Astronomers, to see not only whether there has " been any change of late, but even for many past Ages.

" The Antients took great care to compare the parts of the Heaven with " those of the Earth, observing the Circles of the Heavens which corre- " sponded with the Mountains, Promontorys, and other notable parts of " the Earth; and from time to time took notice whether these did alter: " 'Twas not long before they found some. *Eratosthenes* about two Thousand

Alteration of the Latitude of Places.

" Years since found by preceding Charts (as *Strabo* relates) that the Moun-
" tains plac'd on the East part of the Continent, had chang'd their Site,
" declining more to the North, as had also the *Indies*. He corrects those,
" and by a new Chart draws a parallel passing between *Hercules*'s *Pillers*, thro'
" the *Streights* of *Sicily*, over the South extreams of *Peloponesus*, and con-
" tinu'd through *Cilicia* to the Gulph of *Issus*, and from thence to the *Indies*,
" over the Mountain *Taurus* parting *Asia* into the North and South. These
" in *Ptolomy*'s time, four hundred Years after, had changed places, *Taurus*
" lying three Degrees more North than the *Streights* of *Hercules*. But if
" the heights of the Pole in *Ptolomy*, now 1550 Years since, were exact,
" the Poles are gone back and are come to the places where *Eratosthenes* found
" them, *Taurus* and the *Streights* being both plac'd at 36°, but this parallel
" runs two Degrees South of *Sicily*; and indeed the most part of the heights
" the Pole, observ'd by the Antients, differ very much from those found at
" present. If any could be rely'd on, those should be at *Marseilles* and *Byzan-*
" *tium*; the one made by *Pytheas*, and the other by *Hipparchus*, two of the
" most famous Observators of their times. These were made by *Gnomons*
" of great height, and at the Summer *Solstice*, well circumstantiated, and
" with all the exactness Astronomy was then able to effect. Now if these
" were exact, 'tis certain great alterations have happen'd since the times of
" *Hipparchus*; for *Hipparchus* found *Byzantium* in the parallel *Pythias* had plac-
" ed *Marseilles*; yet *Strabo*, who liv'd 150 Years after *Hipparchus*, affirms
" *Byzantium* to be more North than *Marseilles*: For the Parallel that past
" through the *Streights*, was only 3°, 34′, South of *Marseilles*, but from *Bi-*
" *zantium* it was remov'd seven whole Degrees. The Oriental Astronomers,
" who liv'd divers Ages after *Strabo*, make *Byzantium* two Degrees more
" North than it was in *Hipparchus*'s times, as is plain by the Tables of *Nasser*
" *Eddir*. and *Ulug Beg*.

" But in this Age on the clean contrary, *Marseilles* is two whole Degrees
" more North than *Bizantium*; for *Cassini* going on purpose to *Marseilles* in
" 1672, found the Latitude of it 43, 17. and *Deschales* at *Byzantium* observ'd
" its Latitude only 41°. 6′. which agrees also with the Observations of Fa-
" ther *Besnier*, from all which, if suppos'd true, there must have happen'd
" great changes.

" The difference also between the Latitudes of divers places recorded by
" *Ptolomy*, and those observ'd in the same places by other Astronomers, since
" may be argument enough for our Beleif, that the Pole has chang'd much
" since the time of *Ptolomy*. This difference appear'd so convincing to *Do-*
" *minick Maria* of *Ferrara* (a Man of an excellent *Genius* as *Maginus* affirms,
" and who was Tutor to *Copernicus*) that he asserted that the height of the
" Pole did continually change, and that places now in the *Torrid Zone*, would,
" in process of time, come into the Frigid and the contrary; and that the
" Mountains of *Æthiopia*, now roasted by the Sun, would in time be co-
" vered by Snow and Ice. *Maginus* also, and the Astronomers of his time,
" affirm the Poles also to have changed. And *Ticho* was so far mov'd by this
" Opinion, that he desir'd the State of *Venice* to send an able Astronomer
" on purpose to see, if the present Latitude of *Alexandria* were the same that
" *Ptolomy* had found it; but this without effect; however 'tis expected from
" some, since sent for that purpose by the *French* King. 'Tis true, the ex-
" actness of antient Observations was not to be compar'd to the Modern,
" and therefore no more shall be said on that head at present.

" But next to come to Observations less to be suspected, as being made
" this last Age. *Rothman* assures *Ticho* by a Letter, that he had found a dif-
" ference of the height of the Pole of a Minute or two, between the Win-
" ter and Summer of the same Year. *Snellius* and *Ricciolus*, who are both a-
" gainst this Opinion, do yet report Observations that confirm it, as that
" *Ticho* observ'd the Latitude once 50°. 6′. another time 50°. 4′. 30″. such are
" the Latitudes of *Paris* found by several Men, 48. 39′. [48. 45.] 48. 50. and
" some 48. 55. Great differences are also found of the Latitude of the same
" place taken at different times by *Riccioli* and *Grimaldi* with the greatest ex-
" actness. *Grimaldi*, in 1645, finds the Tower of *Modena* in 44°. 37′. ex-

actly,

" actly, and the same *Grimaldi* with *Riccioli* in 1654, finds it 44. 38'. 50". the " same found a place on the Mountain of *Bolonia* 44°. 27'. and the same " place another time 44. 27'. 50". The same in 1646, found his Observatory " in *Bolonia* 44°. 29'. 30". but in 1655, he, with *Cassini*, found it 44°. 30'. 20". " the same says, *Ferrara* was once observ'd 44°. 50'. another time 44°. 51'. " 7". and *Cassini* another time since, by repeated Observations, found it 44°. " 52'. In the Year fifty six *Cassini* found the Palace of *Farnesi* in *Rome* 41°. " 52'. but in sixty eight he found the Palace of *Cardinal d'Este* (which should " have been more) only 41°. 51'. At *Paris* 1668. *Cassini* and *Picart* found the " height of the Pole-star at the Kings Library 48. 53. and by that the height " of the Observatory must have been 48°. 51'. 10". two Years after when " the Observatory was finish'd, *i. e.* in *September* 71. *Cassini* finds it 51°. 19'. " 40". and the twelfth of *October* following 51°. 19'. 50". and the eighth of " *September* 51°. 19'. 10". *Picart* at *Uraniberg* 1671. on the eighth of *Octo-* " *ber* finds the greatest height of the Pole-star 58°. 23'. 15". but in *November* " he finds it 58°. 22'. 55". and in *December* 58°. 22'. 45". He adds other in- " stances of his own and other Observations too long to repeat at this time, " by which he seems to prove a change of the Latitude of Places, or the " height of the Pole even at the Observatory of *Paris*. But after all he pro- " ceeds thus———.

" Notwithstanding all these Observations of apparent variations, it may " be said only, that in these later times there has happen'd no extraordi- " nary change either in the height of the Pole or Meridian Altitudes of the " Sun; but also that the Heavens have at all times kept the same Position " to the Earth that they have at this present Age; since it may be believ'd " that all those variations, of which I have spoken, may have proceeded from " Defects in the Observations: As, First, From the defaults of Instru- " ments, since it is certain that Instruments do suffer alterations from time " to time, the causes of which are imperceptible, which is the cause why " they are sometimes examin'd and corrected. Secondly, From the difficulty " of distinguishing the parts of a Minute. Thirdly, From the differing " Refraction of the Air, especially at the Observatory of *Paris*, being on the " South side of so great a City. Fourthly, As there is a variation of the " direction of the Magnetical Needle, so there may happen some change of " the direction of the Perpendiculars of Instruments, and these changes may " be more sensible in some places than in others. Lastly, As to the Observa- " tions, of these the Antients were made with very course Instruments, they " had no regard of Refraction or Parallax or other Circumstances that might " cause Errors, and thence we need not wonder at such considerable differences " among them, besides the mistakes of Numerical Figures by the Transcribers; " so that making allowances for all these, there will remain little difference of " Position of the Heavens to the Earth, or the motions of the Stars to be " rely'd on, and it is more reasonable to ascribe those that are found to these " accidents than to a change in the Heavens.

" And yet it is most probable that there is some small variation of the " height of the Pole which happens from time to time, but that never ex- " ceeds two Minutes, and it will be settled in time. This is very remark- " able in the height of the Pole of *Alexandria*.; for *Ptolomy* with all his " care found it sometimes 30°. 58'. at other times 31°; so tho' there be a " little change, yet this must not pass as extraordinary, since it exceeds not " two Minutes. The difference between those of *Ticho* and those of *Picart*, " in 71 and 72. is but 50". in 88 Years; and we must consider that this is " not in proportion, since we have found a greater change in one and the " same place in one Year. For twenty two Years now since the Observatory " has been built, *Cassini* has found but two variations: This variation the " said *Cassini* has attempted to reduce to some Rule; he fancies the Altitudes " of the Poles diminish as the Sun approaches the Æquinoctials and Solstices, " and increase as it departs from them.

" Mr. *Cassini* also believes there is some change in the Solstitial Altitudes, " and has actually found them, but those not so great as those of the Pole; " and these variations he conceives, will in time settle also. We have al-

ready

" ready seen, that those of *Pythias* made at *Marseilles* three hundred Years " before Christ, and *Cassini*'s in 1672. differ but some Minutes, and we may " shortly expect, whether those sent by the King on purpose to *Alexandria*, " will find any difference from *Ptolomy*'s Solistitial Altitudes.

" It is of great importance in Astronomy to know to what preciseness the " height of the Pole can be found; for if we cannot with all our care, be sure " of it within half a Minute, 'tis in vain to make use of it for finding the " Parallax of Planets above the Moon, or for setling the hour of the Sol- " stice, where some few Seconds are considerable; but indeed for *Geogra-* " *phy*, *Navigation*, or *Chorography*, this is curious enough".

The Authors Reflections.

What the design of this long Discourse of Mr. *Cassini* may be I cannot gather, unless it be to seem to deny the variation of the Altitude of the Pole, because possibly he is oblig'd so to do, and yet at the same time exactly prove it; or by a new way to solve the annual Parallax of the fixt Stars; which he seems to grant, but yet 'tis by a new fancy of his own, for which I can conceive no reason. Me thought Monsieur *Comiers* was much more conceivable, tho' extravagant enough, that every Star mov'd in a little Epicicle of a Minute in Diameter, once round in a Year. Next I cannot but wonder to find him at the same time relying on Observations of the Antients to prove what he would have to be so, and rejecting as far (and bespattering indeed all) that are not for him; an easy way to prove or dispove any thing. Thirdly, I observe, that tho' what I had formerly spoken of the alteration of the Center of the Gravitation of the Earth, were look'd upon as a very extravagant and improbable Opinion, yet I conceive it is not so esteem'd by the *Parisian Academians*; otherwise it would not have been Printed. I am also now apt to suspect that *Ticho Brahe* did *doulein Hypothesei*; since, by *Rothman*'s, he was advertis'd of such an annual Phænomenon or Change, and that he might easily have satisfy'd himself by his own Observations, without sending to *Ægypt* for information. To conclude, as Monsieur *Cassini* conceives these little variations or swayings of the Poles and Solstices will, in some short time, settle and fix in their true places; so I conceive that all these struglings to make it this or that, somewhat or nothing, more or less, will at last terminate in that Explication thereof, which I have long since propounded.

La Meridiana del Tempio di S. Petronio, &c. *i. e.* The Meridian Line of the Church of St. *Petronio*, drawn and fitted for Astronomical Observations in the Year 1655, Revis'd and restor'd in the Year 1695. by *Joh. Dominico Cassini* primary Astronomer. Pontificial, Mathematician, and one of the Royal Accademy of Sciences; Printed at *Bolognia* 1695, in twenty two Sheets in Folio.

Of the Meridian Line at St. Petronio.

In this Book written by Mon. *Cassini*, but Publish'd by *Dominico Guglielmini*; there is an account given of the occasion of making this Meridian Line in the Year 1650, of the method of doing it, and of the exactness with which it was perform'd by Mr. *Cassini* at that time; then of the uses that have been made of it, and of the alterations that have happen'd to this Church since that time, and of the Restauration and Examination of it in the Year 1695, by Monsieur *Cassini* himself; and lastly, of the uses that may be made of it for the future.

To this is adjoined a Discourse of Snr. Dominico Guglielmini, Mathematician and publick Lecturer of *Bolognia*, giving an account of the Operations made, and of the Instruments us'd in this last Restauration of the said Meridian Line. Monsieur *Cassini* in the first Section, says, this verifycation was the more considerable, First, Because it fell out to be the Year before the last intercalation of the *Gregorian* Year, before the omitting of one Leap Year (which is to be done in the Year 1700, in order to make the vernal Æquinox to be on the twenty first of *March*) and so would give an opportunity to observe exactly the time of the Suns entrance into *Aries*. And, Secondly, For determining a Controversy much agitated now among the Learned, whether the Position of the Meridians and Parallels on the Earths Surface do really alter; for that not only the present posture of them are found very different from those of the Antient Geographers; but differences are found also among the more modern Observations, as the present Meridian of *Uranibur*

Difference of Meridians among the Moderns.

neburg has been lately found by Monsieur *Picart* and others, to vary 18′. towards the East from that fixed by *Ticho Brahe* above a hundred Years since; and the *Pyramid* of *Egypt* has been found newly to stand in a posture that two sides of it respect the South. Now he having found that the Meridian and Parallel of *Bononia* have not alter'd at *Bononia* in fourty Years, conceives those other alterations, suppos'd to be found, are to be ascrib'd to the defects of the Observations themselves. In the next place he relates the first occasion of making a Meridian Line in this Church of St. *Petronio*, to be for rectifying the time of *Easter*, and the Feasts of the Church which depend on the true time of the Vernal Æquinox. Now the Prelates of *Alexandria* (who were deputed by the Council of *Nice* to state that time) found it then to be on the twenty first of *March*; but Pope *Gregory* being inform'd, that it, in this time, fell on the eleventh of that Month; he alter'd the *Julian Account*, and made the eleventh to be the twenty first. This was the occasion of *Ignatio Dante*'s first making a Meridian Line in the Pavement of that Church in the Year 1575, before this alteration which was in 1683; but this Line being found to vary from the present Meridian, and to be serviceable only for observing the Solstices, and being suspected to be so misplaced by reason of the obstruction of the Pillars of that Church was the occasion of Monsieur *Cassini*'s finding a fitter place, and fixing there his new Meridian Line in the Year 1655. the place where, and manner how he more particularly and fully expresses, because it was of so considerable, and, as it were, of sacred use to the Church: He names all the eminent Astronomers who were his Concomitants in the Operations, as witnesses of the exactness of it. After this he relates several variations that have happen'd to that Fabrick since he first fixed this Line, and thereby shews the necessity and use of the Restauration, and adjusting it, for the time to come, by which any further alteration that may happen to that Building for the future, may be so far remedied, and the essential parts of this Line so far restor'd and rectify'd, that they shall be as effectual as if no alteration had happen'd. The uses of which will be not only to shew the true time of the Suns ingress into the Tropicks and Æquinoctial Points, but likewise into all the other Signs, and so serve for the verifying or rectifying the Calender. The same being now so plac'd as that the Perpendicular height of the hole by which the Light is admitted (which is an Inch in Diameter) is a thousand Inches of the *Paris* Foot above the Pavement and the Meridian Line which is as a tangent to it, as the tangent of 45°. divided into 100000 parts upon one of the Marble Cheeks that border the Ruler of Iron that expresses the Meridian Line, and upon the other Cheek of Marble are mark'd the Degrees of the distance of the Sun from the *Zenith*, whereon are also mark'd the places of the Signs of the Ecliptick. From the Observations made by this Line Monsieur *Cassini* calculated his Tables of Refractions, which have been since verify'd by other Observations.

These considerations induc'd the Senators of *Bononia* who had the care of the said Edifice committed to them to be at the charge to repair the said Line, and to take care that it should be preserv'd for the future; to which intent they not only caus'd the Instruments made use of in the fixing this Line to be safely preserv'd, but they also desir'd *D. Guilelmini* to make so good a description of them, that in case of decay it may be known how to supply and make use of them for this purpose for the future; which intention and desire the said Learned Professor hath fully perfected and compleated in his Discourse subjoined to that of Monsieur *Cassini*, and has likewise added some useful Tables, as that of the parts of the Radius answering to the divisions of the Tangent into Degrees, Minutes and Seconds. Secondly, That of the Refractions and Parallaxes of the Sun at several Altitudes. And, Thirdly, A Table of the Declination of every Point of the Ecliptick, answering to the Minutes of Declination for the obliquity of the Ecliptick, which he makes to be 23°. 29′. 12″. He says also, that he by accurate Observations finds the height of the Pole at that Church to be 44°. 30′. 15″. which is 1′. 15″. greater than what Monsieur *Cassini* had found it in the Year

The Authors Remarks.

1655. All which Particulars, and many other remarkable will be found in the Treatise itself, to which the Reader is referr'd.

That the Meridian Line which was fix'd by *Dante*, was not plac'd in the true North and South Line, but did vary a little from it at first I can easily grant, by reason of the Position of the Church and the Pillars thereof which would not supply a fitting Room and Space for a more convenient Situation of it; and for that I find the Author *Dante* to acknowledge as much in his *Anemographia*, Printed 1578. namely, that it did deflect a little towards the North-East; for that he says, that the Sun, when it come to pass his Line, was a little fallen from its Meridian Altitude; but whether the same did then respect the Meridian with the same Inclination as now it is found to do; namely, with an inclination of 9°. 6′. 20″. as *Riccioli* observ'd it, we have no Evidence; and I do very much doubt whether we should have been acquainted with it if there had been found a real variation; because the very imagination of such a variation was condemned in *Galileo*, who brought it as an Argument to prove the motion of the Earth; who, as *Riccioli* words it, *ex nimio Pruritu annuum motum telluris undecumq; fulciendi, Statim ac audivit mutationem Liniæ Meridianæ a Marsilio assertam concepit animo Spem hinc argutum aliquid pro terræ motu annuo excudendi.* And such as are zealous to defend a Profession of their own, or receiv'd Doctrine of the Religion they profess, or of the Church of which they are a Member, are very unwilling to hear any Argument that shall be urged against it; much less to produce or publish any new Argument or Evidence of their own finding; however, 'tis very hard to suppose the noble *Ticho Brahe* to have been so negligent or ignorant as to place it eighteen Minutes wrong, and the variation observ'd by *Guilielmni* of the Latitude of *Bononia* to be different from that observ'd by Senr. *Cassini*, seem to argue somewhat for a variation. But let Time determine this Controversy to Posterity, and every one for the present satisfy himself as well as he can with what evidence he can meet with: That there are as great mutations as these in the Globe of the Earth, and of some of the other Globes I hope I shall be able some other time to prove.

Vide p. 530.

HAving met with the following Paper among the Authors loose Manuscripts, I judged it might not be unacceptable in regard the foregoing Discourses, concerning the Rumb-line, is left so imperfect.

R. W.

Sep. 25. 85. The projecting the Rumb-line from the Pole, maketh it a proportional Spiral upon a plain parallel to the Æquator, and consequently the Rays from the Center being Meridians, are the true tangent Lines of half the Angles from the Center, or of half the Degrees of the Complement of the Latitude, and consequently the intersection of the Rumb-line is easily found by the propriety of the proportional Spiral, equal differences of Longitude dividing the said Meridian or Tangent Lines into continual Proportionals; which continual Proportionals are easily found by the Logarithms, and by the Logarithms of the half Tangent Lines the Degrees of the Complement of the Latitude are also found; and in a plain projection upon a Cylinder, the division of the Meridians are made in proportion of the Logarithm of the half Tangents of the Complements of the Latitude; but if it be made by the projection beyond the Æquinoctial, then the Logarithms of the half Tangent of the Latitude will give the divisions of Latitudes upon the Meridian.

The

THe Author not proceeding any further in the former Disquisition as to the other methods of finding the Longitude at Sea, except some fragments relating to the improvement of Time-keepers, which possibly I may some time or other give an Abstract of, if I can reduce them to any Order, they coming to my Hands very imperfect, many parts of the Discourses being lost: I say, the Author breaking off the former Discourse abruptly, I shall here present the Reader with a method by him propounded for finding the Latitude of Places.

R. W.

Read before the Royal Society, May 11*th*. 1687.

I mention'd, in some former Discourses, some ways of discovering the Latiudes of places at Sea without knowing the Meridian, and without taking an Altitude, which were perform'd by the help of some true Projections of the Cælestial Hemespheres, whereof the Polar Points were the Centers, by finding and observing some remarkable Stars in some one Azymuth or Perpendicular, and two other remarkable Stars in some other; and this to be performed either when such Observations happened to be made both at the same instant, or the one of them some known or noted time after the other.

The former of these two ways, which supposeth both the said Observations to be made at the same instant, I shew'd by the Tangent Projection upon a Plain touching the Polar Point, or any other Point of the Sphere that comprehended all the four Stars; the Zenith Point of the Place, and the Polar Point or Æquinoctial Circle, was very easily perform'd by the help of a Ruler and Compasses, by drawing a straight Line cross the Projection with black Lead, passing through two of them that were observ'd in one Azymuth, and then laying the Ruler over the other two that were observ'd in the other Azymuth, and noting the Point where the said Ruler shall cut the former Line drawn with black Lead upon the Projection; for that That Point of Intersection will represent the true Point of the Heavens then in the Zenith of the place where such Observation shall be made. Now by finding the true distance of that Point of Intersection either from the Polar Point, if it be comprehended in the Projection, or from the Æquinoctial Circle, if that be comprehended, it will not be difficult to find the true Latitude of the place; and, if it be desir'd, the Positions of those Azymuths and the hour of the Night, and the true Meridian Line, and the like, which would be too long to explain and exemplify at this time and place.

Ways of finding the Latitude.

I do not remember to have seen the Lecture preceding this.

The former of these two kinds of Observations may also be perform'd by the planispherical Projections, or the half Tangent Projections, where the Polar Points are made the Center of the Projections more easily, or somewhat more difficultly where any other Point of the Sphere is made the Center of the Projection; which is perform'd by drawing great Circles upon the said Projections with black Lead which shall pass through each of the two Stars observ'd in the one and the other Azymuth or Perpendicular; for that the Point of Intersection of the two great Circles thus drawn, will shew, upon the said Projection, the true Zenith Point of the place, whose distance from the Polar Point of the said Projection (which is easily measurable) will give the Complement of the Latitude of the place. The greatest difficulty in this way, is the drawing of a great Circle upon the Projection, which shall pass though the two Stars observ'd in the same Azymuth or Perpendicular. But this, as it may be perform'd divers ways, some more easy, some a little more difficult, some of which are Printed, and others may if occasion require; so I think none so difficult, but that an ordinary Capacity may, in a short space, be inform'd how to effect and perform the same with accurateness enough. But the explaining these ways would be too long for this present Meeting.

As

As for the ſecond ſort of Obſervations, wherein the two Azymuths are obſerv'd at two differing times; that is, the ſecond Obſervation of any two noted Stars in ſome Azymuth is taken, ſome known or meaſur'd ſpace of time after the firſt hath been taken notice of: Theſe may be made alſo ſerviceable for the finding not only the Latitude of the place, but alſo of all the other *Poſtulata* mention'd to be found by the former way, but with ſomewhat more of Operation, and that not only by the Projections of the Sphere made according to the Tangents, but alſo by thoſe of the ſame made by the half Tangents of diſtance from the Central Point thereof: And both theſe may be divers ways effected upon the ſaid Projections; but the moſt eaſy, and that which is accommodated to both theſe kinds of Projections, is by ſuppoſing that part of the Heavens to ſtand ſtill, wherein the firſt Obſervation was made, whilſt the reſt of the Heavens have paſs'd on their uſual progreſs proportion'd to the interval of Time between the firſt and ſecond Obſervation; for by that means the two Azymuth-Circles both paſſing through the Zenith of the place, both the ſtraight Lines repreſenting them in the Tangent Projection croſs each other in the Zenith Point, or in a Point as far diſtant from the Pole of the Projection, as the Zenith of the place is from the true Pole in the Heavens; and alſo the Circles in the half Tangent Projection repreſenting thoſe great Circles of Azymuths will croſs each other in the Zenith Point at the later Obſervation.

Tab. 12. *Fig.* 4. To make this the more intelligible, let ℞ r, ♋ ♂ repreſent four notable Stars truly plac'd in a Tangent Projection of a large part of the Northern Hemiſphere, whoſe Polar or Central Point let P repreſent.

Let ℞ r, by Obſervation, be found to be in the ſame Azymuth or Perpendicular one above the other at ſome time of the Night; lay a Rule over thoſe two Stars in the Projection, and draw the Line FA r ℞; this Line therefore muſt repreſent the ſaid Azymuth Line or great Circle in which is the Zenith-Point at the time of Obſervation; which Zenith-Point we are yet to ſeek and find out, becauſe the great Circle that paſſeth through the other two Stars ♂ ♋, doth not croſs the former now in the Zenith-point, but in ſome other Point, as A at an unknown diſtance from it; but by watching them they are found by ſome good Time-keeper, as a Pendulum-watch, or the like, to meaſure the Time, and a convenient Inſtrument to find when they are in ſome one and the ſame Perpendicular, at two Hours after the firſt Obſervation, to be in one Azymuth Line. Now, tho' not before, a ſtraight Line drawn through them, repreſenting a great Circle, will alſo be a true Azymuth Circle, and will paſs through the Zenith-point of the place at the time of the later Obſervation. Let a, n, g, repreſent the Angle made at the Pole by the Heavens moving Weſtward in the ſpace of two Hours, *viz.* thirty Degrees. Suppoſe then the Azymuth Circle firſt taken, *viz.* FA r ℞ to ſtand ſtill, and all the reſt of the Heavens or the two Stars ♋ ♂ to be mov'd forwards or Weſtwards thirty Degrees, and ♋ ♂ be now at S s, draw the ſtraight Line through them, *viz.* b S s, cutting the other FA ℞ r, not in A as at the time of the firſt Obſervation, but, at Z, I ſay; this Point of Interſection Z, ſhall repreſent the true Zenith-Point of the place, both in the firſt and laſt Obſervation; for APB is made equal to a n g, denoting the interpos'd time, and P b s S is made equal to the Angle PA ♂ ♋, which ſhews their reſpects to the Pole in the later and firſt Obſervation. Now FA℞ and b s S both paſſing through the Zenith, there can be no other Point in them to repreſent the ſame, but where they croſs each other, *viz.* Z. Z therefore is the true Zenith Point, and its diſtance from the Polar Point P being meaſur'd upon the Projection, will give the Complement of the Latitude of the place.

The ſame thing may be perform'd upon the half-Tangent Projection, and with more convenience, by reaſon of its great Capacity, and the leſs inequality of diviſions: It hath only one Operation ſomewhat more difficult than the other, and that is the drawing great Circles through the ſaid Stars inſtead of ſtraight Lines in the preceding way; but in all things elſe the Method and Demonſtration is the ſame with that, and the Point of Interſection

ſection of the fixt Azymuth, and remov'd Azymuth is the Zenith-Point of the place.

Now the ways of drawing a projected great Circle which ſhall paſs thro' two Points given of this kind of Projection, being many, and moſt of them eaſy enough; I conceive this method of finding the Latitude of places may be of very good uſe for Navigation, eſpecially at ſuch times, as, by reaſon of Foggs or other Impediments (as the unknown declination of the place) Altitudes cannot be ſo well obſerv'd or made uſe of at Sea.

But for the finding the exact Latitude of places upon the Land where great Inſtruments may be us'd, I have other methods, not depending upon the ſuppos'd true placing of the Stars, whereby that inquiry may be anſwer'd to what accurateneſs ſhall be deſir'd, which will be of very good uſe for that other queſtion which I have propounded; that is, whether the Latitude of places alter and vary upon the Earth in proceſs of time; and ſince, if there ſhould be any ſuch, the variation is but ſmall, and therefore very ſlow, and the unaccurateneſs poſſibly of former Obſervations cannot much be depended upon; I conceive that by thoſe ways it may be poſſible to reſolve that in a very few Years, which, by the commonly known methods, cannot be expected in leſs than ſome Ages, which is the beſt way of redeeming Time by making the beſt uſe of what we have yet to come.

This Lecture, and the following, treat of the inequality of the Earths Motion, and of the methods of obſerving and examining it.

May 25. 1687. It has been no ſmall diſcouragement to my progreſs in explicating ſome Phænomena of Nature by ſome new Hypotheſes, to find that they have been miſrepreſented, or at leaſt miſunderſtood or miſconſtru'd; miſrepreſented I mean, when, Firſt, I have been ſaid to aſſert that abſolutely and poſitively, which I only propounded as an Hypotheſis, or as Queries to be further examin'd by Reaſon, Experiments and Obſervations. And, Secondly, When I have been repreſented, as affirming things which I never did nor could have done with coherency to the Hypotheſis; as that the Earth hath been many times, beſides in *Noah*'s Flood, all cover'd with Water and dry'd again: Miſunderſtood I mean, when the Arguments I produc'd were not rightly conſider'd and duly weighed, and that it ſeem'd indifferent to the Examiners to conceive of the matter as I had argued for it, or the quite contrary: As to conceive that the Figure of the Earth may be either a prolated Sphæroeid, or an oblong Sphæroeid, or neither of theſe. Miſconſtrued I mean, when that which I propounded for one end and uſe, is wreſted to quite another; as becauſe I had doubted of the ſufficiency and certainty of the Aſtronomical Obſervations for this purpoſe, only for determining whether the true Latitude of places, or their true Meridian Lines, had varied, therefore I am repreſented as calling in queſtion all Hiſtory, both Divine and Humane. Theſe kinds of proceeding might have been expected from a provoked Adverſary; but why they come, whence they they do, I know no reaſon. However, by the Sequel I doubt not but that even thoſe who ſhew the moſt prejudice, will make it evident by the benefit and uſe they make of them, that there was no reaſon for ſuch kind of treatment; nor ſhall it deter me from proceding to propound ſome other Conjectures; which, whether rightly propounded or not, I ſhall leave to further examinations by Experiments and Obſervations, as I did the former; all I deſire is a fair trial; let the Teſtimonies of Nature itſelf be examin'd, and their Evidence not wreſted nor baſled.

Of an inequality of the Earths diurnal motion.

The thing I ſhall at preſent propound, is what I hinted in my attempt to prove the motion of the Earth. *Page* the 27, *Line* the 31, 32, *&c.* I did there hint, that I had then, in ſome of the foregoing Obſervations there mention'd, diſcover'd ſome new motions even in the Earth itſelf, which perhaps were not thought of before; one of which was this which follows, which whether it were aſcribable to this or any other cauſe, I will not contend; let trials more accurate and curious than poſſibly thoſe firſt were may determine it; I propounded it only as a query for examination. It is eighteen

Years since I made the Observations, and they were made by a Clock which went three Years without winding up more than once, which was the first of that kind, where the weight of the Pendulum was very near as big as the weight that kept it going for so long a time; whether the cause of the inequality were to be ascrib'd to the Clock, or the Earth, or some other unheeded Circumstance, I will not now contend; yet I did, with what care I then could, consider of all I could think of, and upon the whole conceived them to be ascribable to some inequality in the motion of the Earth; but let further trials determine it.

The Error was in the pendulum-rod which being shortest in cold weather, caused the winter revolution of the Earth to seem longer.

I conceiv'd then that there was some inequality in the diurnal Revolution of the Earth, not such a one as *Kepler* supposeth, only of the Earth turning quicker when nearer the Sun, and slower when further from it, but an inequality in every Revolution; that is, that in one part of the Revolution it was slower, in another somewhat quicker; which, whether to ascribe it to the power of the Sun, or that of the Moon, or both, let farther examination determine; for there may possibly be causes, why both of them may effect it in its diurnal Revolution. I do therefore propound as Queries, whether there may not be in the Body of the Earth some parts which, tho' as to the gravitating powers of the Earth, may be duly situated and poised for its equal Revolution upon its Axis, yet with respect to the gravitating Power of the Sun or Moon may not be counterpois'd, but be over ballanc'd on one side of its Axis.

That there may be a difference in the kinds of gravitation in different Bodies.

I know that if the gravitating Power in the Sun and Moon be exactly the same with that of the Earth, the Query I propounded can have no ground; but tho' they may in most particulars be consonant, as I shall prove in my Theory of Gravity, yet there may be a cause (and there seems to be some assignable) why there may be something Specifick in each of them, of that kind which I now propose, as may be possibly conceiv'd from the Moons Libration, or its turning or keeping pretty near the same side of its Body to the Surface of the Earth. For tho' the supposing it to turn upon its Axis in respect of the Sun, so as to make a Revolution Isocrone to its Synodick Revolution about the Earth, be an ingenious Hypothesis; yet the Physical Reason of such an equality seems pretty difficult to be conceiv'd, unless we suppose some cause from the Constitution of the Body of the Moon itself, which makes one part of it gravitate more towards the Center of the Earth than another in such a Revolution. And if such there be (as I see yet no clear reason to the contrary) then must the unequal progresses of the Moon produce a kind of Vibrating, Librating, or Pendulous motion thereof; so that the equal motion suppos'd will be blended or compounded with a Pendulous motion of that part towards the Center of the Earth. I will not presume to assign what this cause may be in the Body of the Moon; whether one side of its Body next the Earth be more dense and solid, and the opposite more porous and spungy, or whether the one be constituted of Bodies more heavy in Specie than the other, as that those parts which respect the Earth, should be more of the Nature of Earth, Stone, Rocks or Minerals, and the opposite of Waters, Seas, Atmosphere, Air, or somewhat anologous to them; which some appearances do seem to favour, and some others purposely and designedly contriv'd and perform'd, may give us further information of: But upon the whole it seems to me there is a necessity of some such supposition to solve the Phænomena hitherto taken notice of; and there may be a necessity of some other suppositions to solve some other Phænomena which I shall on another occasion mention. As to suppose that the Body of the Moon, tho' it be Sphærical as to its Circumference which appears in the Full and New Moon, in Ecclipses of the Sun, when view'd from the Earth, yet that its Body may be in that Diameter of it which respects the Earth much longer than in any other Diameter; that is, it may be of an oblong oval Figure whose longest Diameter respects the Earth; whose Centers of Gravity, tho' they are in the Axis, are yet not in the middle thereof, but nearer towards the Earth. Now if there be such a diversity of the Body of the Moon with respect to the Earth, why may there not be some such in the Body of the Earth with respect to the Sun, nay, tho' it have a Revolution upon its

Of the Moons Librating and Constitution of its Body.

its own Axis? For supposing the Earth suspended on its Axis of motion, if any one part of that with respect to the Gravitation towards the Sun do more than over-ballance the part opposite to it on the other side (tho' as to the Gravity to the Earth they are ballanced) then must that part have a tendency towards the Center of the Sun, if at any time it be remov'd out of that Position; and that tendency must be Analogous to that of a single Pendulum (here suspended) towards the Center of the Earth; so that when the motion of Rotation is carrying it towards its lowest or direct Point, that power must accelerate that motion, and when it hath pass'd that Point, and is beyond it, that power must retard it according to the Degrees or Proportions by which a vibrating Pendulum is accelerated, when mov'd towards the Perpendicular, and retarded when mov'd from it; and this Acceleration and Retardation must intermix and blend itself with the equal Circular motion, and Accelerate it in one part, and Retard it in another part of its Revolution; as will be more conceivable by the Experiment I shall by and by shew with a Wheel whose Axis lies Horizontal, and one of whose sides is somewhat heavier than the other. Now, as I Conjecture or Query, whether there be not some such Principle acting with respect to the Sun; so I do somewhat farther query whether there be not some such Anomaly with respect to the Moon, between which and the Earth there seems to be a much nearer kindred and affinity than between that of the Earth and of the Sun; and possibly somewhat of the Phænomena of the change of the Sea by Tides and Currents, and of the Air by Winds or Motions thereof may be found to be influenc'd by such a Discovery.

Of the cause of the inequality of the Earths diurnal motion.

What ever the event may be upon a strict examination by Experiments, I conceive it will not be unacceptable, since it will be a truth in Physick ascertain'd, which will influence many other; and I know no other way of trying it, than by that which gave me the first hint of it, which was the observing the Velocities of several Stars at several times of the Night in their passing by the Zenith, by comparing the several Arches they make in a certain space of time with one another, and with the time exactly kept by a curious Pendulum Clock; for if we find that several Stars plac'd in or very near the parallel of Declination which passeth over the Zenith in several parts thereof do all of them pass a certain Arch thereof when they transit the Zenith in the same space of time exactly, then we may conclude that the diurnal Rotation is equal and uniform in a whole Revolution; but if it shall be found that some of them pass an equal Arch in a longer, some in a shorter time; (which was the Phænomena I took notice of) then it will be further requisite to prosecute such other Observations as may determine the Reasons and Causes thereof, and farther Light will follow from it whatever way the Experiment shall determine it, provided they be carefully and accurately made with accurate Clocks, and with Instruments fitted with Telescope Sights.

Now because the things to be observ'd, which are necessary to compleat the Observation, are only two, namely, First, The length of an Arch mov'd by a Cælestial Body. And, Secondly, The time wherein that Body that moves such a determinate Arch; therefore I have contriv'd two Instruments of sufficient accurateness in their respective kinds for performing these Observations; and they are, First, A Telescope for the Sights of the first Instrument for determining the parts of the parallel Circle, or Circle of Declination in which the Cælestial Body moves. And, Secondly, A Pendulum to measure and divide the time, during which the Body doth actually move such an Arch.

As for the first, namely, the Telescope, I have already sufficiently describ'd it in my Discourse of a way for accurately finding the Meridian Line and the Axis of the Earth; and therefore I shall not here need to repeat it. *Vide.* p. 358. *Supra.*

Instruusents for the Observation.

But for the second because of the curiosity of the Observation to be made by it, I shall be somewhat more particular in its description.

There are then three sorts of Pendulums, which may be so adapted, as that, by the help of them, the time between the transits of a Star over two Meridians, at ten, twelve or fifteen Degrees distance may be measur'd to the fifteenth

The Pendulum for this Observation.

fifteenth part of a second of time, if by the use of the Telescope Sight there be occasion for so great exactness.

The contrivance of them all consists in these particulars; First, That they all move during the whole interpos'd space by the first impress'd force when they are first put into motion, without any addition of new force to continue their motion, and by that means all irregularity, caus'd by the Wheel-work, is avoided.

Secondly, That they are all made with very heavy Weights, and of the most proper Shapes for passing through the Air, so that they receive very little Impediment from it, and much less of Irregularity by reason all extraneous motion of the Air is kept off by the case in which they are included.

Thirdly, That their decrease of motion is regular and certain; so that tho' their extream Excursions do approach nearer the Center or Perpendicular, yet that being always done in the same proportion, the same number of Vibrations will always be made in the same quantity of time; that is, how many Vibrations, and what part over doth measure the time of an hour at one time, so many and such part will measure the time of an hour at any other time, whether of the same Day or Night, or at times distant more than a Day.

Fourthly, For that the motion of them is so adjusted, that be the Vibrations greater or less, they shall be all isocrone and of equal duration.

Fifthly, That the time of the motion through the whole length of one excursion, whether longer or shorter, shall be actually divided into equal parts by unequal divisions, but proportion'd so as to answer exactly to the given Proportions or Divisions of time.

Sixthly, That they are all so contriv'd, that the observer shall be able to mark the very moment of the last Transit himself, and the same of the first Transit by the help of an assistant; and this to as small a time as a humane Moment, or as quick as Thought: So that he shall be able certainly to know in what point or part of the excursion, the weight of the Pendulum is in, when the Star is observ'd to be in the Zenith or Meridian of the place, or in any other Meridian where the Stars there appearing does terminate and finish the second Transit, or the end of the time to be observ'd.

This contrivance consists in two parts, First, To let go, or set in going, the Pendulum by a touch of the Finger at the very moment of the first Transit of the Star to be observ'd, which hath this also of convenience or perfection rather, that the Pendulum is always set in going, or beginning with the same Arch of Descent, and not at an uncertain heighth. Secondly, That with the like touch of the Finger at the moment of the second or last Transit, there is a part of the Instrument that marks the very point of the whole excursion, through which the Center of the moving Pendulum is at that moment passing.

It may be perform'd with three sorts of Pendulums, namely, the Circular, the Slope and the common Perpendicular Pendulum; each have their advantages wherein they exceed the other two, and each their disadvantages wherein they are exceeded by them; but upon ballancing the whole three I do most approve of the last before either of the other, for the simplicity of its make and thence its exactness and certainty of going; its Regularity in not loosing its power and motion, but by Degrees very slow, which bear a proportion to the number of Vibrations, and the regularity of its motion as to the dividing the Excursions into parts answering to equal Moments or Spaces, and the easiness for letting go, and also for taking notice of the last moment; all which particulars I shall more particularly explain in the Module I shall produce, which will much more intelligibly express it than a Draught or Scheme.

WHat this Module was I never knew, but the ingenuous will easily apprehend the contrivance and meaning of the Author without any Scheme, by considering the following Paragraph; therefore I have not thought fit to trouble the Reader with a Conjectural Draught of my own. R. W.

As

As to the divisions of the parts of an Excursion, the whole length of the Excursion on each side of the Perpendicular Point is to be made as the Radius of a Circle of that length, and to be divided into a Line of Sines answering to such Divisions of an Arch of a Circle, answering thereto, as shall be convenient for the Division of the time of an Excursion; as if the whole Excursion be perform'd in a Second of Time; then for Thirds the Semicircle is to be suppos'd divided into sixty equal Parts, and accordingly the Radius into a Line of Sines answering to every three Degrees, which make thirty in the half, and sixty equal times in the whole Vibration; for the Velocities in the Diameter being in proportion to the ordinate Sines, the times will be as the Secants complement, and consequently as the parts of the Arch.

Wensday June 25. 1687. I shew'd here, at the last Meeting, one sort of Instrument for the measuring and dividing the parts of time to as great an accurateness, as I conceive, 'tis possible to be done by any kind of Mechanical Invention whatsoever; for that it is capable of dividing and measuring it, not only to the accurateness of the Thoughts of a Man, but, if need require, even to Moments that are shorter some hundred times than humane Moments. What I mean by humane Moments, I have formerly, in some of these my Cutlerian Lectures explain'd to this Honourable Auditory; and because I find that sometimes the repetition of former Experiments and Observations are not ungrateful to some, I shall now again shew that the Thoughts of a Man move or change in a limited space of Time; not so quick but that such moments are yet divisible into moments infinitely smaller or shorter of duration, and thence that each humane moment is capable of Division into any definite Number of Parts, how many soever shall be assign'd; as if the humane moments be as small as a third Minute of Time, which yet, I conceive, very few are able to distinguish by their Thoughts, yet that Third of Time containeth sixty Fourth Minutes, and each Fourth containeth sixty Fifths, and each fifth containeth sixty Sixth Minutes of Time, and so onwards, which we find Astronomers will take notice of, and account for in their Computations of equable Divisions, tho' they are in themselves but very small and altogether insensible parts of one humane moment: I say insensible, by reason that they are quicker than the Thought of a Man can distinguish a Prior from a Posterior moment: For who is there that can distinguish the 3600 part of the Time of a Second, which yet is but a fourth minute of Time? Much less will any one be able to distinguish the 216000 part, which is a fifth or a 12960000 part thereof, which is a sixth, and yet we must acknowledge that such parts there really are included in every Second minute of Time, tho' never so much smaller or shorter in duration than a humane moment, and that they really have their Power and Effect in natural motions and alterations proportionable to such their duration, and are measurable or conceivable there, tho' they are so much quicker than our Thoughts and Abilities to distinguish one from another: For if we take for a round Number that a Semidiameter of the Earth be four thousand Miles, and thence find that the Circumference under the Æquinoctial Line be 25132 Miles, and 741228718345 9, 10000000000000, which is 0129088820865 0 of a Mile in a Second of Time; or to omit the accurateness of the Fractions and to keep to round Numbers, which, in this case, serve better where the Matter and Design aim'd at is but Illustration, and to help Conception, let us conceive that a part of the Earth, under the Æquinoctial, moving in a Second of Time an 86400 part of that Circumference of the Earth; which, to keep still to round Numbers, we may conceive to be near $\frac{1}{10}$ of a Mile, of 6000 Foot to each Mile; then will each part of the Earth there move every Second of Time 1800 Foot, and in every Third of Time thirty Foot, and in every Fourth of Time six Inches, and in every Fifth of Time $\frac{1}{10}$ of an Inch. Now, tho' the Conception of this part of Time be really impossible, otherwise than by Proportion and Analogy to the sensible parts, yet the motion of Nature doth really measure it, and its progresses are adæquate to such moments, and each fifth Minute of Time the part hath mov'd a tenth of an Inch forward into another place, in respect of its Position to the Heavens,

At the end of the Lectures of Light.

Of the Minute divisions of Time.

Heavens, or to the parts of Space consider'd as immovable: And the progresses of progressive or local motion being suppos'd equal or commensurate to the moments of Time (how small soever) the Body must move in every sixth Minute of Time, a six hundred part of an Inch forward; which length our Senses can reach and distinguish, tho' it cannot the minim of Time, which is not so to be magnify'd.

This Speculation I have been the more large upon, to shew that there may be a use of this Instrument for distinguishing and numbering the parts of Time, which are abundantly much less than a humane Moment; which, tho' not distinguishable by our Thoughts, yet have their effects, in Nature, and, in many Experiments, are very considerable and pertinent to be taken notice of; as I shew'd by many Experiments try'd before this Society above twenty Years since, by an Instrument somewhat like this, for the measuring the times of falling Bodies, which possibly some here present may well remember.

Tho', I say, these small moments of Time are not distinguishable by a Man's Thought, yet by many Mechanical Contrivances they can be made distinguishable, and thereby they can be made useful in multitudes of Physical and Philosophical Inquiries, and even in this, which gave the occasion of the mentioning of it; namely, the measuring of the exact time that any Star that shall be observ'd, is moving from any one Position to any other; and that even to a shorter or lesser time than that of one third Minute of an Hour, which, if the motion of the Star be in, or near, a great Circle, is about a quarter of a Second of a Degree. The way of effecting which, is the making the Telescope to move along with the Star, and when the Star is come to a certain point, and consequently the Telescope that follows it, then doth that Telescope let go the Pendulum, and set it going with a certain degree of Velocity; and again, the same Telescope being kept moving along with the Star, at least, some small time before it arrive at the second station; then doth it, in its motion, let go the Stopper, or Stay of the Pendulum, or Index thereof, just at the very moment as the Star is passing the Point of the second Station; which denotes the precise moment of such Touch or Transit. Now, tho' this be abundantly more quick than Thought, and so cannot be perform'd so nicely by the motion of the Finger, yet by this means I speak of, where the Telescope is kept in motion with the Star, which is easily enough perform'd, as I have often had Experience, the moments, tho' exceeding small, will yet be numbred thereby. To this I could add the description of a second Instrument, which is made with a Pendulum also, but moving Circularly suspended by a round Steel Wire, and is to be let go, and to be stay'd in the same manner, by means of the motion of a Telescope, which follows the motion of the Star; in which Instrument the circulating motion of the Pendoulus Weight doth describe a Spiral Line, which, by equal Angles from the Center, is divided into equal Spaces of Time, and thereby the number of the Spaces in that Spiral, past by the Pendulum between the two Transits of the Star, being computed, do give the exact number of third Minutes of Time that have pass between the two Observations; but this Instrument being somewhat more complicated than the former, and that being sufficiently accurate for such trials, I shall omit the further description thereof at this time.

And because I understood that the Demonstration I read of the true way of dividing the Arch of its motion, into parts of equal duration, or of equal Time, was not so fully comprehended by some then present, which was this I now read;

These Schemes are lost.

Therefore for a more full Demonstration, and particular Explication thereof, I have drawn some Schemes, by the explaining of which I doubt not to make it evident, in every particular thereof, to any one that shall doubt of any part thereof, whereby the truth and certainty thereof will more plainly appear.

June 29. 1687. I spent some time in my last Lecture upon the consideration of sensible Time, and of the equal Division and Mensuration thereof; for which purpose I explain'd two Instruments, the most exact that have been thought

thought of, far exceeding, as I conceive, any that have been yet publickly known, and capable of performing, or of helping to perform, such Observations of Cælestial Bodies as no Istrument, yet made use of, has perform'd; at least, not the best that I had ever heard of; some Instances of which I shall shortly acquaint you with; for tho' our Methodists have made compleat Systems of Sciences, yet, when they come to be a little more nicely survey'd by a doubting Examinant, many of those Maxims, that are so Dogmatically and Positively asserted, will be found not altogether so Congrous to the truth of Nature as they have hitherto been believ'd; and those none of the least Considerable and Fundamental.

I could carry this Mechanism yet further, by shewing some Instruments by which to measure the parts of insensible moments; I mean such moments as a Man cannot distinguish by his Thoughts into a preceding and subsequent moment, or is able to number or distinguish one from another by his Eye or Ear, far less than that I call insensible; not but that the Sense doth really distinguish moments, yet prodigiously less above a thousand times, nay, ten thousand times, as I shall afterwards prove; but it is not under the Idea of Time and Number, but under that of sound, Tone, Harmony, and the like; wherein how curious the Sense of Hearing is, I appeal to such as are skilful in Musick, who can easily, by their Ear, tell you when the Vibrations of Musical Strings are one as quick again as the other, that is, when Diapasons, when their Proportions are as 3 to 2, or as 3 to 4, or as 8 to 9, that is, as a Diapente or Fifth, that is, a Diatesseron or Fourth, that is, a whole Note or Tone, and the like, and when they are of such or such a determinate Tone, as *Gam ut*, *A re*, *B mj*, and the like, which they distinguish, I say, by the Ear, or the Sense of Hearing, tho' not under the same Idea or Phantom as they do when the Vibrations are so slow as to be singly distinguish'd one from another, but under the Idea of Sound; which, when the Vibrations are Isocrone, as I have formerly here prov'd those of strained or extended Strings to be, which act upon the principle of Spring; as also Bells or sounding Metals, and the Vibrations of the Air, which depend also upon the Spring and Power of Recoile, they are Musical Sounds; but when they are not Isocrone they are not Musical. In these cases the Sense runs a step higher and brings us into another Region, where we find another prospect of Time, and the Partitions thereof far differing from that of the first and inferior Region, wherein we distinguish the parts of Time by Monades or Unites; for in this we distinguish them by Aggregates, Bodies, Bulks, Armies, Thousands, and the like great Numbers, not considering them singly, but together; for this purpose I shall hereafter produce some Mechanical Contrivances, by which these quick motions and minims of Time may be reduc'd to Number and Computation, which I conceive absolutely necessary in all Philosophical or Physical Experiments; but I shall not now digress into Experiments of that kind, but proceed in that method which I have begun, to shew the use of this Instrument I have already describ'd, and shewn the Module thereof, by explaining how the same may be of use for finding the Latitude of a Place without the incumbrance of Refraction, at least by such a way as is the least of any I have yet known discover'd by any, in Print, or any other ways.

This method I describe in order to the prosecution of that Inquiry which I lately propos'd of examining, whether the Axis of the diurnal Rotation of the Earth did, or doth change its Position in respect of the parts of the Earth; that is, whether the Latitudes of Places do, in process of time, vary as well as the Meridian Line; for if the said Axis doth vary, one of these two ways, or both, will be sufficient to discover it in any part of the Earth whatsoever; for if such motion of the Axis as I have propounded shall happen to move in the Meridian Line of the place where the Observation of the Meridian, for that purpose, shall be made; then, tho' no such variation of the Meridian Line can be, by that means, observ'd, there being none, yet this way for examining the Latitude of the Place will soon detect it. Again, if that motion should happen to be at right Angles to the Meridian of the Place, then this way would be ineffectual, and the former way of finding

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the true Position of the Meridian Line, with respect to the known parts of the Horizon, would perform it; and in case its motion be any other way inclin'd to the Meridian, then the comparing of both these two ways together will state and determine it, as it doth also in both the preceding Cases, because it determines which way and how much in all.

It was necessary therefore that the way of finding the Latitude of a place should be as accurate and as little liable to Objections, as the way I have already shewn of finding the Meridian Line; which I conceive is the most exact that has been hitherto discover'd, and may be as easily made, and is sufficient to perform what is requisite in the Inquiry propos'd.

P. 358. *supra & alibi.*

The method then for finding the Latitude of a Place, is by finding out the true Zenith-Point of the Place where the Observation is to be made; how to do this I have elsewhere shewn, and therefore shall not need here to repeat it: This may be done to what accurateness shall be desir'd; for that longer and longer Telescopes may be made use of for the determination thereof; and it is not difficult to procure Object-glasses of any length desir'd, accurate enough for performing such Observations: Having determin'd that, I observe what Stars pass over the Zenith-Point, or pretty near it, whose distance from that Point, in the Meridian, I can accurately measure; then the following Night I observe that Star, I pitch upon, an Hour, or an Hour and half, or some certain time before it come to the Zenith, marking exactly the Point where I so observe it at the time I let go my Pendulum or Time-keeper, and measuring exactly the Angle that Ray maketh with the Perpendicular, finding also, if I please, the position the Plain thro' those two Lines hath to the Plain of the Meridian; tho' that may be omitted, when it is only us'd for finding the Latitude: Then I compute the Time exactly that passes between such and such Observations, and the time it passeth the Zenith or Meridian; and at an equal time, after such Transit, I again observe it on the other side of the Meridian, and find the Point or the Angle that Ray also maketh. From the comparison of which two 'tis evident, that the Declination of that Star is certainly determin'd, and consequently that the Latitude of the place, where such Observation is made, is also given. Now the reason why I observe it on both sides of the Meridian is this, because I thereby almost wholly avoid the Refraction of the Air, and yet measure a large Arch; for that the Refraction of the Air is hardly sensible even to Telescopes of so great a length, as may be made use of for this Observation, when the distance from the Zenith is not greater than what is requisite to determine this Inquiry, to what accurateness almost shall be requir'd, and the Observation on both sides doubling the Angle at the Zenith, or the Arch of the Parallel, when it is only made on one side, the Refraction, what it is, is still made more insensible when an equal subtense of an Arch of the said Parallel is obtain'd by Observation on both sides, that when on one side only. This way of finding the Latitude of a Place, I did, at the same time, formerly acquaint this Society with, tho' not so particular, when I told them also the way of making use of the Stars in the Perpendicular for finding the difference of Parallels for measuring a Degree upon the Earth; but this part of the Contrivance I do not find that the *French* have made any use of in their Observation of a Degree, tho' they have of the other; possibly it might be, that he that acquainted them with the one, did not so well comprehend the other, and the rather too, because the Invention of the measuring and determining the small parts of time was not at the same time describ'd, but some of them before, and some of them afterwards upon some other occasions; as that of the direct *Pendulum* was upon the occasion of the Experiments of falling Bodies, and that of the Circular Pendulum æquated by its motion in a Parabolical Conoeidal Surface at another, tho' both these parts or inventions which were omitted by the *French*, have been Publish'd by Mr. *Huygens* as his own, in his Book *De Pendulo Oscillatioar* many Years since.

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THE following Lectures contain the Description and use of some Sea Instruments: They were first read before the Royal Society on the third of December, 1690. *and afterwards on the fifth and twelfth of* December 1694. *with some additions, as they are here Printed. The Instruments are the Portable Barometer, a Quadrant, and some hints relating to the improvement of Telescopes. As to the first there is some Account Publish'd in the Philosophical Transactions N.*185. *p.* 241. *and for the last I shall sometime present the Ingenious with what, I suppose, new, when I am a little at leisure to make some Experiments of a Hint given by Dr.*Hook *in a Paper about the improvement of Optick-glasses, wherein I will candidly relate the success, and what I know of the Invention.*

R. W.

December 3. 1690. As the Design of this *Lecture* was for the improvement of the History of Nature and of Art, so was the Institution of this *Honourable Society* for the improvement of Natural Knowledge, which, in other words, amounts to the same sense. This as it was at first (upon very mature deliberation, and with great Sagacity and Judgment) settled in a suitable and proper method to attain the end; so, 'till better methods be prov'd, it ought not to be alter'd and laid aside. The Design was for promoting the Growth and Increase, and Vegetation, as I may so call it, of Natural Philosophy from the first Seed or Embrio through all the Ages and Increasings of it, 'till it attain to a State of Perfection of Flowering and Blooming, and of producing Seed, and become Fruitful; for Natural Knowledge may not unfitly be compar'd to a Vegetable, whether Plant or Tree, which springs from a Seed sow'd in a Soil, proper and adapted, by a skillful Gardener, for that Plant. For as the Seed, by small Fibrills or Roots it shoots out, receives, from the Soil or Earth, a nourishment proper and adapted for ascending into the Body or Stalk, to make it grow in bulk and strength to shoot upward, and from thence to shoot forth Branches, and from them Leaves, thereby to draw and receive out of the Air a more refin'd, spirituous and inlivening Juice, which descending back into the Body or Stock, increases its Stature, Bulk, Circumference and Strength by new incirclings, and thereby inables it to send forth more Fibrills and greater Roots, which afford greater and more plentiful Supplies to the Stock or Trunk, and inables that to exert and shoot forth more Branchings, and greater numbers of Leaves; which, repeating all the Effects and Operations by continu'd and constant Circulations, at length bring the Plant to its full Stature and Perfection: Nor will a skillful Gardener suffer it to be tapp'd to have the nutritive and vital Juice drawn off to be us'd for other purposes than the nutrition of its own Body; well knowing it would hinder its Growth, prolong the time of its coming to Maturity, weaken its Constitution at least, if not render it wholly barren.

The increase of Knowledge like the growth of a Plant.

So Natural Knowledge doth receive its first informations from the supplies afforded by Select and proper *Phænomena* of Nature convey'd by the Senses; these improve the Understanding and inable it to raise some Branchings out into Conclusions, Corollarys and Maxims; these afford a nutritive and strengthening Power to the Understanding, and inable it to put forth new Roots of Inquisitions, Trials, Observations and Experiments, and thereby to draw new supplies of Informations; which further strengthening the Understanding, inable it to exert and produce new Deductions and new Axioms: These circulate and descend downwards, increasing and strengthening the Judgment, and thereby inable it to make more strikingout of Roots of Inquiries and Experiments, which cause the like Effects as before, but more powerfully, and so by consent and continu'd Circulations from *Phænomena* to make *Deductions*, and from *Deductions* to inquire *Phænomena*, it brings the Understanding to a compleat and perfect comprehension of the Matter at first propos'd to be consider'd; nor must the Natural Course or Circulation be stopp'd or diverted, 'till the utmost Perfection be attain'd, if at least it be aim'd to compleat and make it prolifique.

Of the difference of Gravitation.

It was a Conclusion by some such method as this produc'd by me, and made known to this Society near thirty Years since, that the *Gravity* of the Earth was differing in differing Latitudes, and that it was greater under the Poles than under the *Æquator*, and the nearer to the Poles the greater; and the nearer the *Æquator* the less. This I first propounded to this Society upon the occasion of the trials of the *Pendulum*-Clocks carry'd at Sea; and again, upon the occasion of the *Pendulum* apply'd for a Standard Measure of length, *&c.* But as things new and Heterodox to the Opinions in Vogue, it met with a check, and so the further prosecution of it could not proceed, I have many times since again repeated the Suggestion, sometimes upon one, sometimes upon other occasions, but, as Extravagancies, they have been pass'd over; the last time I repeated it Dr. *Wallis* wrote a long Epistle to confound it, but Mr. *Newton*, it seems, upon examining it, found some reason for it, and sends up (a Fortnight after Dr. *Wallis*) his considerations upon it, consonant to what I had demonstrated to the Society: This made it begin to be taken notice of, and to be thought worth examining; however many other Doctrines that were deduc'd from as evident premises have been suffer'd to lie by, in expectation of a better opportunity, which I hope Time may afford; which, when I meet with, I shall not be unmindful of laying hold of; and I much rejoice at this which I have now met with of Captain *Knox* his Voyage to *India*, who has promis'd to be very observant of it, and to keep an account thereof; and in pursuance of the Order of this Society, I have got a Pendulum Watch fitted for that purpose, which I now produce.

Description of a Sea Barometer.

There is yet another Inquiry which will, if accurately tried with fit Instruments, afford great and useful Information, both for use at Land, and also for the Sea and Navigation; and that is to find the Posture and Gravitation of the Air. This I propounded to the Society as a thing very well worth Trial and Examination some twenty five Years since; but as the use of the *Barometer*, even at Land, was not then heeded, tho' I had then reduc'd it to as much of Theory for foretelling the Weather, as is is known at this Day; so the Inquiry, after the use of it at Sea, was the less regarded; and when afterwards the thing came to be taken notice of by means of King *Charles* his observing it to follow the Rules that were then set, which was about ten Years after, many had thoughts of having it carry'd to Sea, but attempting it only by the common way of the Barometer, not knowing, I suppose, the way I had propos'd; the use of it at Sea was indeed impracticable, and, as such, laid aside. I shall not trouble you with a new Description, but if you please to afford me your Patience, I shall read the Description which I then produc'd, and it hath ever since remain'd in your Registers.

The Contrivance of this Instrument is much the same with what I explain'd to this Society about thirty Years since.

This being thus prepar'd will fully be sufficient to exhibit all the varieties of Pressure in the Air; and 'tis capable of shewing all those Variations with as great nicety and exactness as shall be requir'd even upon the Sea, tho' stormy and turbulent: Nor is there any great difficulty of preparing or making use of it; save only that, if the Gradations be requir'd to be very large, it will require a very long Tube of Glass; and that Tube to be doubled or folded to and fro to lie in a little room, which I have my self been able to do with no great matter of trouble; but it would be yet much better if a very long Tube of Glass, of forty or fifty Foot in length, were coiled round a Cylinder, after the manner of Sir *Christopher Wren*'s Weather-glass; which, with some few trials, I do not question may be effected; for that thereby it would be easy to make the difference of Gravitation in the Air as large and sensible, as it need to be desir'd; besides it will be, *&c.*

But tho' it will not in those other Tubes, which I propose, be capable of so great an Augmentation of that difference, yet these, if well adjusted, will, I conceive, be found of great use for fore-shewing the approaches of Storms and Calms, which extreams of the motion of the Air are very unwelcome and troublesome Concomitants at Sea. It will also give an account of the

the comparative Gravity of the Air in ſeveral Climates and Latitudes; and thereby afford Indications, by which the Figure, Form, or Conſtitution of the Shell of the Air, which incompaſſes the Earth, may be judg'd of. It will likewiſe ſhew the Nature and Qualities of ſeveral Winds as to Preſſure, and alſo as to Heat and Cold; that is, whether an Eaſterly Wind be every where the heavieſt, and the Southern the lighteſt; as they are generally obſerv'd to be in *England*. What Winds are hotter or Colder; that is, whether Sea-Winds or Brizes, or Land-Winds or Brizes; whether there be any certain difference between the Preſſure in the Night and in the Day, as there is conſtantly in the Heat and Cold; whether the Rains or the dry Seaſons are the Hotter; and many others. And to this end it will be well to note the ſtate of this Inſtrument at Noon and Midnight, and in the Morning and Evening.

Decemb. 12. 1694. The Inſtrument I mention'd the laſt Day, which I had about thirty Years ſince invented and ſhew'd to this Society, is, I conceive, an Invention of ſo great uſe, that if the Knowledge and Practice of making, adjuſting and manner of obſerving with it, be once attained, it may be a means of ſaving many thouſands of Pounds in a Year to the Merchant, and which is more, many hundreds of Mens Lives; and therefore I think it ought not to be any longer neglected, but rather to be made and try'd as ſoon as poſſible; and tho' we cannot as yet procure the means to make it of the moſt perfect and moſt convenient form for tranſportation and uſe on Ship-board, yet ſince it is eaſy and practicable enough to make it to ſhew all the differing Preſſures of the Air as exactly as the common ſingle Barometer does at Land, nay, twice as exact; I think it may be firſt try'd, of the perfecteſt form we can now make it, and poſſibly that form may be moſt fit for the firſt trial, ſince the other being more nice, may ſo much the more perplex the unexperienc'd Mariner, and may better be introduc'd after the practice thereof, for the uſe of the Sea, hath made the Theory thereof more intelligible, and the benefits thereof more ſenſible and evident.

The method and grounds of my Invention, I conceiv'd, were very plain and obvious, as many others are after they are once diſcover'd and explain'd, and ſome are then ſo obvious, that even that becomes the cauſe why they are ſlighted, neglected, and not taken notice of; and poſſibly that may have been one Reaſon why it has fared ſo with this, it being ſo eaſy to be conceiv'd; I did not therefore ſpend much time in the explication thereof; but having the laſt Day apprehended, by ſome Diſcourſes, that the Theory thereof was not ſo perfectly comprehended, but that there remain'd ſome heſitancy or doubts concerning it, I have now made a ſomewhat more particular Deſcription of the Inſtrument itſelf, and of the Ground and Reaſon of the contrivance thereof.

The Hiſtory of the Thermometer.

It is now about ſixty Years ſince the *Thermometer* was invented for the uſe of indicating the degrees of Heat and Cold in the Air, by certain and determin'd meaſures, which was done by means of a bolt Head, or long necked Glaſs, as they are now commonly call'd, the Ball or Head of which, and part of the Neck, was fill'd with Air, but the Mouth or lower end was fill'd with ſome colour'd Liquor, and immers'd in a ſmall Ceſtern or Receptacle of a quantity of the ſaid Liquor; by which means the included Air, which is rarify'd and expanded by Heat, and condens'd with Cold, did either depreſs the ſaid tinged Liquor into the Ceſtern, or draw it up higher into the Neck of the Glaſs; which property of the rarification and condenſation of the Air hath been known ever ſince the time of *Hero*, and probably long before; yet the Application of that knowledge for this uſe, I do not find was put into practice or taken any notice of, 'till about the Year 1630; ſome ſhort time after which I find *Robertus de Fluctibus* or *Flud* did write a particular Treatiſe to explain the ſaid Inſtrument and ſome uſes of it; but *Blancanus* aſcribes the Invention of it to *Sanctorius* much about the ſame time; but I will not diſpute which of them we ought to aſcribe it to; but whoever it were, it was an ingenious Thonght, and adæquate enough to the Theory of the Expanſion of the Air then underſtood. But Experimental Philoſophy hath ſince made a further diſcovery, and ſhew'd us that the Air may

may not only be more or leſs expanded by the Degrees of Heat and Cold in the Ambient Air, but alſo by the alteration of the preſſure of the Atmoſphere, which doth leſs or more depreſs the Surface of the ſtagnant tinged Liquor in the Ciſtern or Receptacle; ſo that That Inſtrument, commonly call'd a Weather-glaſs, is no longer a true Standard to meaſure the Degree of Heat and Cold, but ſerves only to give us the reſult of two Powers acting upon it promiſcuouſly; ſometimes with a Concurrency both tending one way, and ſometimes with Contrariety and Oppoſition, the one promoting the Expanſion, the other the Condenſation thereof; if therefore we can by any means diſcover the effects of the one at all times upon it, we preſently find the Power and Effects of the other. If therefore we can by other means diſcover the Effects of Heat and Cold, we ſhall thereby diſcover what is to be aſcrib'd to the Gravity or Preſſure of the Air.

Now to do this effectually I make uſe of the Sealed *Thermometer* which was firſt invented, as I have been inform'd, by the Grand Duke of *Tuſcany*, and the firſt that I ever ſaw or heard of was a ſmall one brought into *England* by our Honourable Preſident; by which I improv'd it by making ſeveral very large, and tinged the Liquor to make it more ſenſible to the Eye. This Inſtrument being Hermetically ſeal'd, and ſo all the influence of the Preſſure of the Air being excluded, the included Liquor can only be acted upon by the Heat and Cold of the Ambient Air; ſo that hereby at all times I am aſcertain'd of the Degree of that quality; knowing then what the Power of that quality is upon the Weather-glaſs, I can eaſily ſee what part of the Indication is to be aſcrib'd to the Preſſure or Gravity of the Air or Atmoſphere.

The method of making the Inſtrument.

For this purpoſe having produc'd two convenient Glaſſes, the one for the open Weather-glaſs, and the other for the ſeal'd *Thermometer*, by a Standard *Thermometer* made and adjuſted, according to the method I have preſcrib'd in my Micrography, I adjuſt the *Thermometer*, putting all the Degrees of Heat and Cold above and below the freezing Mark where I begin my Account, or 0, and making them with +1, +2, +3, *&c.* above that mark; and with --1, --2, --3, *&c.* below the ſame, I wait 'till ſuch time as the Barometer ſtands at twenty nine and half Inches high, which is here in *England*, at leaſt the ſtandard Altitude between Fowl and Fair Weather; then putting the Balls of both the Glaſſes into Water heated to a certain Degree, which may be hot enough to anſwer to the greateſt Degree of heat that I conceive the Air will ſuſtain in any part of the Torrid Zone, I ſuffer them both together to remain in that Degree of heat, 'till the Liquor in the *Thermometer*, and the Air in the Weather-glaſs, be reduc'd to the ſame Degree of heat; then I obſerve the mark'd Degree of the *Thermometer*, and mark the Weather-glaſs with the ſame; then I permit the Liquor, in which the two Balls are plac'd, to cool by degrees, and thereby obſerve how the Liquor in the *Thermometer*, and the Air in the Weather-glaſs, do contract by the motion of the Liquors in their Stems, and by the Degrees of the *Thermometer*, I mark the Degrees in the Weather-glaſs that anſwer thereunto; and when the Liquor is cold, I intend that Cold, with Niter, and Ice to procure the Diviſions below the freezing mark; by which means I find all the marks of the Weather-glaſs that anſwer to all the marks of the *Thermometer*, when the Gravity of the Air is equiponderant to twenty nine and half: Whenever therefore the Gravity of the Air is more or leſs, I ſhall eaſily diſcover it by the difference there is between the two Glaſſes; for that a greater Preſſure will more condenſe the included Air in the Weather-glaſs, and a leſſer will ſuffer it to expand more than it would have otherwiſe done by the Degrees only of Cold and Heat. And by this method it will not be difficult to adjuſt two ſuch Glaſſes as will receive no manner of alteration from the motion of the Ship, and may be ſafely and eaſily carry'd and made uſe of in all parts of the World, to the extreameſt hot or extreameſt cold, that can be indur'd by any one that is to obſerve with them. For as there is no doubt to be made of the Experiment of the Spirit of Wine ſeal'd in the *Thermometer*, ſo there is no fear of looſeng or freezing of the Quickſilver in the Weather-glaſs, if it be made after the way that I have herein propos'd; the varying of which Inſtrument I have

many

many ways contriv'd, and ſome other methods, if I can procure Glaſſes made, I ſhall ſome other time acquaint the Society with.

As the Subject of my laſt Diſcourſe was the Deſcription of two ſeveral Inſtruments that I conceiv'd would be of great benefit to Navigators and Navigation in general, ſo I deſign in this Diſcourſe to add the Deſcription of a third, which, I judge, will be much more advantageous, by reaſon of its frequent, nay conſtant, uſe and becauſe ſo much of information concerning the true Latitude of the place, where the Ship is, depends upon the exactneſs and practicableneſs of it, I have propounded it by way of Query to divers very skilful both in the Theory and Practice of Navigation; but (like things of this Nature before they are known) they have all judg'd it to be impracticable, if not impoſſible, and yet I doubt not (when it comes to be known) ſome of them may ſay, they knew as much as this before: Others poſſibly may perſiſt in the uſe of ſuch Inſtruments, as they have been hitherto acquainted with, and others be offended at it becauſe it is new; and yet I doubt not but that, after ſome time, it may become of general uſe. The Inſtrument which I ſhew'd the Society, ſome Years before the Sickneſs, by making uſe of a Teleſcope-glaſs, inſtead of the ſmall hole or ſlit of the Shadow-vane of a Back-ſtaff, was not made uſe of 'till about ten Years after, and yet now it meets with general approbation, and is of continual uſe, and pretended to be the invention of another, tho' my ſhewing thereof was Printed in the Hiſtory of the Royal Society. It cannot well be expected that I ſhould ſpend my Time and Studies in inventing Inſtruments, and be at the expenſe of making and putting in practice thoſe which I have contriv'd, without receiving any Benefit or Aſſiſtance from thoſe to whom they may be of uſe, or any other. It may, I conceive, be judg'd ſufficient, by reaſonable Men, for the inventor to contrive and deſcribe the Means and Ways how ſuch as have occaſion, or deſire of experimenting the thing, may, with eaſe enough, put the ſame in practice; at leaſt, if his Reward be conſider'd, which, as the Learned Author of the Hiſtory of the Royal Society has obſerv'd, is commonly ill Treatment, and not only rough Uſage from thoſe that envy his acquiſts, but even from the Artificers themſelves, for whoſe ſake he has labour'd; whilſt another that adds ſome ſmall matter to it, is inrich'd thereby, but the firſt diſcoverer is diſmiſt with Contempt and Impoveriſhment.

Of a new Sea Quadrant.

The Inſtrument which was for a long time us'd for taking the Altitude of the Sun at Sea, was an *Aſtrolube*, which is yet in uſe among the *Spaniards*, as I am inform'd; the Inſtrument is, by many Authors, very fully and ſufficiently deſcrib'd that it need not be here repeated, ſince that, the *Engliſh*, *Dutch*, and *French* have made uſe of a *Croſs-ſtaff*, *Back-ſtaff*, or *Quadrant* for that purpoſe, as being found by Experience to be much more exact and certain, and the adding of a Teleſcope-glaſs to the Sights, hath, as I mention'd before, much improv'd both theſe qualifications; but they are yet liable to ſome Inconveniences and Defects.

The Inſtruments now us'd.

As, Firſt, They are of little uſe in a dark Night, by reaſon of the difficulty of exactly ſeeing the Horizon.

Their Defects.

Secondly, They are uſeleſs alſo in the Day time, if Foggs or Miſts do hinder the diſtinct diſcovery of the Horizontal Line.

Thirdly, They are uncertain when Refraction doth elevate or change the true Horizon, which a certain vaporous Air, near the Surface of the Sea, doth often cauſe.

Fourthly, They are uſeleſs when the Sun is in or pretty near the Zenith.

Fifthly, They are troubleſome and require great Dexterity and much Practice to be us'd ſo as is neceſſary.

Sixthly, They can hardly be ſo well made or ſo well us'd, as to afford the Obſerver a nearer certainty than about half a Degree.

All which inconveniences I hope may be avoided by the Invention which I have here made a Module of, in order to make it the more intelligible. For,

First, It is as proper and as practicable to take the Altitudes of the Stars in a dark but clear Night as in the Day, and that to as great exactness; tho' neither the Horizontal Line, nor any Stars near the Horizon, by reason of Foggs or Clouds that darken them, can be discover'd.

Secondly, It is sufficient to take the Altitude of the Sun whenever it appears, tho' the Horizon be not discoverable by reason of Foggs or Vapours.

Thirdly, It will be sufficient for the same purposes, whenever the Horizontal Line may be displac'd by Refraction, and thereby misguide the diligent observer in the other way.

Fourthly, It will be sufficient to find the true height of the Sun, tho' never so near to the Zenith, and that with as much ease and certainty, as if it were near the Horizon.

Fifthly, The use and practice of making Observations with this Instrument, I conceive to be no more difficult, than the easiest way of observing with any of the Instruments now in use.

Sixthly, I conceive that Observations may be made with this Instrument, much more accurate than 'tis possible to make with those now commonly us'd; and as they may be made more exact, so the instrument itself doth afford a greater certainty, by reason that the Eye-glass doth make the Divisions as large and distinguishable, as if the Instrument, without that help, were four times as large at least, nay, I can safely say, as if the Instrument were ten times as large.

Tab. 12. Fig. 5. *THe Author himself having given no Description or Draught of the above-mention'd Quadrant, I judg'd it would be acceptable to have some farther account of it; wherefore finding a Rude Model of such an Instrument, I have here attempted a Delineation and Description thereof, rather than it should be quite forgotten and lost, tho' I am sensible that I have omitted several Particularities, which if the Inventor had made the Description himself, would have render'd the Instrument more compleat and manageable; which Defect I hope some ingenious Mechanician will at some time supply.*

ABC the Quadraut, C the Center, which is so contriv'd, that the Socket, with the Eye-glass, is fixt into it at right Angles to the Quadrant. DE a Telescope moving on the Center C upon the back of the Quadrant, on which also the Divisions of the Degrees are made with Diagonals, as usually. D the Object-glass. At the end C, of the Telescope, is placed a Reflecting-plate at an Angle of 45°, casting the Image to the Eye-glass. AF a Plumb-line passing over the Center of the Instrument between the Reflecting-plate and the Eye-glass, by which means the Object and Perpendicular are seen in the Center at the same time, and so the true Altitude of the Object taken, by fastning the Telescope on the divisions on the backside. G H I K an hollow Cover over the Plumb-line, which serves also for an Handle for the Quadrant. It may be likewise very convenient to have the Plumbet play in a small Vessel of Water fastened to the lower end of the Handle at F, by which means the Plumbet will be less subject to vibrate far, by the opposition of a thicker medium than the Air, which yet will not in the least hinder its Perpendicularity.

The preference of this Instrument consists in the taking the Angle from the Zenith, rather than from the Horizon, which many times is not distinguishable, and always subject to uncertainty from the difference of Refraction.

R. W.

Of a Sea Telescope.

There is another Instrument which will be of great use for discovering the Latitude of places both by Sea and Land, and that is a small Telescope; whereby a skilful Navigator, or any other ingenious Person, may easily discover the Eclipses that happen of the *Satellites* of *Jupiter* upon the Sea; the use of which Eclipses, as *Galileo* did first mention, so have they been by many Persons approv'd of for that purpose, and several have indeavour'd, by Observations, to perfect the Theory of them, as *Hodierna*, *Borelli*, Mr. *Rooke* of this Society and Colledge, and now lately the *French* King's Astronomer Monsieur *Cassini*, and a very curious discovery has been made by Monsieur *Romer* the *Dane*, which is generally now approv'd of by knowing Astronomers,

mers, tho' Monsieur *Cassini* (possibly because the Invention of a Tramontane) seems to hesitate concerning the certainty of it. Mr. *Hally* also has lately indeavour'd to facilitate the use of Monsieur *Cassini*'s Tables for calculating the true times of them, which, I conceive, he may yet make more easy for vulgar Capacities, such as many of the Seamen are, who will have occasion for the use of them. But such difficulties, I confess, will be easily remov'd by Ephemerides, purposely calculated by some skillful Astronomer, and Publish'd in a Sheet of Paper for seven or ten Years before hand, which Mr. *Hally* can easily perform; but yet they will be of no great use for the Sea, 'till such time as they are supply'd also with convenient Instruments for the Observation of them, which, I hope I may have the freedom and opportunity to communicate in some short time, and should have done it long since, if I had not been discourag'd by undeserv'd Troubles. But I see it to be the general Fate of all such as make any new discoveries, and therefore bear it with more patience; however I do not doubt but that the humour of Mankind, in that particular, has stifled the Productions of many useful Discoveries.

Certain it is, that the invention of Telescopes is not yet brought to its greatest Perfection, no nor of Microscopes neither, tho' Mr. *Leuwenhook* seems to have some of greater Perfection than ordinary; but I doubt not but that I shall be able to shew, that both the Telescope and the Microscope may be easily enough advanc'd to much higher degrees of Perfection than what have been hitherto produc'd. It is not very long since the invention of Convex Eye-glasses was found out for seeing a larger Area of the Object; which, tho' it do not, I confess, make the Object more distinct, yet is it of great use in Cælestial Observations, especially at Sea for the easy finding and retaining of the Object in the Telescope, which, in Telescopes, with Concave Eye-glasses, is extreamly troublesome, even in the shortest, and much more in long ones; however this seems not to have been found out 'till about the time that *Reita* Publish'd his Book call'd *Oculus Enochi & Eliæ*, i. e. about the Year 1645. for perusing that Author in Sir *Ch. Scarborough*'s *Auction* I accidentally met with two places, wherein he has, in a secret Character, communicated some Secrets about the making and use of Glasses, which seem to have been unknown to the World at that time: These, as finding little else considerable in it, I transcrib'd, and having since deciphred them, I find them to comprehend these words, *Chartam patinæ lenissimo pulmento ingeniose agglutina tripoli vitrum polito in ea.* This seems to be much the same way which Mr. *Marshal* did here shew this Honourable Society, tho' what he apply'd it unto for Polishing many Glasses at once, is an addition of his own, of which he says he took the hint from what I did Publish in the Preface of my Micrographia, concerning the Polishing of many Object-glasses at once for Microscopes. This Ænigma of *de Reita* is to be seen in Page 344 of his Book, now mention'd in these Characters,

Reita's Secrets deciphered.

Cphaatritnaæ lpeunlimsesnitmoo jang ggelnuitoisnea
Turijtproulmi pionleiato, &c. *Pag.* 344.

The other Ænigma or Secretum, as he callsit, is in Page 356. in this Cypher.

Cqounauteuxoar---mdeitcituas---oebrijegcutnat
Maumlptluimf---qiuceat---ruietreo---tceorlt---
Lioucma icnopnufnucstiuomnis---Suuennto---vtirtiraa--
Occoun luaer xiaa---oobujaerttuimuum--.

That Deciphered I find to contain these words.

Convexa quatuor melius, dicta Objecta erigunt multumq; amplificant. Rite vero tertium Colloca in punctum confusionis. Sunt vero vitra tria ocularia convexa, Objectivum quartum.

This

This it seems was then a secret, tho' now generally known and made use of for Day Objects, and that even in short Lengths; but for the Cælestial Observations where there is not great need of erecting the Object, one or two Eye-glasses is much more convenient; for that they may be made to take in a much larger Area, and represent the Object much more bright and distinct; howbeit they are both capable of much further improvement, and consequently be much more adapted for the use of the Sea, for which occasion I have at this time discours'd of them.

And I will undertake to accommodate Navigators with Telescopes of two Foot in length, with which they shall be inabl'd, not only easily to find the Object, but to discover also the times of the Eclipses of the *Satellites* of *Jupiter*, as exactly as shall be needful.

Let therefore such Ephemerides be provided, and I shall procure an ingenious Workman, who shall provide such Telescopes fit for that purpose; so that nothing will then be wanting to compleat the use of those Eclipses for the discovery of the Longitudes of such parts as they shall be observable in, save only an exact Time-keeper to observe the precise times of such appearances, which I can also accommodate them withal; so that if the precise time of the Setting of the Sun for that Night be known, they shall be sure of the time of the Eclipse to a very few Seconds.

By such Methods and Instruments as I have now describ'd, if carefully us'd, I doubt not but that the Sea-Coasts of all frequented parts of the World might be truly plac'd as to their Longitudes and Trendings; and the method of taking Latitudes being a little amended, the exact Situation of all such places in some few Years, might be obtain'd, which would be of great benefit for the perfecting that part of Geography which at this time is very imperfect.

In my last Discourses I explained three several Instruments for the Use and Benefit of Navigation, two of which have not been ever yet thought of by any (that I have heard of) which yet I conceive will (if well made and put in practice) be of very great advantage to Navigators; for that they are new assistants to them in giving them information of what they have no other ways of Learning: For by means of the last of the three they will be inabl'd to discover the Latitude, when, by the commonly us'd Instruments, they are necessitated to depend only upon Conjecture; namely, at such times either of the Day or Night as the Horizon is not visible, and when the Sun passes near the Zenith; and 'tis so much the more useful, for that Nocturnal Observations may be made at all times, when the parts of the Sky, near the Zenith, shall be clear and free from Clouds. And Observations may be taken of such Stars as pass over or very near the Zenith with more ease and certainty than of the Sun itself in the Day time; for that the Star observ'd doth more precisely shew the very Points, when and where it passeth the Zenith or the Meridian near it; and the Declination of the Star (which may be learned from Tables ready calculated for that purpose, especially for the most notable and conspicuous) will readily give the Latitude of the place.

As for the assistances the other may afford, it is hard to ascertain, yet since it hath been found to be of very good use at Land to prejudge the Constitution of the Weather, especially of great store of Wind or Rain, 'tis very probable it may be of as much, if not more, benefit at Sea, where the Air seems to be of more general uniformity, especially in such parts of it as are far remov'd from any Lands; for that the Situation of Mountains or other diversify'd parts of the Earth, which are oftentimes the Causes of Storms and Rains on the Land, have little influence upon the parts of the Sea far remov'd from them: Tho' possibly it may be found that the Gravity of the Air may be differing at Sea from what it is at Land; which, if so, might be of no small benefit to the Navigator, if he could from that be inform'd of his approach to Land. 'Tis not impossible neither, that it may afford him some intimation of the depth of the Sea where he may be, and many other things very desirable to be known, which I will leave to the discovery of the diligent Observer. There are many things, that before they are discover'd, are look'd upon as impossible, which yet, when the are found,

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are ſaid to be known by every one, the inventor only excepted, who muſt paſs for an Ignoramus.

I have many Years ſince ſhewn to this Society (as will, I ſuppoſe, appear by their Journals) an Inſtrument to keep an exact account of the way of a Ship through the Water; whether it has been ſince try'd I know not, yet I have many Years ſince that, heard of one or two who were getting a Patent for a like Inſtrument; whether they ſucceeded or not, I have not inquir'd, for I freely imparted it for a general Good, and ſhould be glad to here that it were put in practice, and perform'd what may, in all probability, be expected from it, which, I conceive, will be a very exact and certain information of the way of the Ship that uſeth it through the Water, it not only meaſuring the length of the Run, but the Rumb of the Leeward way; and the Angles made upon the ſeveral Tacks and Courſes; but yet 'tis defective for finding the true way of the Ship over the parts of the Earth ſubjacent to to that Sea, becauſe it diſtinguiſheth not the current or ſetting of that part of the Sea without ſome other aſſiſtances, whence, 'till they are added, 'tis uſeleſs for the invention of the Longitude, which is to be found by other means: However, 'tis of great uſe to know the true Velocity of a Ship through the Water, in ſhort Voyages, or in foggy or dark Weather; becauſe it is a great help to judge of their preſent Poſition as to the true Courſe they deſign to hold, and in narrow places they can better judge when 'tis fit to tack about and ſtand another way. *Of a way wiſer for a Ship at Sea.*

There is another addition which I thought might alſo be of good uſe and information to a Navigator, and would afford him a means of exactly meaſuring that which he now knows only at random and by gueſs, and that is an Inſtrument, which being fixt at the top of the Antient or Flagg-ſtaff, ſhould, at all times, give the true ſtrength or velocity of the Wind; and the information thereof may eaſily be convey'd into the great Cabbin or the Steeradge of the Ship. By the help of this and the former way of meaſuring the way of a Ship, it would be eaſy to find with what Winds, whether large or ſcanty; with what Sails, whether more or fewer, or how plac'd; with what Trim, with what Burthen or Lading, with what Ballaſt, *&c.* the Ship makes the beſt way. This is a Propoſition hitherto only prov'd by gueſs and ſtrong Opinion, for the moſt part very prejudicate and precarious; but by this means it might be brought to a certain Standard of meaſure. By this means alſo the comparative goodneſs of Ships for ſailing or making their way through the Water might be brought to a certainty of meaſurement, which cannot ſo well be done by any other way now uſed; for tho' two Ships may now ſail not far aſunder, and both intend the ſame courſe, yet which ever has the better of it in ſailing faſteſt, it will be diſputable whether that be the better Sailer; for tho' they are not far aſunder, yet that which came firſt to the Port, might have great advantages of the Wind, which the other had not; and poſſibly it might be the contrary, there being yet no certain way of determining it, unleſs by multiplicity of ſuch trials, it ſhall always be found that the ſame Veſſel has the advantage, and yet even in this way the probability indeed is greater, but yet 'tis but a probability, ſince 'tis poſſible that ſuch advantages may happen for five or ten times together, and yet may fail the eleventh time; whereas by this Inſtrument it will plainly appear which hath had the greateſt quantity or ſtrength of the Wind, and which the leaſt; and by the ſame Inſtrument it may be certainly determin'd with what Sails, with what Trim, with what Burthen and with what Courſe, whether by or large, a Ship, comparatively, Sails beſt; as alſo it may be practically examin'd with what Trim or ſet of the Sails a Ship ſails the beſt when it goes near a Wind, and the like to ſee how far Experience will agree to the Theory; as alſo whether flat and taught Sails do better than bellying or bunting Sails, which I conceive they do, tho' the moſt part of Seamen do believe and affirm the contrary with great confidence. I could enumerate many other uſeful informations theſe Inſtruments duly made would afford, but it is needleſs at preſent, ſince what I have mention'd are matters of ſo great concern in Naval Affairs to be truly inform'd of, that they alone are ſufficient (one would think) to induce ſome Inquiſitive Men concerned, to be *A Contrivance to know the ſtrength and point of the Wind.*

knowing in these Affairs, to cause some trials to be made thereof, since no one can deny but that the Consequences that I have asserted must necessarily follow; that is, that all those Particulars which are hitherto only acquir'd by Conjecture and Guessing are by means hereof reduc'd to certainty of Number, Weight and Measure; and tho' some very skillful in these Affairs may say they can do all that is requir'd well enough, without any such Invention, by their own Judgments and long Experience; yet, I conceive, that he that uses a pair of Compasses shall be able to draw a truer Circle than ever *Apelles*, or the greatest Artist that ever drew Line with his Hand, would be able to do without them.

The Instrument I design for this purpose, is but little differing from that which I long since contriv'd for measuring the velocity of the Wind, and caused one of them to be made for the Weather-clock. It has been sufficiently seen and try'd, and therefore will not, for this time, need a more particular Description; however, if any one designs to make trial thereof, I shall not be wanting to give the Workman, that makes it, sufficient Instruction.

ALL that I can find of these Instruments are only the two following Extracts out of the Registers of the Royal Society, which I have here publisht, hoping they may give the Ingenious some hints of improving them, which indeed has been my chief aim in Printing many of the foregoing Discourses.

R. W.

November 14. 1683. *Mr.* Hook *shew'd an Instrument to measure the Velocity of the Air or Wind, and to find the strength thereof, which was by four Vanes put upon an Axis, and made very light and easy for motion; and the Vanes so contriv'd, as that they could be set to what slope should be desir'd: It was several times try'd and examin'd in the long Gallery in* Gresham College; *whereby it appear'd, that by walking from one end thereof to the other, and carrying the same above ones Head, the Doors and Windows of the said Gallery being shut, and so the Air within it being not in motion but stagnant, the Instrument made so many turns as there were Circumferential lengths of the said Vanes in the length of the Gallery; and if by trial it were found to be more or less than the due measure of the Circumferential lengths, then by setting the said Vanes either flatter or sharper in respect of the way of its motion through and against the Air, the same was easy to be adjusted; the use of which may be of very great consequence in the business of Sailing and steering a Ship upon the Sea, and for examining the power and strength of the Wind upon Land in order to the Theory of Shipping for which it was design'd.*

A Way wiser for the Sea; *November* 28. 1683.

I shew'd an Instrument I had contriv'd, and shew'd some of the Society above twenty Years since, by which the way of a Ship through the Sea might be exactly measur'd, as also the velocity of any running Water or River, and thereby the comparative velocity of it in its several parts; by this also the quantity of the Water vented by any River into the Sea, or any other River, might be found; it was one part of a way wiser for the Sea. The whole Engine being design'd to keep a true account not only of the length of the Run of the Ship thro' the Water, but the true Rumb or Leeward way, together with all the tackings and workings of the Ship. This part of the Engine now shewn was the Vane, Fly, or first mover of the whole, feeling, as it were, and distinguishing the several Qualifications of the Ships Course, but was to be regulated by several other Additions in the compleated Engine, which I design shortly to get executed.

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A Lecture of the preference of strait to Bunting Sails, Read March 5. 168$^{8}_{9}$.

I have in this place formerly read several Discourses, and shewn many Experiments concerning Light and Gravity, which are two great and universal powers in Nature; by the later of which all Terrestial Bodies are powerfully, and (if their way be not impeded by the *Media*, through which they pass) most rapidly mov'd towards the middle parts of the Earth, with velocities always accelerated in sub-duplicate proposition of the aggregate of Powers moving; of the effects of which Monsieur *Huggens* hath treated no further than thereby to find what is the comparative Gravitation here upon the Surface of the Earth, with respect to the Gravitation at the distance of the Moon; by which Examination of the proportion of Gravity he is much convinc'd of the truth of that Theory which I had the happiness first to invent, and of which I shall have occasion to discourse more at large on another Subject. The other effects of Gravity upon Bodies here upon the Earth, which he omits, have been fully discover'd by *Galileo*, *Torricellius*, and divers others since that time, who have all proceeded upon the equal power of Gravity, and consequently suppos'd an equal addition of Acceleration in equal spaces of time; which in short spaces of Descent near the Earth, is *quoad sensum* true, there being no sensible difference between the power of Gravity in so small a difference of height, as Nature has allow'd Mankind a Liberty or Power of arriving at, to make his trials in: As the top of some high Hill, or at the bottom of some deep Mine; tho' yet possibly with curious Instruments and accurate Observations, somewhat of discovery might be made on such a Hill as *Tenariff*, or the *Alps*: For which Inquiry therefore one of the Experiments, which I formerly propos'd, to be try'd at *Tenariff* (and which I try'd many times my self, both at the top of St. *Pauls* and at *Westminster-Abby*, tho' without finding any sensible difference) was intended; as will appear by the accounts of those trials, tho' they were unsuccessful as to what they were design'd for; however several other Discoveries were made not unuseful. But I shall not further proceed upon that Contemplation at present, but, rather, in this following Discourse, consider a third Power of Nature arising from the motions of the Air and Water, two fluid Mediums which incompass the Body of the Earth. And among the various Effects they produce, I shall at this time, consider only one which is procur'd by means of Art, and that is for the moving or regulating of Ships or Vessels by means of Sails, Oares, Rudder, and the like artificial Methods of gaining and making use of their Powers: It being of great use for Merchant Ships in those times of danger, to know the best Methods and Means of making these Powers the most serviceable to them that may be for flying from and escaping the pursuit of their Enemies. There are therefore very many things that must be consider'd, in order to the perfecting of this effect to the greatest advantage that is possible. As the Shape and Bigness of the Vessel with consideration of its Use and Design, the manner of Rigging it and fitting it with Masts, Sails, and other Tackle, and with Rudder, Oares, Keel, Leeboards, *&c.* The Shapes and Magnitudes of each, and the ways of applying and using them to the best advantage. And herein will come the consideration of the Power of the Wind upon Sails, Masts, Rigging and Hulk of the Vessel: The power also of the Water against the Rudder, Oares, Leeboards, Keel, Head and Sides of the Vessel will come under consideration; for it must be determin'd what quantity of Sails this or that kind of Vessel will bear; and what the form of the Sail is best to be, and how to be order'd or fitted to the Vessel; how much Ballast such Vessels so built and rigged, will require, and what strength of Wind each kind of Vessel can indure; what the strength of the Wind is with relation to its swifter motion or higher blowing; what strength and length of Oares is necessary for induring the powers to be apply'd to them; and what Powers, whether of Men, or other, can be apply'd; and what are the best and most advantageous

Traite de la Lumiere.

Several matters to be known in the Art of Sailing.

vantageous ways for such applications: These, and many other particulars, ought to be fully examin'd, both by the known Principles of Mechanicks, and by Experiments on the several Materials that must be introduc'd into the Propositions of such Ratiocinations; for that abstracted Notions will not be so serviceable in these Inquiries as the knowledge of the concrete Qualities and Proprieties. And to be furnish'd with these many an pertinent Experiments must be invented, made, and diligently, as well as knowingly, observ'd; for that the preponderancy of such Effects, may, and do often lie in unheeded Circumstances, and in almost insensible differences; which, nevertheless, upon the result of greater trials, prove very notable; and yet, by reason of the Difficulty, Charge, loss of Time, and many other Inconveniences, which are the necessary Concomitants of such greater Experiments, the smaller trials, tho' they require much more watchfulness and perspicatiousness are much to be perferr'd: For that more may be examin'd and verify'd in a Year by these, than by the other in an Age. And tho' the business of Shipping and Navigation hath been many Ages in a way of improvement, and somewhat very considerable has been done towards it, insomuch that the present state thereof is look'd upon as the highest Perfection it is capable of, yet a few small trials might easily make the groundlessness of that Opinion plainly appear, almost in every particular of the artificial Structure of Vessels fitted for that design. I am not insensible of the difficulties that attend any one that shall be an asserter of this Doctrine; I have experimentally verify'd the effects of propounding new Inventions to improve such as are at the present in vogue; witness the improvment of Astronomical Instruments, the Spring-watches, the universality of Gravity, and the motions of the Heavens, according to the Rules and Laws of Mechanical Motions. And yet after all the obloquy and reproaches, and unhandsome treatment I have met with for making those discoveries, I find the things themselves, in tract of Time, become to be approv'd, and come to be of general use. There are, I believe, but very few in the World now that will adhere to *Hevelius* his magnify'd Contrivances for Instruments with plain Sights, tho' at the same time they joyn with him in the Aspersions he hath cast upon me. But to let those Reflections pass at present, I know very well, that I shall find, opposite to this Doctrine about Ships, not only all the Architects or Ships-Builders, but the Crue of Navigators also, who are very hard to be brought to the Use and Practise of a new Method, and are not otherwise to be prevail'd with but *gradatim* by length of Time, and dear bought Experience. But tho' the most are thus qualify'd, yet they are not all: There are some that are willing to be better inform'd in this or that Particular, and will make use and trial of things, tho' they carry with them but a probability; for the sake therefore of such, 'tis if any discovery be made; but for the rest *Si Populus Vult, decipiatur.*

Of flat Sails. I have had many Discourses both with some of the ablest Ship-writes, and with as skilful Navigators, and both agree in their Opinions or Judgments, that a Bellying or Bunting Sail doth more promote or carry a Vessel to Windward, than a flat and smooth Sail that bellies not at all; the contrary of which I have divers times indeavour'd to defend. In order to clear the reasonableness of this Assertion, I have, in the first place, consider'd the Nature and Power of the Wind upon the Area of a Sail, various ways expos'd to it; by which, by degrees, I shall come to the evident Demonstration of what I have asserted: But because, possibly after all that can be said and manifested by such a Demonstration; those that have asserted the contrary, will not grant the Conclusion, after the Demonstration; I shall prepare an Apparatus for the trial of an Experiment where the effect itself shall speak the Conclusion, and that beyond the power of Contradiction.

To come then to the Reasons that induc'd me to make this Conclusion; I say that fluid Bodies mov'd, do impress a motion to other Bodies, they are mov'd against proportionate to their Gravity and Velocity: This may be prov'd by thousands of Experiments: Next I find the Air to be a ponderous fluid Body, whose integrant parts have both bulk and weight in them as well as the integrant parts of other fluid Terrestial Bodies; as Water,

Oil,

Oil, Quicksilver, and the like; and tho' they have a less proportion of Gravity, if compar'd to their bulk, or the space they seem to fill, and that so very small, that they have, for a long time, been asserted to have a contrary quality of lightness, yet, by undeniable Arguments drawn from Experiments, they are demonstrated to have their proportion of Gravity with relation to their bulk: Which proportion compar'd to the like proportion of Water, is, for the most part, near as 1 to 800 or 900. It follows therefore, that the motion of this fluid Body must, according to the quantity of its Gravity, impress upon another Body that it is mov'd against, such a quantity of motion in the same manner as the like quantity of another fluid Body, as Water, and if the motion be the same, the motion communicated will be as 1 to 800. If the Motions be reciprocal to the Gravities of the striking Bodies, the motions or powers communicated will be equal; for if there be by the Velocity 28, 3 times as much Air in bulk mov'd against the Recipient Body as there is of the bulk of Water in the same time, and that the Velocity be 28,3 swifter than that of the Water, then 28, 3 x 28, 3 will produce an equality of Motion with the eight hundred Gravitating parts in the Water mov'd with one degree of Velocity, as I shall more particularly prove afterwards. Thus, if on a Stilyard a weight of thirty Pound be hung at thirty times the distance from the Center that a weight of nine hundred Pounds is hung, the Stilyard shall remain in æquilibrio, and neither end prependerate; for the thirty Pound cannot be mov'd but it must have thirty times the Velocity that the nine hundred Pound must have, and therefore the Stilyard must remain without any motion at all, but stand in a æquilibrium. Since the product of the bulk and Velocity of the one is equal to the Product of the Bulk and Velocity of the other; this therefore holds where effects equiponderate.

The Wind then is nothing else but the Body of the Air mov'd as a fluid with a certain degree of Velocity towards a certain part of the Horizon upon the Surface of the Earth or Sea, and, as other fluid Mediums, it taketh the easiest and shortest way it findeth to continue its direct motion; moving round the edges of the Body that standeth in its way, after it hath beat against it, and been reflected from it, and the parts reflected are quickly again, by the succeeding Parts, recruited in their motion, and move along with the other parts which have received no Impediment The power of the Wind therefore is to be computed according to the bigness of the Prism of the Air which cometh to dash or strike against the Body that is expos'd to it; and according to the Velocity that this Prism is mov'd forwards to strike against it: For a fluid Medium, in motion, is to be consider'd as made up of an indefinite number of small Cylinders, Prisms, Wires or Strings lying close together, and so making up the Solidity of the greater Prism of the Body of the fluid that is mov'd towards the Obstacle; and again each of these small Prisms or Wires may be suppos'd as made up of an indefinite number of small Beads or Dies lying one behind another, and so following each other immediately in the same Line, and with the same Velocity of motion, and every one of these compounding Beads or Dies coming to beat or strike against the Body that lieth in its way, it so strikes it and communicates a motion; what motion it doth not communicate to that Body it meets with, is reflected back from it, with, or by an Angle equal to the Angle of Incidence. So that upon this consideration each of the small Prisms may be computed as a single Bullet or Die, so striking the Surface of the expos'd Body with one degree of power all of bulk equal to the many single ones separate; and the larger Prism made up of an indefinite number of these lesser Wires or Prisms, may be conceiv'd and computed as a larger Bead or Die, relation being always had to the Gravity and Velocity of the impelling or striking Body. Now a round Body being mov'd against another Body, impresseth on it some degree of motion, and what it doth not communicate, is reflected from it, according to the known Laws of Reflection; that is, the reflected Angle is equal to the Angle of Incidence upon the plain of the Body struck, and the Body struck receiveth a motion Perpendicular to the Surface of it that is so struck.

To come then to the Application of the Power of the Wind upon the Sails of a Veſſel, we are to conſider the Expanſion of the Sail, as it is expos'd to the Impulſe of the Wind; whether the Surface of it do cut the Priſm of the Wind that beareth againſt it at right Angles or Oblique; if it cutteth the Priſm at Right Angles, then the whole power of a Priſm of Wind or Air that cometh to blow upon it for a certain time, whoſe Baſis is equal and at right Angles with the length of the Priſm, is to be computed as communicating all its motion: But if the Area of the Sail cut the Priſm at oblique Angles, then we muſt conceive the Scalene Priſm as cut at right Angles, and compare the Area thereof with the Area of the Sail; and this will give the magnitude or quantity of the impelling Priſm of Wind againſt the oblique Sail. Again, to know with what force this Scalene Priſm doth preſs or impel the Sail ſo obliquily poſited Perpendicularly to its Surface, we muſt compare the Degrees of Velocity, with which it is mov'd directly towards the Area of the oblique Sail, and ſee what proportion it holdeth with the direct and perpendicular motion upon the direct Sail; and by both theſe Examinations duly made, the comparative power of the Wind upon the Area of the ſloped Sail will appear. Let ab then repreſent the breadth of a Sail of a given height, and let a b c d repreſent a Priſmatical Body of the Air, which being mov'd from dc to ab in a given ſpace of Time, maketh a Wind of ſuch ſtrength bear or beat againſt the Surface of the Sail ab directly oppos'd to its courſe, and in the given time all the parts of the Priſm a b c d have ſtruck againſt the Surface of the Sail ab. Suppoſe then a b n o, to repreſent a Priſm of Water, of equal Baſe with the ſaid Sail ab, and that an, or bo, the length of the ſaid Priſm be $\frac{1}{30}$ of the length ad or bc the Priſm of Air mov'd the contrary way with thirty times the Velocity, if the proportion of the Gravity of the Air be to the Gravity of the Water, as one to nine hundred: I ſay, the Sail ſhall not be mov'd either way, but remain in an æquilibrium: For as the Velocity of the motion of the Water an, 1 is to the Velocity of the motion of the Air ad 30; ſo the Gravity of the Priſm of the Air a b c d 30, to the Gravity of the Priſm of Water a b o n 900. Now becauſe the ſame power is impreſt on the Sail, whether the Cylinder of Water be mov'd againſt the Sail from no to ab, or the Sail be mov'd againſt the Water from ab to no; if the ſaid Cylinder of Air be made one degree ſwifter, it muſt drive the ſame Sail from ab, to no.

The Calculation of the ſtrength and difference.

Next ſuppoſe Ef to repreſent the ſame Sail, ſet obliquely to the Priſm or Current of the Wind, draw eh, and fg, parallel to ad. Firſt then it is plain, that a k h d and b c g i of the former Priſm do now not at all touch the ſaid Sail ef, but only the middle part of the ſame, namely, k i g h; now the quantity of this to the quantity of the former, being as ki to ab; that is, as pf, the ſine of the Angle of incidence p e f to the Radius ef, or ab; it follows that the quantity of Wind upon the direct Sail to the quantity ſtriking the oblique Sail is, as Radius to the ſign of the Angle of Incidence.

Again, the power of this Priſm upon the oblique Sail ef, is to the power of it upon the direct Sail, equal to ki, as el to f l; that is, as fp to fe; that is, as the ſine of the Angle of Incidence p e f to the Radius; therefore the power of the Wind upon the Sail ab, directly oppos'd to its motion is to the power of it upon the ſame Sail ſet oblique to its motion, as the ſquare of Radius, to the ſquare of the Angle of Incidence, or of the obliquity to the Wind p e f.

Now that the motion of the oblique Sail is to the motion of the direct Sail by the ſame Priſm of Wind as pf to fe, will plainly appear: Suppoſe p f g h a ſolid Cylinder meeting with pf a direct Sail at pf, and fe the oblique Sail; then pf will be carry'd on to ql, at the ſame time that ef will be mov'd to lm; the motion therefore of pf is equal to fl, but the motion of ef is equal to el: But as fl to el, ſo fe to fp, ſo Radius to the ſine of Inclination or Obliquity.

Now that the ſtrength or power of the Wind upon the Oblique Sail is Perpendicular to the ſaid Sail, is evident from this Conſideration, that if the Sail be ſuppos'd perfectly flat and ſmall in its Surface, there is no part that the Wind can take hold of to drive it forward in its own way, and having no

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part opposite to the power thereof, but only the said smooth Surface that can only receive a Perpendicular pressure, and that pressure can only move or thrust it toward the Perpendicular of its Surface: If therefore a Sail be perfectly flat and smooth, all the force it receives is towards the Perpendicular of its Surface. Which Perpendicular force notwithstanding may cause it to move in any other direction which is inclin'd to the said Perpendicular, by some Angle less than a right, according as the said Sail may be so fix'd to a Body that shall have a more easy way for it to pass that way than towards the Perpendicular. This may be explain'd from the consideration of the power of Gravity: The power of Gravity then we know tends to move the heavy Body towards the Perpendicular of the Horizon, that is, towards the Center of the Earth; but if the heavy Body be so posited on a Plain that has any inclination to the solid Perpendicular; that is, maketh a less Angle with it than a right Angle; we know that the power of Gravity, tho' it acts directly towards the Perpendicular, yet it moveth and impelleth it to descend obliquely in any other Plain dipping below the Horizon. Now the proportion of the power of the Wind upon the oblique Sail to drive it backwards towards the Perpendicular, is to the proportion of its power to drive it in any other Plain, is easy to be determin'd, but that I shall refer to another opportunity.

Now since by this afore recited Cause it is evident, that the power of the mov'd Air or Wind upon an oblique Sail, doth press or protrude it Perpendicularly to the Surface of the Sail, and thence, if there be as free a passage that way, as any other, the Sail will be mov'd, and move the Vessel to which it is fix'd in the said Perpendicular; it follows, that if there be any other part of the said Sail that has a differing inclination, it will have a differing Perpendicular, and consequently every part of the bent Sail will have a differing pressure and a differing tendency; and because that part of the Sail which is next the Wind, is less belly'd than that which is from the Wind, more of the Perpendicular Tendencies will be to fall from the Wind than to go nigh or towards the Wind, and consequently, the composition of all the tendencies together, will have less power to press the bent Sail towards the Perpendicular of the set of the Yard of the Sail, than if the Sail were all smooth in the plain of the Yard; for the fore part of the Sail next the Wind becometh, by the bellying, to stand too sharp and near the Wind, and so receiveth little power or force from the Wind, to promote it according to those Perpendiculars, and the Aft-parts of the Sail stand too full, and so receive most of its power, whose Perpendiculars tend too much from and before the Wind; and the middle parts of the Sail which stand only true, are so small a part of the whole, that the most part of the effect of the Wind is lost or mistaken for the desir'd end.

This is one of the great Reasons why a Vessel, that is thus rigged, is not able to sail on any Rumb within four Points, and why even there so little way is made to the Windward, tho' there are several other Reasons also; of which I shall Discourse on another opportunity.

A Lecture of the manner of Rowing the Antient Gallies, *Read* July *the* 2d. 1684.

THo' this Lecture was read several Years before some of the former, yet I thought it best to reserve it to the last; the foregoing seeming to me more to depend upon each other, and by some sort of Connection join together. In this the Reader will find the Authors Sentiments very differing from all that have wrote upon this Subject; I think his Reasons have a considerable weight in them; but this is left to the Readers Judgment, as all other matters contain'd in this Volume, which I shall end with these Discourses, finding no more that properly belong to Navigation or Astronomy, and reserve some Miscellaneous Tracts, Fragments on several Subjects, some Inventions, accounts of Experiments, &c. for a Supplement or second Volume, which I purpose to publish in some short time, if this first find any acceptance, and not increase the bulk of this, which has prov'd longer than I at first expected.

R. W.

A Lecture of the manner of Rowing of the Antient Gallies, *read* July 2. 1684.

The greatest promoter of Mens Industry, Study and Invention for the discovery of Arts, has been the necessity of usefulness of them for humane Life. To which end next to *Agriculture* and *Architecture*, I conceive *Navigation* may be rank'd, by means whereof Men have pass'd to places of the Earth otherwise inaccessible, and the whole Surface of the Land has been inhabited and peopl'd. And as it has been very useful in itself, so it has been the occasion of inventing and perfecting many other Arts and Sciences, as *Geometry*, *Astronomy*, *Geography*, &c.

And tho' the devouring Teeth of Time hath scarce left us any scrap of History that should acquaint us with the knowledge and practice of Men in the first Ages of the World, yet such as we have do sufficiently inform us, that in the younger times of the World, Ships and Navigation were known, witness *Homer*, *Jason*, and the *Argonauts* not now to insist on, what we find in Holy Writ concerning the *Ark of Noah*, which, tho' the Shape, Dimensions and Manner of building that Vessel, which was for a very peculiar and extraordinary Use, were divinely reveal'd to *Noah*, yet it seems not unlikely but that there might be many other sorts of Vessels known and in use long before that time, as in probability there were many Arks or Chests for common use long before the Lord directed *Moses* in the Bigness, Form and Materials of the second *Ark*, which was the *Ark of the Testimony*. But this I shall not insist on; I know the Accounts are but very short, and so nothing positivively concluded from thence that there were Ships; much less can we find what they were, or to what perfection *Navigation* was practis'd: Nay, we are much to seek what was the true form of Ships in the more modern Times of the *Greeks* and *Romans*; of which times, notwithstanding, in respect of other particulars, we have much more full and compleat Relations. That there were Vessels of prodigious bulk and burthen, we are assur'd by *Pliny*, *Plutarch*, and others; that they carry'd prodigious numbers of Men, both of Soldiers and Seamen, that they had great numbers of Oars and Men to manage them; and that they had Ballast, Masts, Sails and Rudders, and could Sail both before and by the Wind, is also evident. But then what was the true shape of the Vessel, both under and above the Water; what the form of their Oars and how they us'd them; what their greatest velocity either of Sailing or Rowing; what their strength for bearing Sail, or enduring the Sea, and the like; of these Histories give so little an account, that the best Judgments of the greatest Criticks, are but uncertain Conjectures and short of giving satisfactory Answers and Solutions. And had not the antient Carvers help'd the Historians, we should have been much more to seek; for according to the Descriptions that Criticks have given us of the way of using their Oars, which is much after the Modern way of using them in Boats, Barges and Gallies; I see not how it could be possible to manage the uppermost Oar of forty or fifty; for so many, 'tis said by *Plutarch* and *Pliny* and others, have been us'd in each order. I have therefore omitted all the Criticisms concerning this matter; of which there is much to be found in *Budæus*, *Bayfius*, *Scaliger*, *Snellius*, *Pancirollus*, and more especially *Meibomius*; and apply'd my self to consider the thing as I find it express'd in the remaining *Basso Relievos* of the Antients. And upon the whole I conceive that the way of Rowing us'd by the Antients, was wholly differing from what we now use, and not at all like that which the Learned *Meibomius* has taken so much pains to explain.

I shall not trouble you with long *Ambages* either in confuting the Opinions of others or Criticising upon the Words or Phrases of Historians, but rather in short tell you the sum of what I judge of this matter.

First then, I conceive, that the Oars us'd by the Antients were very much like the Oars now us'd, but broader and flatter, shorter and lighter, and manag'd only by one or two.

Secondly, That they were mov'd not vibrating forward and backwards as ours now are, but inwards and outwards.

Thirdly,

Thirdly, That they did not lie Horizontal as ours do, but almost Perpendicular; and when they lay a ground, the Oares serv'd instead of Legs or Props to sustain the Vessel or Hull when its Belly was not broad enough to lie upright, and it was crank sided.

Fourthly, That they were not lifted out of the Water, but always remain'd immers'd.

Fifthly, That they always promoted the Vessel whether they were mov'd outwards or inwards.

Sixthly, That the Rowers did seldom sit with their Faces to the Poop of the Vessel, but sometimes with their Faces toward the Prow, and, for the most part, with their Faces outward and forwards.

Seventhly, That in the smaller Vessels as *Biremes*, *Triremes Quadriremes*, and *Penteres*, the Oares went through round holes made in the sides.

Eighthly, That in the *Triremes* the *Thranites* sat formost, and at the top the *Zygites* just behind him and below him; and 3*dly*, The *Thalamites* behind the *Zygites* and below him, and so the *Zygites* Oare was mov'd up and down behind the back of the *Thranites* and the *Thalamites* behind the *Zygites*.

Ninethly, That the Hull of the *Triremes*, &c. were built much bredthing or spreading upwards, and over hanging, so that the holes that were made for the Oares of the *Zygites* and *Thalamites* went out almost Perpendicular; and in some there was an oversailing or projecture of the Hull at the place, but especially in greater Vessels; the Oares of the *Thranites* were either put thro' a hole of the checquer'd Railings at the top, or else laid in a Notch on the edge of the Ships sides, and bound down either with an Iron or Rope; so that when the *Thranites* thrust the handle of his Oar from him, it would not rise out of the Notch.

Tenthly, That the *Remiges* or Rowers in greater Vessels, such as the *Hepteres*, *Octoeres*, &c, were plac'd in Galleries which oversail'd the Hull of the Vessel, which were made by Beams lying quite cross the Hull of the Ship and made a very broad Deck, not like the Modern Gallies, but such, as I conceive, was quite flush from end to end of the Beams; at the other side of which Galleries there was made a grating or side to defend the Rowers. In these kinds of Vessels the *Remiges* or Rowers did stand side to side, and the Oar went Perpendicular into the Sea, in the out part of the oversailing Beams, and the Rowers, in the way of Skulling, mov'd their Oars altogether, either outward or inward; by which means they were able to employ such a vast number of Rowers, wherein every one should be able to exert his whole strength in promoting the Ship, and so must needs be able to make it move with a prodigious swiftness, much beyond the swiftness of any Gally or Galliot.

By this means what *Plutarch* writes concerning the Vessel built by *Ptolomæus Philopator* may be well conceiv'd, which would otherwise seem incredible and impossible; for 'twas 280 Cubits long, or, as *Snellius* computes, 420Cubits and 38 in bredth, or 57 Foot; the height from bottom to top was 52 Cubits; it carry'd 400 Mariners besides 4000 Rowers, and near 3000 Soldiers. How these Rowers should be plac'd according to the forms they conceiv'd, both *Scaliger* and *Snellius* were at a great loss; insomuch that *Snellius* thinks it impossible to dispose the Rowers, unless they were pack'd up like Salt Herrings. *Ut nefas sit credere hæc transtra a Remigibus occupari potuisse, nisi forsan cos tanquam halices & salsamenta stipatos intelligas*, are his words. And, according to the manner of Rowing they conceiv'd, it would have been very difficult. Nor would *Meibomius* his Contrivance have help'd them; but in the way I propounded of the spreading of the Vessel upward; it will not be difficult, where, tho' the highest Oars will be still the longest, and so they will need a Counterpoise of Lead at the Handle to ballance the weight of the Shank, as *Atheneus* affirms they had in this Vessel of *Ptolomæus Philopator*, yet going down into the Water nearer to a Perpendicular than a Horizontal Posture, it may easily enough be conceiv'd; but these kind of monstrous Vessels were rather for shew than use, as *Snellius* well observes.

Eleventhly, That the flat of the Blade of the Oar did not go into the Water Perpendicular, and cross the length of the Vessel, as our Oars

now, but rather parallel with the length of the Vessel, and so were canted with the foremost edge outwards, when they were strained outwards and the foremost edge inward, when they were strain'd towards the Vessel; by which means they always promoted and impell'd the Vessel forwards, and that in a very natural and efficacious way; in the same manner, as all Fishes do swim and force their way through the Water.

Twelfthly, To confirm this Opinion, I shall only instance in the Modern Practise, which is yet in use in the *East-Indies*, where this manner of Rowing is still in use, tho' somewhat mixed with the Northern or our modern way of Rowing; for in their Barges the Rowers all stand, and indifferently with their Face or Back to the Prow of the Vessel, and sometimes half one way half the other, and so indifferently can make the Vessel move forwards or backwards without altering their posture; as, without question, all the antient Vessels could likewise be mov'd; which gives a Reason why, in *Ptolomy*'s Vessel, there were four Rudders, namely, one on each side before, or in the Prow, and one on each side behind or in the Poop. And the *Indian* Rudder also which is still in use, is of the same fashion with that of the *Greeks* and *Romans*, save only, that instead of planting it on each end the Vessel, they place it in the middle abaft, and so it indifferently serves for Steering the Vessel, whether going forward or backwards, and is much more convenient and easy to manage than the way of Rudders now in use with us. The Curry Curries also are still mov'd or row'd in the same manner with those of the Antients, as I conceive, the Rowers sitting all on Bamboos at a distance from the Vessel and Sculling the Vessel by canting the Oars in the manner I have describ'd; and 'tis not unlikely but the Gallerys of Gallies might have been some Remainder of the Galleries of the Antients, tho' they are accommodated to the Modern way of Rowing.

I am not insensible how great the Difficulties are in the introducing a new Opinion: Or to persuade one, that has long believ'd a thing to be one way, that it is another, especially about such matters as are thought to be thoroughly understood, and most generally put in practice and approv'd. But then I know also, that how generally soever any thing be believ'd and asserted to be true, and the best that 'tis possible, yet that there may be, hath been, and always will be left room enough to find out farther Discoveries and Improvements of Mens Knowledge and Understanding, even in that particular, and that 'tis as hard to find and set Bounds and Limits to the power of the Mind; as to set what is the greatest or least Extension or Demension of Body in Nature: I expect the Criticks first, next the Skilful in the present Naval Architecture, And, Thirdly, Such as have not so much consider'd this part of Mechanicks, may be opponents to this particular Opinion and Explication of this piece of antient History, whose fate it hath been hitherto either not to be understood, or not to be believ'd; for what hath hitherto been the cause of these Effects may still remain so to have an influence upon Mens Minds, as not easily to admit the entrance of a new or contrary proposal. However, as far as I am able, I shall indeavour to satisfy each of these Opponents in the explication of those things which may seem the most difficult.

It cannot be expected, I suppose, that from some few collected Rafts and Fragments which have scap'd the devouring Sea of Time, in which the Arts and Knowledge of the Antients have been Shipwrack'd and lost, I should be able to give so true and positive an account of every particular part, as could not be contradicted: But taking for granted that the Histories are true that afford us that information we have; I conceive there is no difficulty to shew a way how the same might be effected which is affirm'd to have been done; and to begin with the smallest which was the μονόκωπος, or a Boat with one Oar: This was fastned to one side behind, in the same manner as the *Temo* or Rudder, by a Strap or Ring, or else was put through a hole; the handle of which, the Rower sitting with his Face towards the Prow, and holding in his two Hands, mov'd fromwards and towards the side of the Vessel, canting the *Tonsa* or Blade thereof with his Hands, by which the Vessel was both readily promoted and also guided; of this Oar the *Tonsa* or blade was very broad,

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by which means the Rower could exert his whole strength the better. The Δίκωπος or Δίσκαλμος had two of the flat Oars behind on each side one, which were either mov'd by two Men, or else sometimes by one who manag'd the two Oars, in each Hand one. So *Lucian* brings in *Charon* in his Dialogues thus speaking, *Ego quamvis senex duos remos concitans navigo Solus.* Not like our common Scullers which manage their Oars almost on a level, but after the same manner, as I before mention'd was done by the Μονόκωπος: The manner of using these will appear plainly from the Basso-Relievos on the *Columna Trajana*, which is a most undeniable Record of History, and to be prefer'd before any Writings in Books of those times, since there may have been so many Transcripts or Coppies made one after another, of Historians, and every one of those might multiply the Errors and Mistakes of the first Transcriber, whence Criticks find and amend so many Errors and make more, whereas this has undoubtedly stood the same since it was first erected, which was in the time of *Trajan* when those Vessels were actually made and us'd. This gave me the first Hint or Conception of this way of using the Oars, and I cannot find any one passage either in the Carving or Writings of the Antients that doth any ways contradict it; and taking that for granted, it will be easy to explain all that is related in History concerning their greater, even their greatest Vessels which had the greatest numbers of Rowers and Oars, which I take to be almost impossible to be done any other way.

Now that this is not so preposterous a Conception as some may imagine, nor so fantastical, ridiculous, silly and insignificant a way of using Oars, as some have thought; give me leave to add one Argument, and that is this, that Nature is generally the best guide for Art to imitate. If this be doubted, I can produce Arguments enough to evince it; but if it be not, then, I say, that this way of Rowing (which I propose) comes the nearest to the method of Nature in the making animated Bodies pass through fluid Mediums, and therefore 'tis probably the best; for there is scarce a Fish in the Water, a Bird or Insect in the Air but moves itself through those fluid *Media* by the same method with this I propound; that both the Tails and Fins of Fishes are this way mov'd, is most evident to any one that shall strictly examine it; and *Borelli* in his Book *De motu Animalium*, has well explain'd it, that several of those Birds that dive under Water, such as *Didappers*, *Coots*, *Puffins*, &c. do under Water move their Wings in this manner, I have often times seen my self and observ'd: And that all Birds and Insects by the same kind of motion of their Wings, fly in the Air: Any that will examine will so find it. So that could there have been a better way, Nature would have taken it. Some motions indeed there are that seem a little to imitate this, and that is the motion of the Sea Fowl, *Swans*, *Geese*, *Coots*, &c. at the top of the Water, when they begin to rise and take the Wing; but then 'tis but by accident; for all these Fowl indeavouring to use their Wings by striking the Air, being near the Water, strike the Surface of it with the extreamity or blade of their Wings, after they have first struck the Air; and with the flat of their Feet help to push themselves forward to get a celerity of Progression, which is necessary for their rise, treading, as it were, the top of the Water, and for want of that help, some of the short Wing'd Fowl, as *Puffins*, &c. are not able to rise into the Air from plain ground, but from the Rocks they precipitate themselves on their Wings to acquire a necessary velocity; which all other long Winged Fowl are able to procure by the help of their Feet, swiftly treading the Ground, and with their long Wings beating the Air.

The greatest Objections I have yet met with are these, First, That 'twas absurd to conceive, that the Ships Row'd sometimes backwards as well as forwards, and had Rudders at both ends, but for this *Suidas* upon the word Δικέλος, says *sunt & quædam quæ binis gubernaculis a prora & a puppi instructæ sunt, ut ubiq; conversione in hostes navis feratur aut Recedat, eosq; tam progressu quam Recessu fallat.* And that some Ships had such Rudders. *viz.* two before and two behind, is evident from the Description of *Philopator*'s Ship also in the fifth Book of *Athenæus*, where he says it was Δίπρωρος καὶ Δίπρυμνος, *biprora & bipuppis*, a double bottom'd Vessel, or two join'd together; for otherwise I cannot conceive how three thousand arm'd Men could be plac'd between the Rowers,

Rowers, on which there were two thouſand on each ſide. Now by this way of Rowing, I ſuppoſe the Rowers could very eaſily, with the ſame motion of the Oar, Row the Ship either forward or backwards; and tho' they had but one Rudder, yet they could eaſily Steer the Veſſel by it, tho' it were mov'd backwards; for the Blade *Tonſa*, or palm of the Rudder, was broad and equally extended on both ſides the Stalk or middle, and ſo was always on a Counterpoiſe.

The manner how the *Tonſa* of the Oar cut the Water will be better underſtood by the Figure than by the words alone. Let AB repreſent the Water Section of a Dicrotos; E and N the canting Section of the Palm of the Oars in the Water; theſe being mov'd outwards from the Boat, ſlide againſt the Water from E to F, and from N to O, and at the ſame time carry the Veſſel from AB to CD; then the Cants of the Oars being alter'd at G and P, and mov'd inward, they ſlide againſt the ſide of the Water by the Lines GH and PQ, and promote the Veſſel from IK to LM, and ſo ſucceſſively; which is the ſame motion with the Tail of a Fiſh in the Water, by which its Body is moſt powerfully carry'd forwards; which is eaſy to be conceiv'd, and will effectually perform what it ought to do.

This ſingle motion then once underſtood, it will not be difficult to conceive all the reſt in any of their other Veſſels.

For the *Moneres* was nothing but ſeveral Couples of theſe Oars lying one before another, as thick as they could ſit, leaving only room for the Perpendicular motion of the Handle of the Oar behind the back of the next Rower that ſat before him, and not ſo much ſpace as is requir'd in the modern way of Rowing, where the motion of the Handle or Blade of the Oar is Horizontal.

The *Dieres* or *Biremes* were double Orders of thoſe Oars or Rowers; the Rowers ſometimes ſitting ſide by ſide, upon the ſame Bench, the *Thranites* ſitting next the ſide, and the *Zygites* next within; the *Thranites* Oar uſually lay at the top in a half round Notch, and in the inſide was tied down with a Strap call'd *Strappum* by *Vitruvius*, or elſe it way thruſt through ſome hole of the Rails at the ſides of the Veſſel, the Oar of the *Zygites* paſs'd through a hole, a little below and nearer to the Poop, and cut the Water with the ſame inclination.

The *Trieres* or *Triremes* had three *Verſus* or Files of theſe Rowers, there being three in each *Ordo* or Rank; the *Thranites* and *Zygites*, for the moſt part, ſat as in the *Biremes*, but the *Thalamites* ſat upon the Foot-ſtep of the *Thranites*; the Oars of the *Zygites* and *Thalamites* went through round holes in the ſide of the Veſſel.

The *Quadriremes* had four Rowers in a Rank, ſitting upon the upper Bench, and two upon the Foot-ſtep; the *Thalamites* and *Thramites* ſat next the ſide of the Veſſel, and the *Zygites* next within them.

The *Hepteres* had all the Men ſitting or ſtanding in one Rank, and at one Height, but that Rank a little ſloped, to let the Oars have free paſſage one by another.

Thoſe of a greater number of Rowers in an order, had both ſeveral ſtations of Seats and ſeveral Men upon each Seat; as the *Dekeres* might have three aſcents of Seats, and have three Rowers on the loweſt, three on the next, and four on the higheſt Bench: But theſe are but Conjectures, as are, for the moſt part, all the other above the *Triremes*, there being nothing that I have yet met with in the Writings of the Antient Hiſtorians, or in the *Baſſo Rilievos* now remaining that can clear that Doubt. But certain it is, that by this way of Rowing, as great a number of Men may conveniently enough be plac'd to manage each his Oar; and thereupon exert his own ſtrength for the promoting of the Ship, as are Recorded to have been made uſe of by the Antients, which I conceive cannot be done by any other way of Rowing yet known.

I ſhall not now inſiſt upon the great uſe there may be made of this Principle in Shipping, but only hint, that how ſlight ſoever it may at firſt appear, it may poſſibly be prov'd to be of as great concern to *England*, as any thing hitherto done in Shipping.

FINIS.

Tab: VIII.

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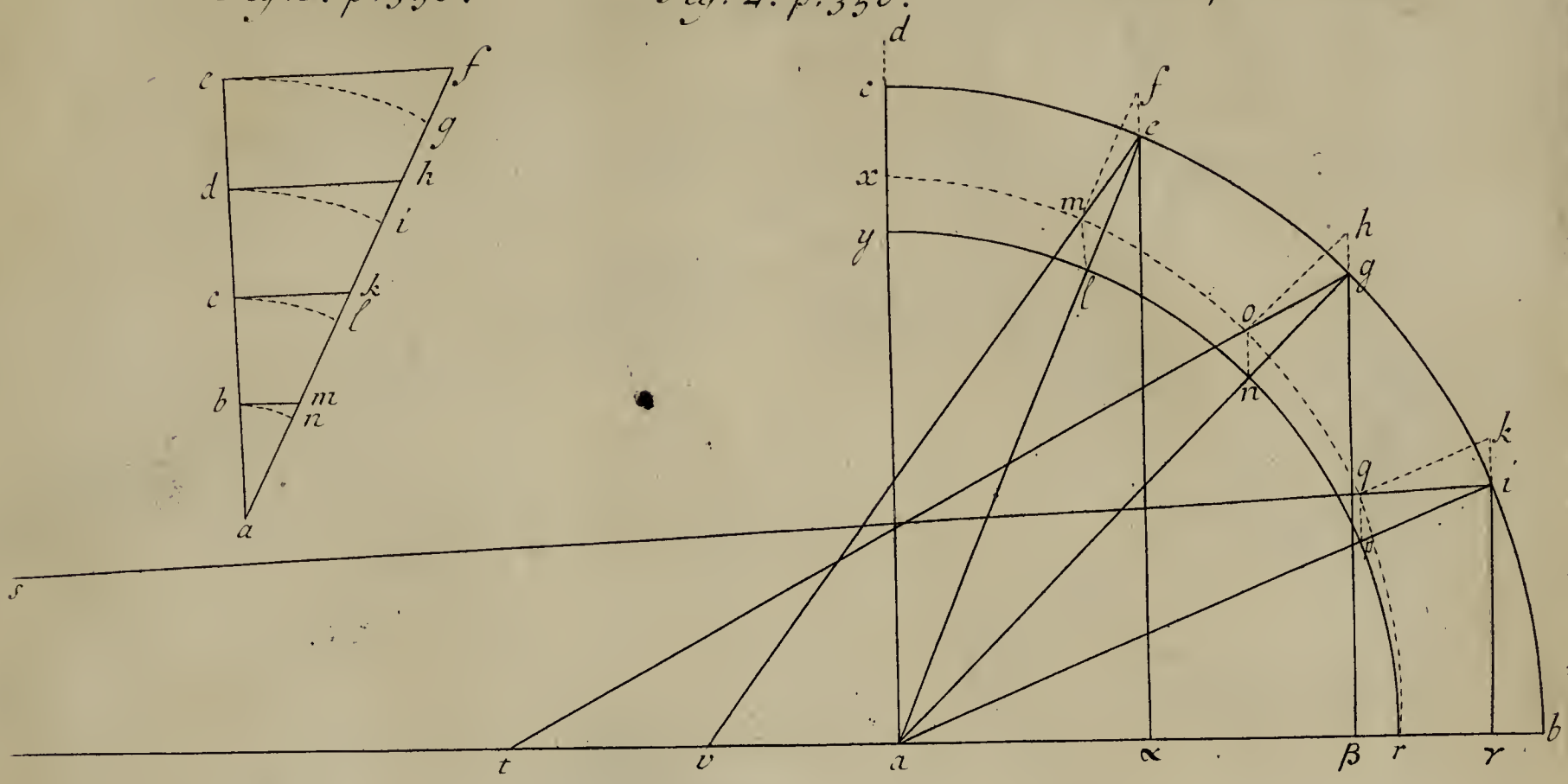
Fig: 1. p: 356.

Fig: 2. p: 356.



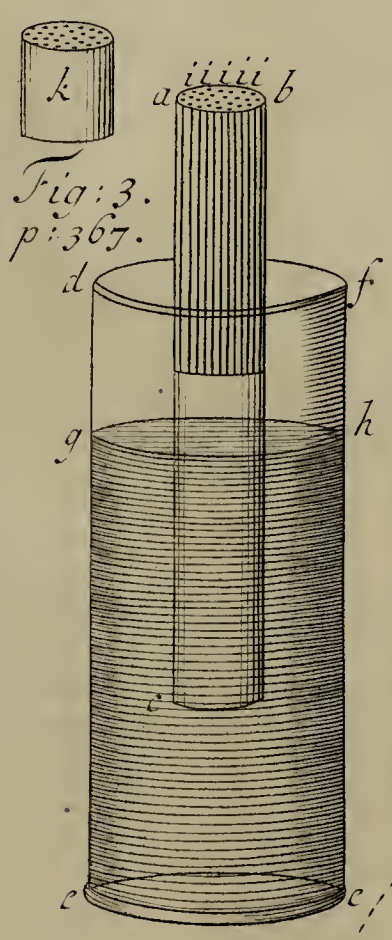


Fig: 3. p: 367.

Fig: 4. p: 370.

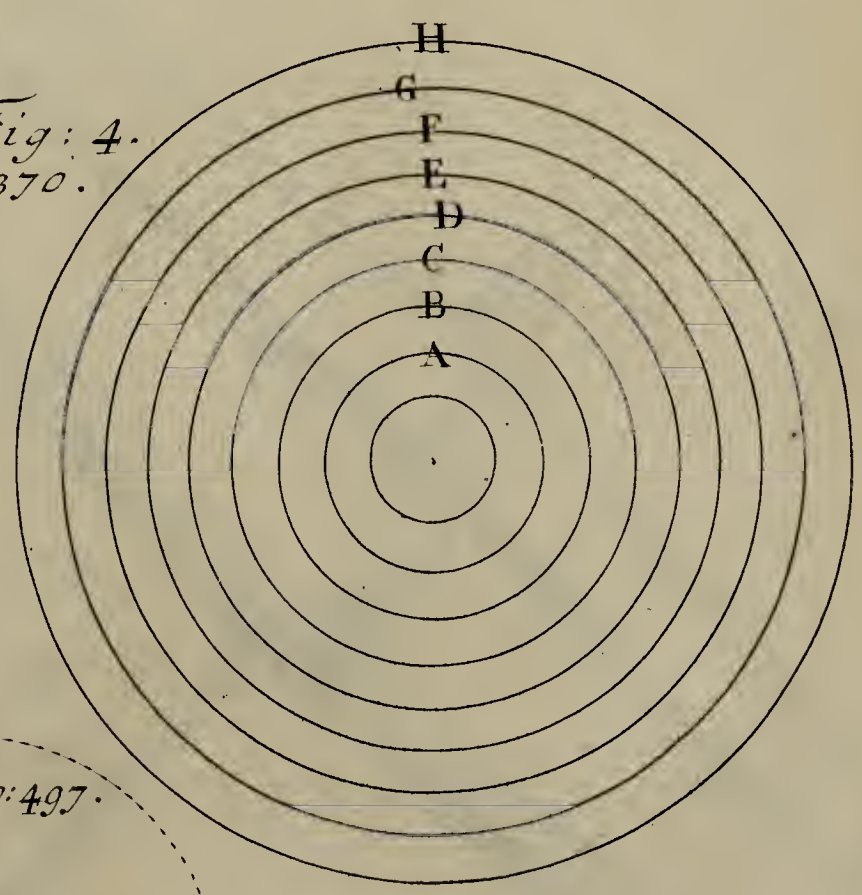
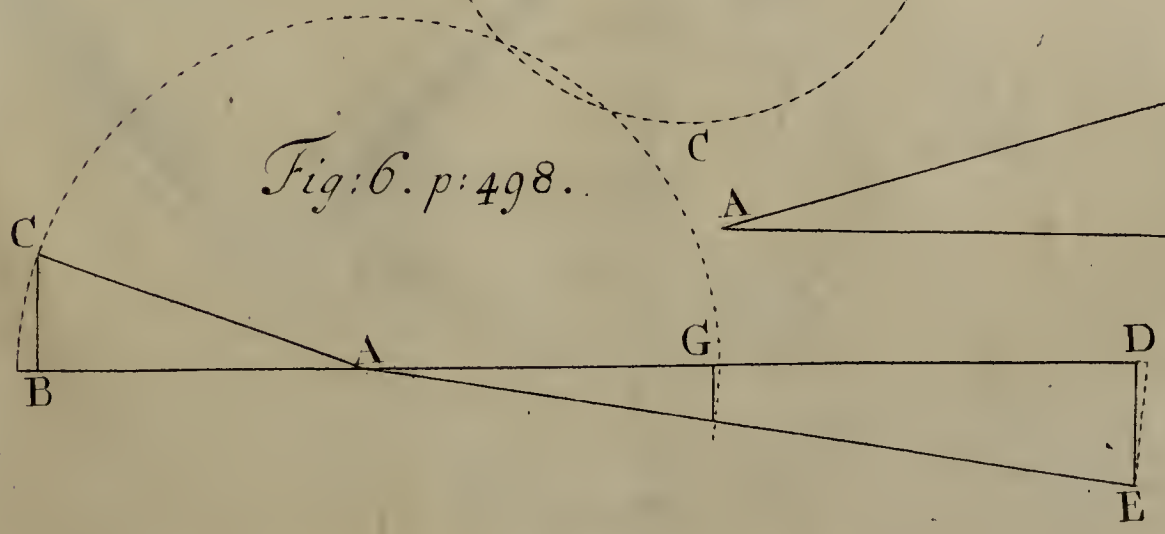


Fig: 5. p: 497.

Fig: 6. p: 498.



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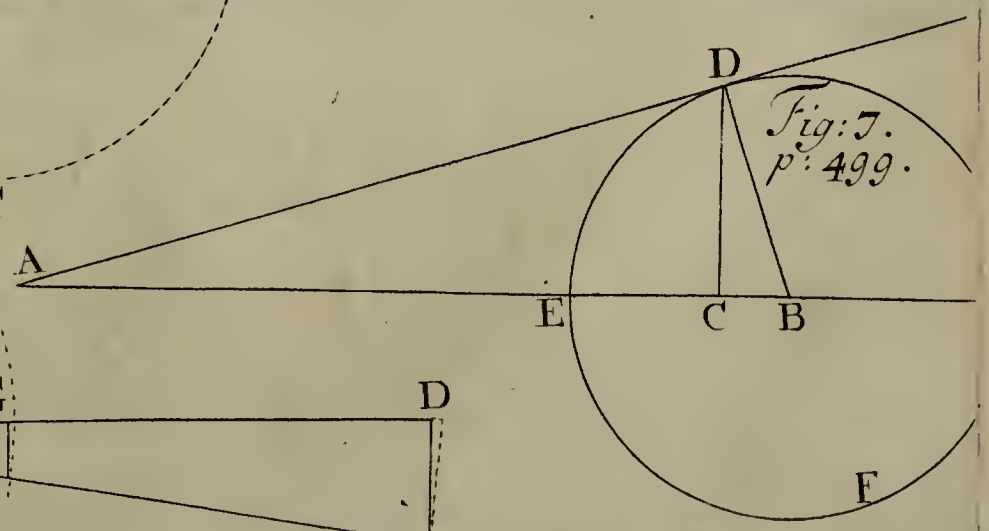

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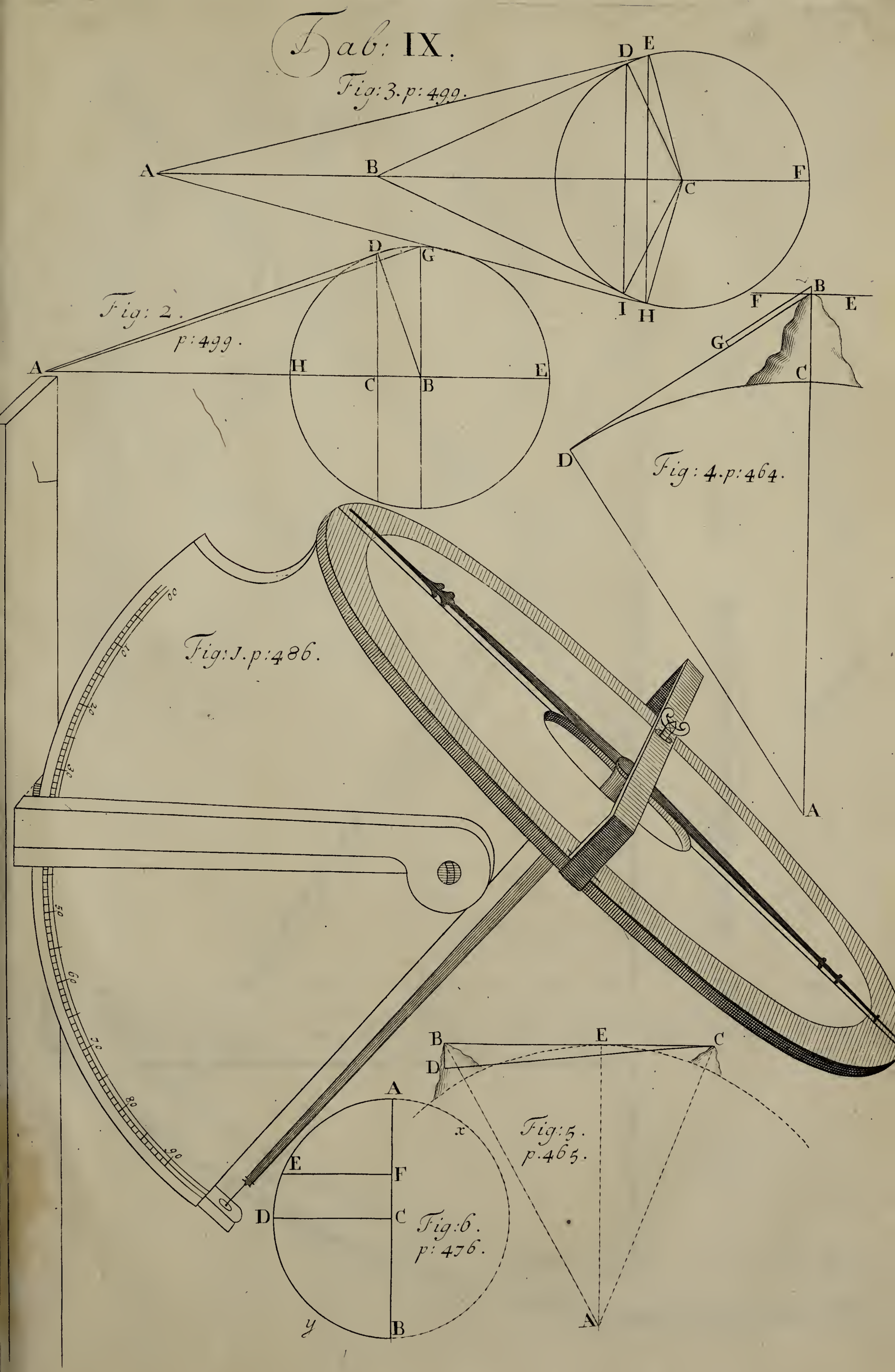
Fig: 3. p: 499.
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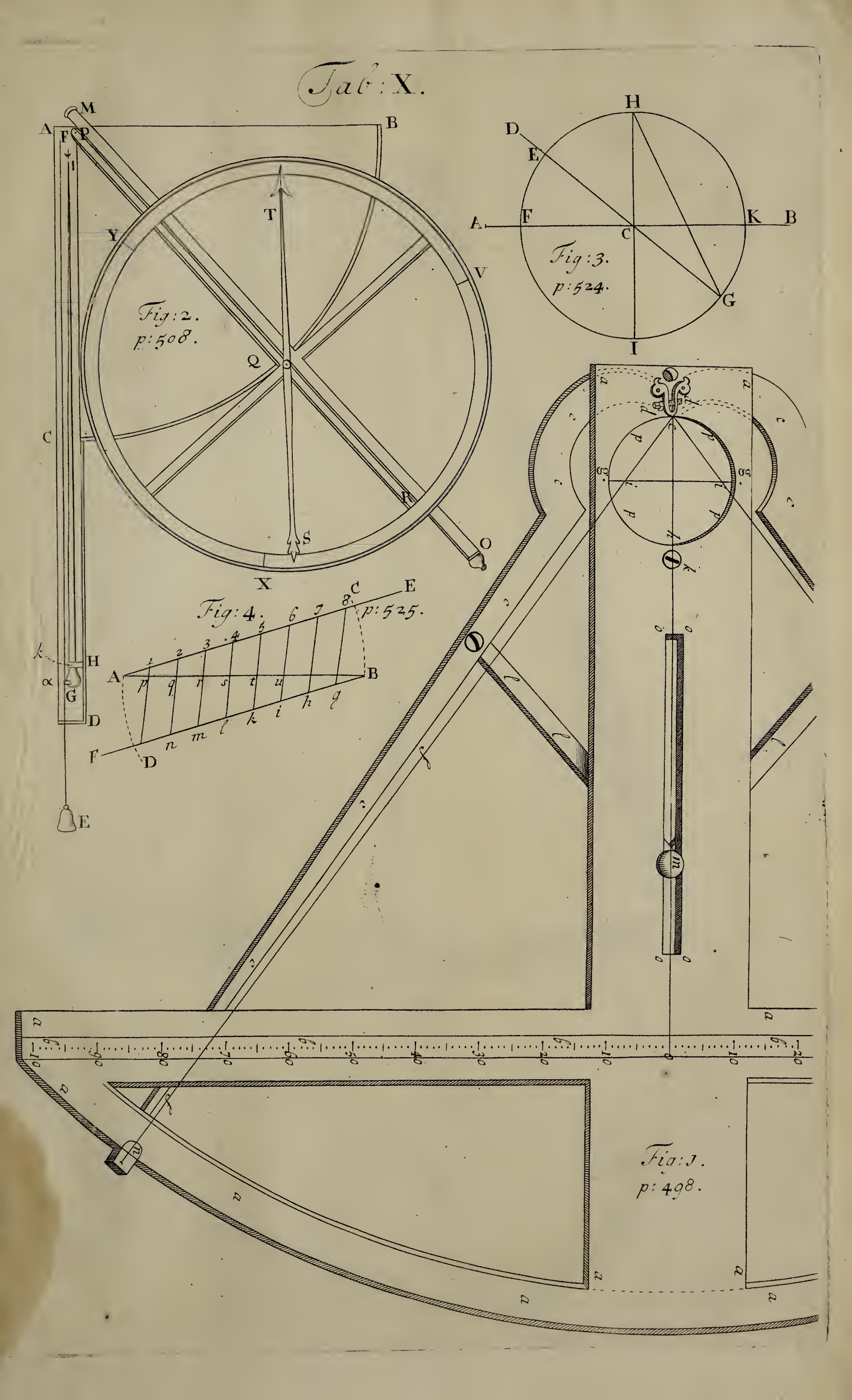
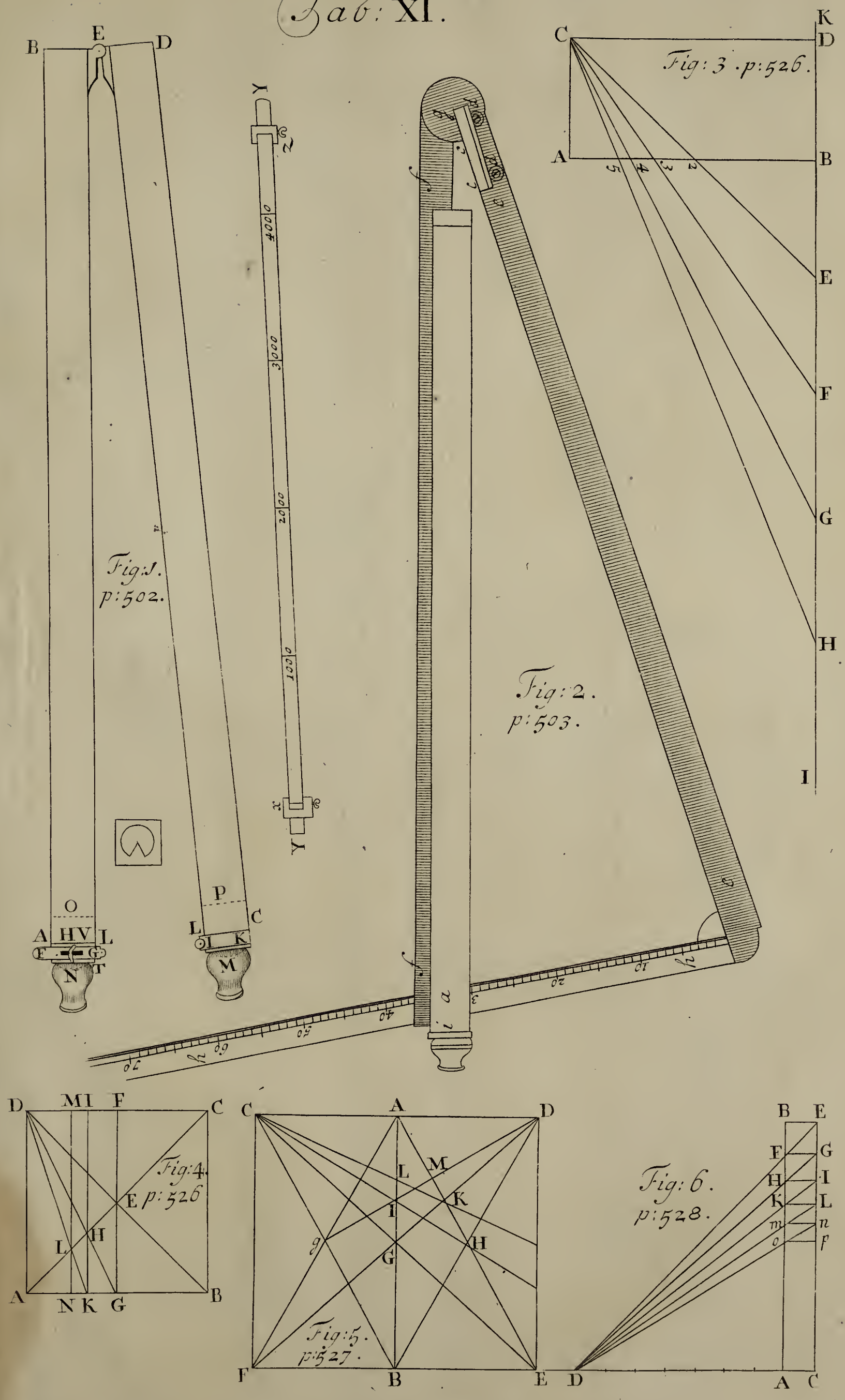
Tab: X.



Tab: XI.



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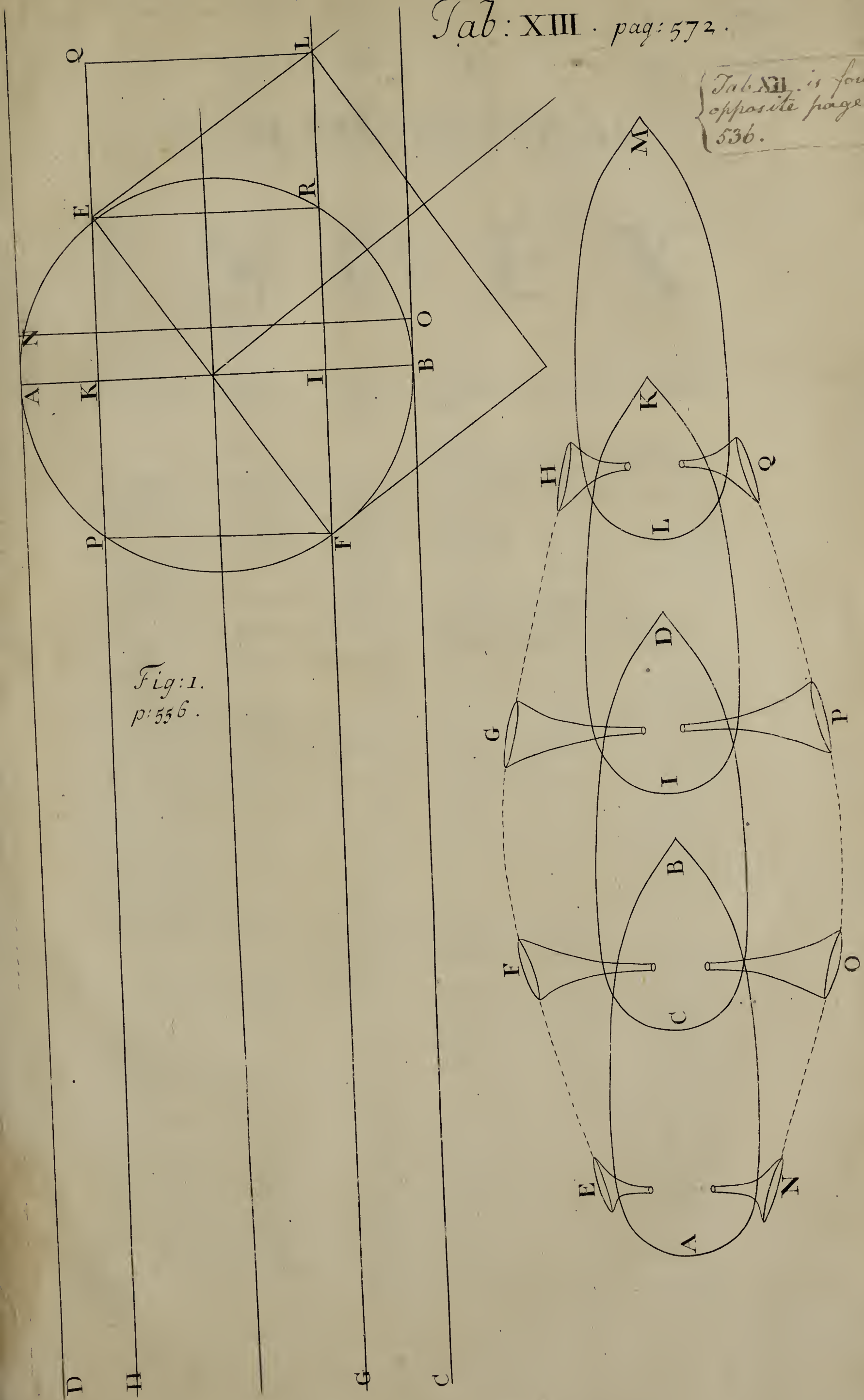

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An ALPHABETICAL

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