
WILKINS
MATHEM-
ATICAL
MAGICK
1680

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Mathematical Magick:

OR, THE

WONDERS

That may be performed by

Mechanichal Geometry.

In Two BOOKS.

CONCERNING

Mechanical { *Powers.* / *Motions.* }

Being one of the most easie, pleasant, useful (and yet most neglected) part of *Mathematicks.*

Not before treated of in this Language.

By *J. Wilkins,* late Ld Bp of *Chester.*

Τέχνῃ κρατοῦμεν ὧν φύσει νικώμεθα.

a

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u

To His Highneſs the Prince Elector *Palatine.*

May it pleaſe Your Highneſs !

I *Should not thus have preſented my* diverſions, *where I owe my ſtudy and* buſineſs, *but that where all is due, a man may not juſtly with-hold any part.*

This following Diſcourſe was compoſed ſome years ſince at my ſpare hours in the Univerſity. The Subject of it is mixed Mathematicks; *which I did the rather at ſuch times make choice of, as being for the* pleaſure *of it, more proper for recreation; and for the* facility, *more ſutable to my abilities and leiſure.*

I ſhould not, Sir, have been ambitious of any ſo Great *(I could not of any* Better) *Patronage, had not my relation both engaged and emboldned me to this Dedication.*

They that know your Highneſs how great an encourager you are, and how able *a Judge in all kind of ingenious arts and literature, must needs acknowledg your pressures and low condition to be none of the least mischiefs (amongst those many other) under which the Commonwealth of Learning does now suffer.*

It would in many respects much conduce to the general advancement of religion and learning, if the reformed Churches, in whose cause and defence your family hath so deeply suffered, were but effectually mindful of their engagements to it. And particularly, if these present unhappy differences of this Nation did not occasion too much forgetfulness of their former zeal and professions for the vindicating *of your family, and the* restoring *of your Highness; the hastning and accomplishment of which, together with the increase of all heavenly blessings upon your Highness, shall be the hearty daily prayer of*

Your Highness

Most humble and most devoted servant and Chaplain,

JOHN WILKINS.

TO THE READER.

IT is related of *Heraclitus*, that when his Schollars had found him in a Tradesmans ſhop, whither they were aſhamed to enter, He told them, *Quod neque tali loco dii deſunt immortales*, that the gods were as well converſant in ſuch places as in others; Intimating that a divine power and wiſdome might be diſcerned even in thoſe common arts, which are ſo much deſpiſed; And though the manual exerciſe and practiſe of them be eſteemed ignoble, yet the ſtudy of their general cauſes and principles cannot be prejudical to any other (though the moſt ſacred) profeſſion.

It hath been my uſual cuſtom in the courſe of my other ſtudies, to propoſe divers Mathematical or Philoſophical inquiries, for the recreation of my leiſure-hours; and as I could gather ſatisfaction, to compoſe them to ſome form and method.

Some of theſe have been formerly publiſhed, and I have now ventured forth this diſcourſe; wherein beſides the great *delight and pleaſure* (which every rational Reader muſt needs find in ſuch notions as carry with them their own evidence and demonſtration) there is alſo much *real benefit* to be learned; particularly for ſuch Gentlemen as employ their eſtates in thoſe chargeable adventures of Drawning, Mines, Cole-pits, &c. who may from hence learn the chief grounds and nature of Engines, and thereby more eaſily avoid the deluſions of any cheating Impoſtor: And alſo for ſuch *common Artificers*, as are well skilled in the practiſe of theſe arts, who may be much advantaged by the right underſtanding of their grounds and *Theory*.

Scho. Mathem. l. 2. *Ramus* hath obſerved, that the reaſon why *Germany* hath been ſo eminent for Mechanical inventions, is becauſe there have been publick Lectures of this kind inſtituted amongſt them, and thoſe not only in the learned languages, but alſo in the vulgar tongue, for the capacity of every unletter'd ingenious Artificer.

This whole Diſcourſe I call *Mathematical Magick*, becauſe the art of ſuch Mechanical inventions as are here chiefly inſiſted upon, hath been formerly ſo ſtyled; and in alluſion to vulgar opinion, which doth commonly attribute all ſuch ſtrange operations

Agrippa, De Vanit. Scient. c. 42.

unto

unto the power of Magick ; For which reason the Ancients did name this Art Θαυματοποιητική, or *Mirandorum Effectrix*.

The first book is called *Archimedes*, because he was the chiefest in discovering of Mechanical *powers*.

The second is styled by the name of *Dædalus*, who is related to be one of the first and most famous amongst the Ancients for his skill in making *Automata*, or self-moving Engines: both these being two of the first Authors that did reduce Mathematical principles unto Mechanical experiments.

Other discourses of this kind, are for the most part large and voluminous, of great price and hardly gotten ; and besides, there are not any of them (that I know of) in our vulgar tongue, for which these Mechanical arts of all other are most proper. These inconveniences are here in some measure remedied, together with the addition (if I mistake not) of divers things very considerable, and not insisted upon by others.

The

The Contents and Method of this following Discourse.

The first Book.

Ch. 6.

The second Book.

Ch. 4.

ARCHI-

ARCHIMEDES,
OR,
Mechanical Powers.

The first Book.

CHAP. I.

The excellency of these Arts. Why they were concealed by the Ancients. The Authors that have treated of them.

ALL those various studies about which the sons of men do busie their endeavours, may be generally comprised under these three kinds:

- Divine.
- Natural.
- Artificial.

To the firſt of theſe, is reducible, not only the *ſpeculation* of Theological truths, but alſo the *practiſe* of thoſe virtues which may advantage our minds in the enquiry after their proper happineſs. And theſe arts alone may truly be ſtyled liberal, *Quæ liberum faciunt hominem, quibus curæ virtus eſt*, (ſaith the divine Stoick) which ſet a man at liberty from his luſts and paſſions.

Sen. Ep. 88.

To the ſecond may be referred all that knowledg which concerns the frame of this great Univerſe, or the uſual courſe of providence in the government of theſe created things.

To the laſt do belong all thoſe inventions, whereby nature is any way quickned or advanced in her defects: Theſe artificial experiments being (as it were) but ſo many Eſſays, whereby men do naturally attempt to reſtore themſelves from the firſt general curſe inflicted upon their labours.

This following Diſcourſe, does properly appertain to this latter kind.

Now

Now Art may be ſaid, either to *imitate* nature, as in limming and pictures; or to *help* nature, as in medicine; or to *overcome* and *advance* nature, as in theſe Mechanical diſciplines, which in this reſpect are by ſo much to be preferred before the other, by how much their end and power is more excellent. Nor are they therefore to be eſteemed leſs noble, becauſe more practical, ſince our beſt and moſt divine knowledg is intended for action, and thoſe may juſtly be counted barren ſtudies, which do not conduce to practiſe as their proper end.

But ſo apt are we to contemn every thing which is common, that the ancient Philoſophers eſteemed it a great part of wiſdom, to conceal their learning from vulgar apprehenſion or uſe, thereby the better to maintain it in its due honour and reſpect. And therefore did they generally vail all their Arts and Sciences, under ſuch myſtical expreſſions, as might excite the peoples wonder and reverence, fearing left a more easie and familiar discovery, might expose them to contempt. *Sic ipsa mysteria fabularum cuniculis operiuntur, summatibus tantum viris, sapientia interprete, veri arcani consciis; Contenti sint reliqui, ad venerationem, figuris defendentibus à vilitate secretum,* saith a Platonick.

Macrobius Somn. Scip. l. 1. c. 2.

Hence was it, that the ancient Mathematicians did place all their learning in abstracted speculations, refusing to debase the principles of that noble profession unto Mechanical experiments. Insomuch, that those very Authors amongst them, who were most eminent for their inventions of this kind, and were willing by their own practise, to manifest unto the world those artificial wonders that might be wrought by these arts, as *Dædalus, Archytas, Archimedes, &c.* were notwithstanding so much infected with this blind superstition, as not to leave any thing in writing concerning the grounds and manner of these operations.

Quin-

Quintilian ſpeaking to this purpoſe of *Archimedes*, ſaith thus: *Quamvis tantum tamque ſingularem Geometriæ uſum, Archimedes, ſingularibus exemplis, & admirandis operibus oſtenderit, propter quæ non humanæ ſed divinæ ſcientiæ laudem ſit adeptus, hæſit tamen in illa Platonis perſuaſione, nec ullam Mechanicam literam prodere voluit.* *Quint. l. 1 c. 10.*

By which means, poſterity hath unhappily loſt, not only the benefit of thoſe particular diſcoveries, but alſo the proficiency of thoſe arts in general. For when once the learned men did forbid the reducing of them to particular uſe and vulgar experiment, others did thereupon refuſe theſe ſtudies themſelves, as being but empty and uſeleſs ſpeculations. Whence it came to paſs, that the ſcience of Geometry was ſo univerſally neglected, receiving little or no addition for many hundred years together. *Pet. Ram. Schol. Mathem. l. 1.*

Amongſt theſe Ancients, the divine *Plato* is obſerved to be one of the greateſt ſticklers for this fond opinion, ſeverely dehorting all his followers from proſtituting Mathematical principles, unto common apprehenſion or practiſe. Like the envious Emperour *Tiberius*, who is reported to have killed an Artificer for making glaſs malleable, fearing leſt thereby the price of metals might be debaſed. So he, in his ſuperſtition to Philoſophy, would rather chuſe to deprive the world of all thoſe uſeful and excellent inventions which might be thence contrived, than to expoſe that profeſſion unto the contempt of the ignorant vulgar.

Plin. Nat. l. 36. c. 26.

But his Scholar *Ariſtotle*, (as in many other particulars, ſo likewiſe in this) did juſtly oppoſe him, and became himſelf one of the firſt Authors that hath writ any methodical Diſcourſe concerning theſe arts; chuſing rather a certain and general benefit, before the hazard that might accrue from the vain and groundleſs diſreſpects of ſome ignorant perſons. Being ſo far from eſteeming Geometry diſhonoured by the applicati-

Ariſt. Quæſt. Mechan.

on of it to Mechanical practiſes, that he rather thought it to be thereby adorned, as with curious variety, and to be exalted unto its natural end. And whereas the Mathematicians of thoſe former ages, did poſſeſs all their learning, as covetous men do their wealth, only in thought and notion; the judicious *Ariſtotle*, like a wiſe Steward, did lay it out to particular uſe and improvement, rightly preferring the reallity and ſubſtance of publick benefit, before the ſhadows of ſome retired ſpeculation, or vulgar opinion.

Since him there have been divers other Authors, who have been eminent for their writings of this nature. Such were *Hero Alexandrinus*, *Hero Mechanicus*, *Pappus Alexandrinus*, *Proclus Mathematicus*, *Virtuvius*, *Guidus Ubaldus*, *Henricus Monantholius*, *Galileus*, *Guevara*, *Merſennus*, *Bettinus*, *&c.* Beſides many others, that have treated largely of ſeveral engines, as *Auguſtine Ramelli*, *Vittorio Zoncha*, *Jacobus Beſſonius*, *Vegetius*, *Lipſius*.

Moſt of which Authors I have peruſed, and ſhall willingly acknowledge my ſelf a debtor to them for many things in this following Diſcourſe.

CAP. II.

Concerning the name of this Art. That it may properly be ſtyled liberal. The ſubject and nature of it.

Lypſius. Polyorcet. l. 1. Dialog. 3.

That's a ſenſleſs abſurd Etymology impoſed by ſome, *Quia intellectus in eis mœchaſur*, as if theſe arts did proſtitute and adulterate the underſtanding.

THe word *Mechanick* is thought to be derived ἀπὸ τοῦ μήκους καὶ ἄνειν, *multum aſcendere, pertingere:* intimating the efficacy and force of ſuch inventions. Or elſe παρὰ μὴ χαίνειν (ſaith *Euſtathius*) *quia hiſcere non ſinit*, becauſe theſe arts are ſo full of pleaſant variety, that they admit not either of ſloth or wearineſs.

According to ordinary ſignification, the word is uſed in oppoſition to the liberal arts: whereas in propriety of ſpeech thoſe employments alone may be ſtyled *illiberal*, which require onely ſome bodily exerciſe, as manufactures, trades, &c. And on the con-

contrary, that discipline which discovers the general causes, effects, and properties of things, may truly be esteemed as a *species* of Philosophy.

But here it should be noted, that this art is usually distinguished into a twofold kind: *Pappus Proœm. in Collect. Mathem. l. 8.*

1. *Rational.*
2. *Cheirurgical.*

The *Rational* is that which treats of those principles and fundamental notions, which may concern these Mechanical practises.

The *Cheirurgical* or *Manual*, doth refer to the making of these instruments, and the exercising of such particular experiments. As in the works of Architecture, Fortifications, and the like.

The first of these, is the subject of this discourse, and may properly be stiled *liberal*, as justly deserving the prosecution of an ingenuous mind. For if we consider it according to its birth and original, we shall find it to spring from honourable parentage, being produced by *Geometry* on the one

one ſide, and *natural Philoſophy* on the other. If according to its uſe and benefit, we may then diſcern that to this ſhould be referred all thoſe arts and profeſſions ſo neceſſary for humane ſociety, whereby nature is not only directed in her uſual courſe, but ſometimes alſo commanded againſt her own law. The particulars that concern Architecture, Navigation, Husbandry, Military affairs, &c. are moſt of them reducible to this art, both for their invention and uſe.

Thoſe other diſciplines of Logick, Rhetorick, &c. do not more protect and adorn the mind, than theſe Mechanical powers do the body.

And therefore are they well worthy to be entertained with greater induſtry and reſpect, than they commonly meet with in theſe times; wherein there be very many that pretend to be maſters in all the liberal arts, who ſcarce underſtand any thing in theſe particulars.

The ſubject of this art is concerning the heavineſs of ſeveral bodies, or or the proportion that is required betwixt any weight, in relation to the power which may be able to move it. And ſo it refers likewiſe to violent and artifical motion, as Philoſophy doth to that which is natural.

The proper end for which this art is intended, is to teach how by underſtanding the true difference betwixt the *weight* and the *power*, a man may add ſuch a fitting ſupplement to the ſtrength of the power, that it ſhall be able to move any conceivable weight, though it ſhould never ſo much exceed that force which the power is naturally endowed with.

The art it ſelf may be thus deſcribed to be a Mathematical diſcipline, which by the help of Geometrical principles doth teach to contrive ſeveral weights and powers, unto any kind, either of motion or reſt, according as the Artificer ſhall determine.

If it be doubted how this may be eſteemed a *ſpecies* of Mathematicks, when as it treats of weights, and not of

Dav. Rivaltus præf. in lib. Archim. de centro gravitatis.

of quantity; For ſatisfaction to this, there are two particulars conſiderable.

1. *Mathematicks* in its latitude is uſually divided into *pure* and *mixed.* And though the *pure* do handle onely *abſtract quantity* in the *general*, as *Geometry, Arithmetick:* yet that which is *mixed* doth conſider the quantity of ſome *particular determinate* ſubject. So *Aſtronomy* handles the quantity of heavenly motions, *Muſick* of ſounds, and *Mechanicks* of weights & powers.

2. Heavineſs or weight is not here conſidered, as being ſuch a natural *quality*, whereby condenſed bodies do of themſelves *tend downwards*; but rather as being an affection, whereby they may be meaſured. And in this ſenſe *Ariſtotle* himſelf refers it amongſt the other *ſpecies* of *quantity*, as having the ſame proper eſſence, which is to be compounded of integral parts. So a pound doth conſiſt of ounces, drams, ſcruples. Whence it is evident, that there is not any ſuch repugnancy in the ſubject of this art, as may hinder it from being a true *ſpecies* of *Mathematicks.*

Metaph. l. 10. c. 2.

CAP.

CAP. III.

Of the first Mechanical faculty, the Ballance.

THE Mechanical faculties, by which the experiments of this nature must be contrived, are usually reckoned to be these six:

1. *Libra.*	1. *The Ballance.*
2. *Vectis.*	2. *The Leaver.*
3. *Axis in Peritrochio.*	3. *The Wheel.*
4. *Trochlea.*	4. *The Pulley.*
5. *Cuneus.*	5. *The Wedg.*
6. *Cochlea.*	6. *The Screw.*

Unto some of which, the force of all Mechanical inventions must necessarily be reduced. I shall speak of them severally and in this order.

First concerning the Ballance; this and the Leaver are usually confounded together, as being but one faculty, because the general grounds and proportions of either force is so exactly the same. But for better distinction, and

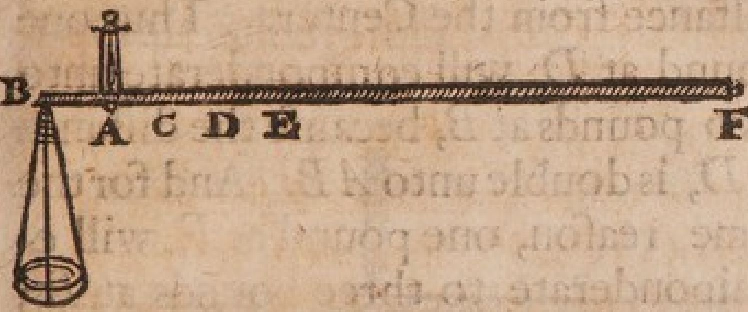
more

more clear diſcovery of their natures, I ſhall treat of them ſeverally.

The firſt invention of the ballance is commonly attributed to *Aſtrea*, who is therefore deified for the goddeſs of Juſtice; and that inſtrument it ſelf advanced amongſt the celeſtial ſigns.

The particulars concerning it are ſo commonly known, and of ſuch eaſie experiment, that they will not need any large explication. The chief end and purpoſe of it, is for the diſtinction of ſeveral ponderoſities; For the underſtanding of which, we muſt note, that if the length of the ſides in the Ballance, and the weights at the ends of them, be both mutually equal, then the Beam will be in a horizontal ſituation. But on the contrary, if either the weights alone be equal, and not their diſtances, or the diſtances alone, and not the weights, then the Beam will accordingly decline.

As in this following diagram.



Suppose an equal weight at *C*, unto that at *B*, (which points are both equally distant from the center *A*,) it is evident that then the beam *B F*, will hang horizontally. But if the weight supposed at *C*, be unequal to that at *B*, or if there be an equal weight at *D E*, or any of the other unequal distances; the Beam must then necessarily decline.

With this kind of Ballance, it is usual by the help only of one weight, to measure sundry different gravites, whether more or less than that by which they are measured. As by the example here described, a man may with one pound alone, weigh any other body within ten pounds, because the heaviness of any weight doth

Cardan, Subtil. l.1.

doth increaſe proportionably to its diſtance from the Center. Thus one pound at *D*, will equiponderate unto two pounds at *B*, becauſe the diſtance *A D*, is double unto *A B*. And for the ſame reaſon, one pound at *E*, will equiponderate to three pounds at *B*; and one pound at *F*, unto ten at *B*, becauſe there is ſtill the ſame diſproportion betwixt their ſeveral diſtances.

This kind of Ballance is uſually ſtyled *Romana*, *ſtatera*. It ſeems to be of ancient uſe, and is mentioned by *Ariſtotle* under the name of φάλαγξ.

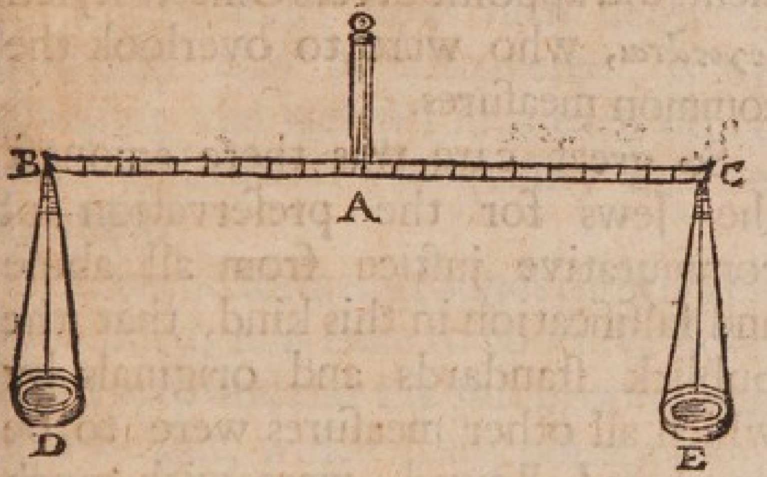
Mechan. ca. 21.

Hence it is eaſie to apprehend, how that falſe ballance may be compoſed, ſo often condemned by the wiſe man, as being an abomination to the Lord. If the ſides of the Beam be not equally divided, as ſuppoſe one have 10 parts, and the other 11, then any two weights that differ according to this proportion, (the heavier being placed on the ſhorter ſide, and the lighter on the longer) will equiponderate. And yet both the ſcales being empty, ſhall hang in *æquilibrio*,

Prov. 11.1 *ca.* 16.11. *Item. cap.* 20.10.23. *Pappus. Collect. Mathem. l.* 8.

as

as if they were exactly just and true, as in this description.



Suppose *AC*, to have 11 such parts, whereof *AB*, has but 10, and yet both of them to be in themselves of equal weight; it is certain, that whether the scales be empty, or whether in the scale *D*, we put 11 pound, and at *E* 10 pound, yet both of them shall equiponderate, because there is just such a disproportion in the length of the sides *AC*, being unto *AB*, as 11 to 10.

The frequency of such cozenages in these dayes, may be evident from common experience: and that they were used also in former ages, may

Quaestion. Mechan. c. 2. appear from *Aristotles* testimony concerning the Merchants in his time. For *Budaeus.* the remedying of such abuses the Ancients did appoint divers Officers styled *Hence the proverb Zygostatica fides.* ζυγοςάται, who were to overlook the common measures.

So great care was there amongst the Jews for the preservation of commutative justice from all abuse and falsification in this kind, that the publick standards and originals by which all other measures were to be tryed and allowed, were with much religion preserved in the Sanctuary, the care of them being committed to the Priests and Levites, whose office 1 Chron. 23. 29. it was to look unto *all manner of measures and size.* Hence is that frequent Exod. 30. 3. expression, *According to the shekel of the Sanctuary*; and that Law, *All thy* Lev. 27. 25 *estimations shall be according to the shekel of the Sanctuary*, which doth not refer to any weight or coin, distinct from, and more than the vulgar, (as some fondly conceive) but doth only oblige men in their dealing and traffique to make use of such

just

just meaſures,as were agreeable unto the publick ſtandards that were kept in the Sanctuary.

The manner how ſuch deceitful ballances may be diſcovered, is by changing the weights into each other ſcale, and then the inequality will be manifeſt.

From the former grounds rightly apprehended, it is eaſie to conceive how a man may find out the juſt proportion of a weight, which in any point given, ſhall equiponderate to ſeveral weights given, hanging in ſeveral places of the Beam.

Some of theſe ballances are made ſo exact, (thoſe eſpecially which the refiners uſe) as to be ſenſibly turned with the eightieth part of a grain: which (though it may ſeem very ſtrange) is nothing to what * *Capellus* relates of one at *Sedan*, that would turn with the four hundredth part of a grain.

There are ſeveral contrivances to make uſe of theſe in meaſuring the weight of blows, the force of powder,

Maſter *Greaves*, Roman foot.

* *De ponderibus & nummis*, *l.* 1.

the ſtrength of ſtrings, or other oblong ſubſtances, condenſed air, the diſtinct proportion of ſeveral metals mixed together, the different gravity of divers bodies in the water, from what they have in the open air, with divers the like ingenious inquiries.

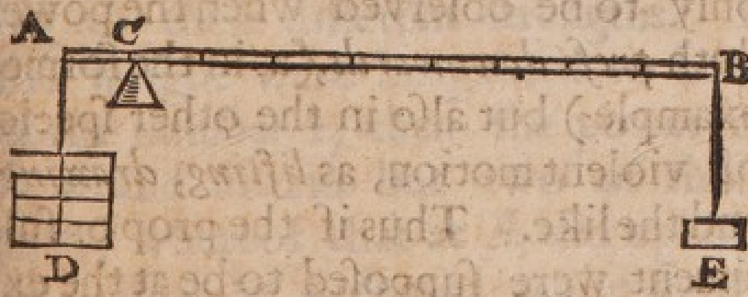
CAP. IV.

Concerning the ſecond Mechanick faculty, the Leaver.

THE ſecond Mechanical faculty, is the Leaver; the firſt invention of it is uſually aſcribed to *Neptune*, and repreſented by his Trident, which in the Greek are both called by one name, and are not very unlike in form, being both of them ſomewhat broader at one end, than in the other parts.

μόχλος. *Ariſtotle Quæſt. Mechan. cap. 4. Archimedes, de Æquiponderant. l. 1. prop. 7. Vitruvius Architect. l. 10 c. 8.*

There is one main principle concerning it, which is (as it were) the very ſum and epitome of this whole art. The meaning of it is thus expreſſed by *Ariſtotle*, ὃ τὸ κινούμενον βάρος πρὸς τὸ κινοῦν τὸ μῆκος πρὸς τὸ μῆκος ἀντιπέπονθεν. That is, is, as the weight is to an equivalent power, ſo is the diſtance betwixt the weight and the center, unto the diſtance betwixt the center and the power, and ſo reciprocally. Or thus, the power that doth equiponderate with any weight, muſt have the ſame proportion unto it, as there is betwixt their ſeveral diſtances from the center or fulciment: as in this following figure.



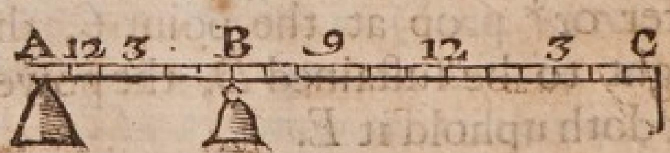
Where ſuppoſe the Leaver to be repreſented by the length *A B*, the center or* prop at the point *C*, the weight to be ſuſtained *D*, the power that doth uphold it *E*.

Now the meaning of the foreſaid principle doth import thus much, that the power at *E*, muſt bear the

* This *Ariſtotle* cals ὑπομόχλιον. *Vitruvius*. *Preſſio*. *Ubaldus*. *Fulcimentum*, *Dan. Barbarus*, *Scabellum*

ſame proportion to the weight *D*, as the diſtance *C A*, doth to the other *C B*; which, becauſe it is octuple in the preſent example, therefore it will follow that one pound at *B*, or *E*, will equiponderate to eight pounds at *A*, or *D*, as is expreſſed in the figure. The ground of which maxime is this, becauſe the point *C*, is ſuppoſed to be the center of gravity, on either ſide of which, the parts are of equal weight.

And this kind of proportion is not only to be obſerved when the power doth *preſs downwards*, (as in the former example) but alſo in the other ſpecies of violent motion, as *lifting*, *drawing*, and the like. Thus if the prop or fulciment were ſuppoſed to be at the extremity of the Leaver,

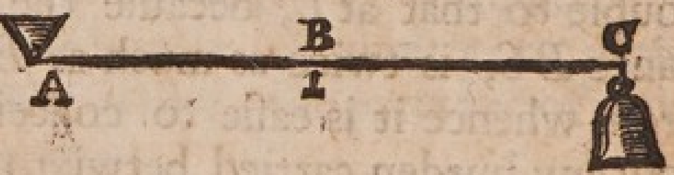


As in this Diagram at *A*, then the weight *B*, would require ſuch a diffe-rence in the ſtrengths or powers that did ſuſtain it, as there is betwixt the ſeveral diſtances *A C*, and *B C*. For as the diſtance *A B*, is unto *A C*, ſo is the power at *C*, to the weight at *B*; that is, the power at *A*, muſt be double to that at *C*, becauſe the di-ſtance *B C*, is twice as much as *B A*. From whence it is eaſie to conceive, how any burden carried betwixt two perſons, may be proportioned accord-ing to their different ſtrengths. If the weight were imagained to hang at the number 2, then the power at *C*, would ſuſtain but two of thoſe parts, whereof that at *A*, did uphold 16. If it be ſuppoſed at the figure (3) then the ſtrength at *C*, to that at *A*, would be but as three to fifteen. But if it were ſituated at the figure (9) then each of the extremities would participate of it alike, becauſe that being the middle, both the diſtances are equal. If at the number (12) then the ſtrength at *C*, is required to be

The right under-ſtanding of this doth much con-duce to the explicati-on of the Pulley.

double unto that at *A*. And in the like manner are we to conceive, of the other intermediate divſions.

Thus alſo muſt it be, if we ſuppoſe the power to be placed betwixt the fulciment and the weight, as in this example.



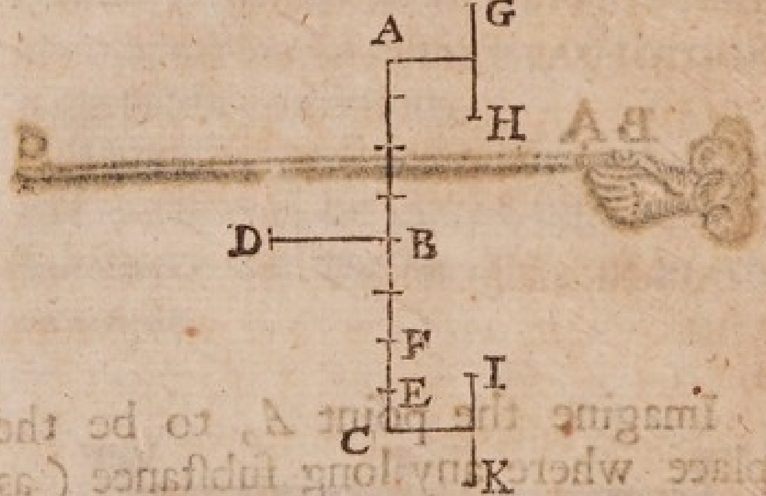
Where, as *AC*, is to *AB*, ſo is the power at *B*, to the weight at *C*.

Hence likewiſe may we conceive the reaſon why it is much harder to carry any long ſubſtance, either on the ſhoulders, or in the hand, if it be held by either of the extremes, than if it be ſuſtained by the middle of it. The ſtrength that muſt equiponderate at the nearer end, ſometimes increaſing the weight almoſt double to what it is in it ſelf.

Imagine the point *A*, to be the place where any long ſubſtance (as ſuppoſe a Pike) is ſuſtained, it is evident from the former principle, that the ſtrength at *B*, (which makes it lye level) muſt be equal to all the length *AC*, which is almoſt the whole Pike.

And as it is in the depreſſing, or elevating, ſo likewiſe is it in the drawing of any weight, as a Coach, Plow, or the like.

Let



Let the line *D B*, repreſent the Pole or Carriage on which the burden is ſuſtained, and the line *A C*, the croſs barre; at each of its extremities, there is a ſeveral ſpring-tree *G H*, and *I K*, to which either horſes or oxen may be faſtned. Now becauſe *A*, and *C*, are equally diſtant from the middle *B*, therefore in this caſe the ſtrength muſt be equal on both ſides; but if we ſuppoſe one of theſe ſpring-trees to be faſtned unto the points *E*, or *F*, then the ſtrength required to draw on that ſide, will be ſo much more, as the diſtance *E B*, or *F B*, is leſs than that of *A B*; that is, either as three or four, as *E B*, to

B A,

B A, or as one to two, as *F B*, to *B A*. So that the beaſt faſtned at *A*, will not draw ſo much by a quarter, as the other at *E*, and but half as much as one at *F*.

Whence it is eaſie to conceive how a husbandman (*cum inæquales veniunt ad aratra juvenci*) may proportion the labour of drawing according to the ſeveral ſtrength of his oxen.

Unto this Mechanical faculty ſhould be reduced ſundry other inſtruments in common uſe. Thus the oares, ſtearn, maſts, &c. according to their force, whereby they give motion to the ſhip, are to be conceived under this head.

Ariſt. Mechan. c. 5, 6, 7. *Vide Guevar. Comment.*

Thus likewiſe for that engine, whereby Brewers and Dyers do commonly draw water, which *Ariſtotle* calls κηλώνειον and others *Tollenon*. This being the ſame kind of Inſtrument, by which *Archimedes* drew up the ſhips of *Marcellus*.

Mechan. c. 29. *Pet. Crinitus, de honeſta Diſciplina l.* 19. *c.* 2. calls it corruptly *Tellenon*.

CAP.

CAP. V.

How the natural motion of living creatures is conformable to these artificial rules.

THE former Principle being already explained, concerning artificial and dead motions, it will not be altogether impertinent, if in the next place, we apply it unto those that are natural in living bodies, and examine whether these also are not governed by the same kind of proportions.

In all perfect living creatures, there is a twofold kind of motive instruments.

1. Primary, the muscles.
2. Secondary, the members.

The muscles are naturally fitted to be instruments of motion, by the manner of their frame and composure; consisting of flesh as their chief material, and besides of Nerves, Ligatures, Veins, Arteries, and Membrances.

The

The *Nerves* ſerve for the convey-ance of the motive faculty from the brain. The *Ligatures* for the ſtrength-ning of them, that they may not flag and languiſh in their motions. The *Veins* for their nouriſhment. The *Ar-teries* for the ſupplyiug of them with ſpirit, and natural vigor. The *Mem-brances* for the comprehenſion or in-cloſure of all theſe together, and for the diſtinction of one muſcle from another. There are beſides divers *fibræ* or hairy ſubſtances, which na-ture hath beſtowed for the farther corroborating of their motions; theſe being diſperſed through every muſcle, do ſo joyn together in the end of them, as to make intire nervous bo-dies, which are called *Tendones*, al-moſt like the griſles. Now this (ſaith *Galen*) may fitly be compared to the broader part of the Leaver, that is put under the weight, which, as it ought to be ſo much the ſtronger, by how much it is put to a greater force; ſo likewiſe by this doth na-ture inable the muſcles and nerves for

De Placit. Hippoc. & Platon. l. 1. ca. 10.

for thoſe motions, which otherwiſe would be too difficult for them.

Whence it may evidently appear, that according to the opinion of that eminent Phyſitian, theſe natural motions are regulated by the like grounds with the artificial.

2. Thus alſo is it in thoſe ſecondary inſtruments of motion, the members: amongſt which, the hand is ὄργανον ὀργάνων, the inſtrument of inſtruments (as *Galen* ſtyles it); and as the ſoul of man doth bear in it the image of the divine wiſdome and providence, ſo this part of the body ſeems in ſome ſort to repreſent the Omnipotency of God, whilſt it is able to perform ſuch various and wonderful effects by the help of this art. But now for its own proper natural ſtrength, in the lifting any great weight, this is always proportioned according to its extenſion from the body, being of leaſt force when it is fully ſtretched out, or at arms end, (as we ſay) becauſe then the ſhoulder joynt is as the center of

De uſu partium. l. 1. c. 2.

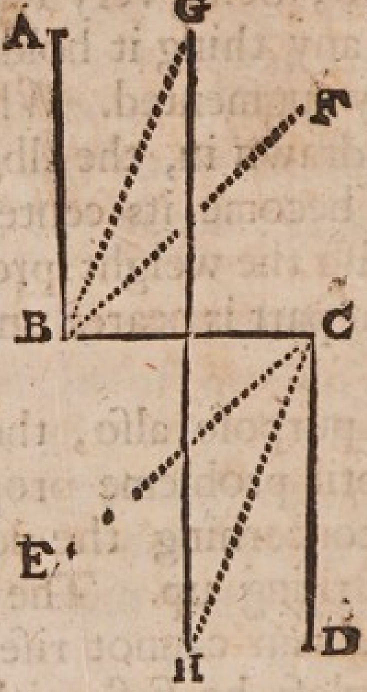
its

its motion, from which, the hand in that poſture, being very remote, the weight of any thing it holds muſt be accordingly augmented. Whereas the arm being drawn in, the elbow-joynt doth then become its center, which will diminiſh the weight proportionably, as that part is nearer unto it than the other.

To this purpoſe alſo, there is another ſubtil probleme propoſed by *Ariſtotle*, concerning the poſtures of ſitting and riſing up. The quære is this, Why a man cannot riſe up from his ſeat, unleſs he firſt, either bend his body forward, or thruſt his feet backward. *Mechan. c. 31.*

In the poſture of ſitting, our legs are ſuppoſed to make a right angle with our thighs, and they with our backs, as in this figure.

Where



Where let *AB*, repreſent the back, *BC*, the thighs, *CD*, the legs. Now it is evident, that a man cannot riſe from this poſture, unleſs either the back *AB*, do firſt incline unto *F*, to make an acute angle with the thighs *BC*; or elſe that the legs *CD*, do incline towards *E*, which may alſo make an acute angle with the thighs *BC*; or laſtly, unleſs both of them do decline to the points *GH*, where they may be included in the ſame perpendicular.

For

For the reſolution of which, the Philoſopher propoſes theſe two particulars.

1. A right angle (ſaith he) is a kind of equality, and that being naturally the cauſe of reſt, muſt needs be an impediment to the motion of riſing.

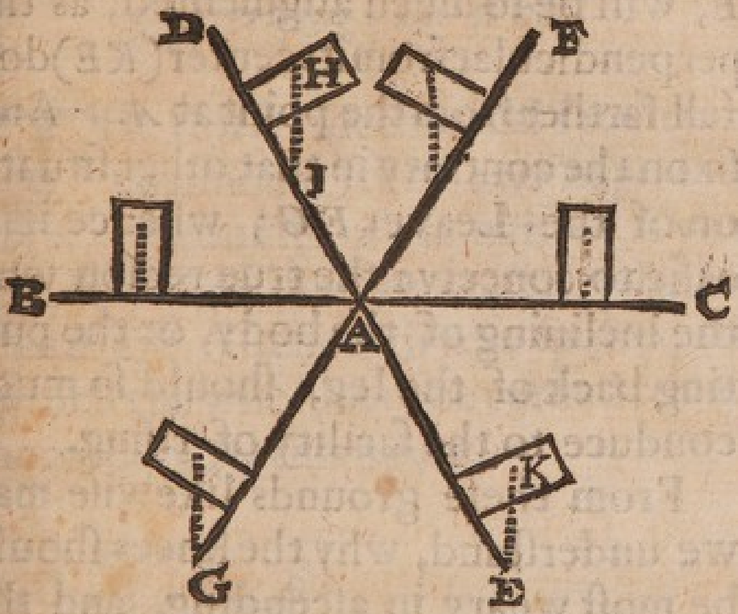
2. Becauſe when either of the parts are brought into an acute angle, the head being removed over the feet, or they under the head; in ſuch a poſture the whole man is much nearer diſpoſed to the form of ſtanding, wherein all theſe parts are in one ſtreight perpendicular line, than he is by the other of right angles, in which the back and legs are two parallels; or that of turning theſe ſtreight angles into obtuſe, which would not make an erect poſture, but declining.

But neither of theſe particulars (as I conceive) doe fully ſatisfie the preſent quære, neither do the Commentators, *Monantholius*, or *Guevara*, better reſolve it. Rather ſuppoſe *B C*, to be as a Vectis or Leaver, towards the middle of which is the place of the fulciment, *A B*, as the weight, *C D*, the power that is to raiſe it.

Now the body being ſituate in this rectangular form, the weight *A B*, muſt needs be augmented proportionably to its diſtance from the fulciment, which is about half the thighs; whereas if we ſuſpoſe either the weight to be inclined unto *F*, or the power to *E*, or both of them to *G H*, then there is nothing to be lifted up but the bare weight it ſelf, which in this ſituation is not at all increaſed with any addition by diſtance.

For in theſe concluſions concerning the Leaver, we muſt always imagine that point which is touched by a perpendicular from the center of gravity, to be one of the terms. So that the diverſe elevation or depreſſion of the inſtrument, will infer a great alteration in the weight it ſelf, as may more clearly be diſcerned by this following Diagram.

Where



Where *A*, is ſuppoſed to be the place of the prop or fulciment, *B C*, a Leaver which ſtands horizontally, the power and the weight belonging unto it, being equal both in themſelves, and alſo in their diſtances from the prop.

But now ſuppoſe this inſtrument to be altered according to the ſituation *D E*, then the weight *D*, will be diminiſhed, by ſo much, as the perpendicular from its center of gravity *H I*, doth fall nearer to the prop or fulciment at *A*. And the power at *E*, will be ſo much augmented, as the perpendicular from its center (*KE*) do's fall farther from the point at *A*. And ſo on the contrary in that other ſituation of the Leaver *F G*; whence it is eaſie to conceive the true reaſon, why the inclining of the body, or the putting back of the leg, ſhould ſo much conduce to the facility of riſing.

Sir *Fran Bacons Nat. Hiſt. Exp.* 731.

From theſe grounds likewiſe may we underſtand, why the knees ſhould be moſt weary in aſcending, and the thighs in deſcending; which is becauſe the weight of the body doth bear moſt upon the knee-joynts, in raiſing it ſelf up, and moſt upon the muſcles of the thighs when it ſtays it ſelf in coming down.

There are divers other natural problemes to this purpoſe, which I forbear to recite. We do not ſo much as go, or ſit, or riſe, without the uſe of this Mechanical Geometry.

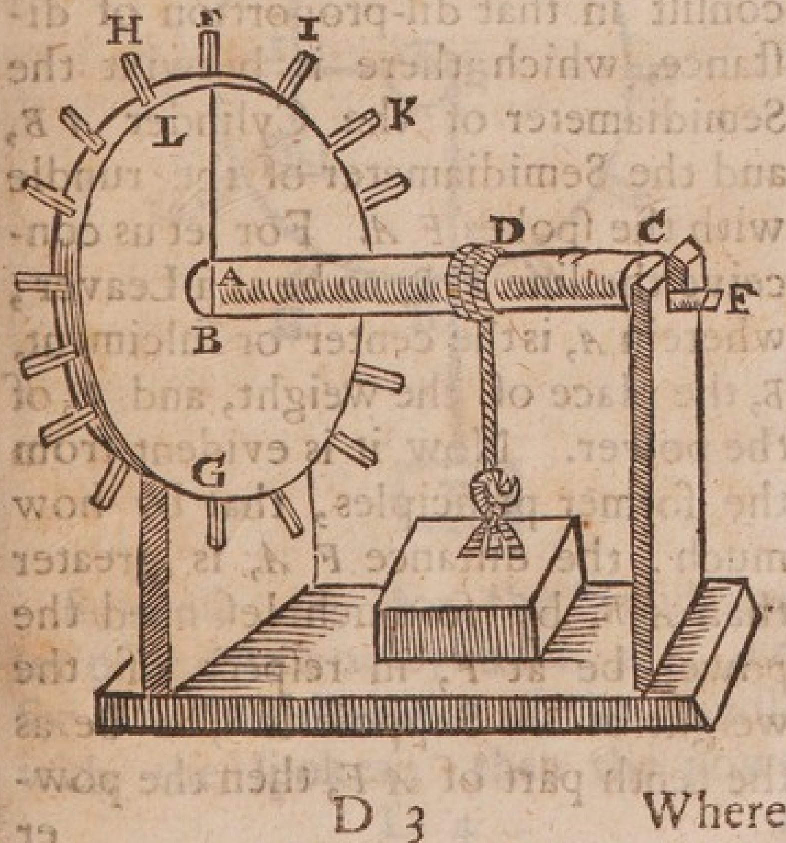
CAP.

CAP. VI.

Concerning the Wheel.

THe third Mechanical faculty is commonly ſtiled *axis in peritrochio.* It conſiſts of an axis or Cylinder, having a rundle about it, wherein there are faſtened divers ſpokes, by which the whole may be turned round; according to this figure.

Called likewiſe ὄνος *Ariſt. Mechan. c.* 14.



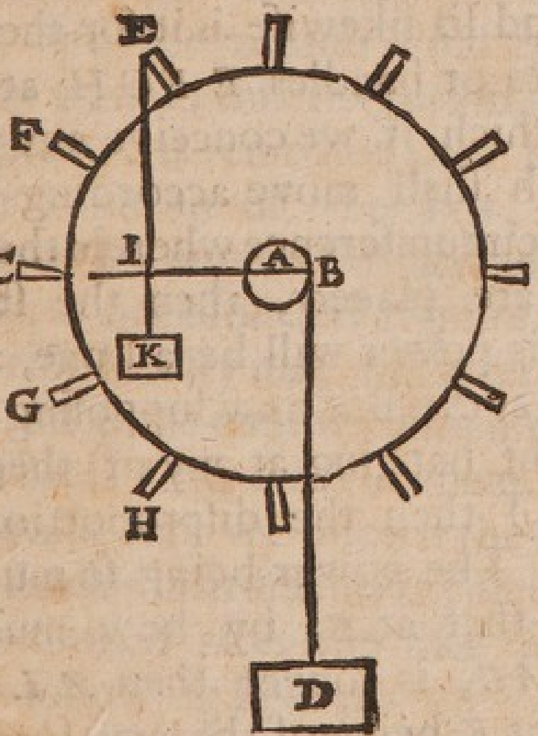
Where *B C*, does repreſent the Cylinder which is ſuppoſed to move upon a ſmaller Axis at *E*, (this being all one in compariſon to the ſeveral proportions, as if it were a meer Mathematical line) *L G*, is the rundle or wheel, *H F I K*, ſeveral ſpokes or handles that are faſtned in it; *D*, the place where the cord is faſtned for the drawing or lifting up of any weight.

The force of this inſtrument doth conſiſt in that diſ-proportion of diſtance, which there is betwixt the Semidiameter of the Cylinder *A B*, and the Semidiameter of the rundle with the ſpokes *F A*. For let us conceive the line *F B*, to be as a Leaver, wherein *A*, is the center or fulciment, *B*, the place of the weight, and *F*, of the power. Now it is evident from the former principles, that by how much, the diſtance *F A*, is greater than *A B*, by ſo much leſs need the power be at *F*, in reſpect of the weight at *B*. Suppoſe *A B*, to be as the tenth part of *A F*, then the pow-

er

er or ſtrength: which is but as a hundred pound at *F*, will be equal to a thouſand pound at *B*.

For the clearer explication of this faculty, it will not be amiſs to conſider the form of it, as it will appear being more fully expoſed to the view. As in this other Diagram.



Suppoſe *AB*, for the Semidiameter of the Axis or Cylinder, and *AC*, for the Semidiameter of the rundle, with the ſpokes; then the power at *C*, which will be able to ſupport the weight *D*, muſt bear the ſame proportion unto it, as *A B*, doth to *A C*; ſo that by how much ſhorter the diſtance *A B*, is in compariſon to the diſtance *A C*, by ſo much leſs need the power be at *C*, which may be able to ſupport the weight *D*, hanging at *B*.

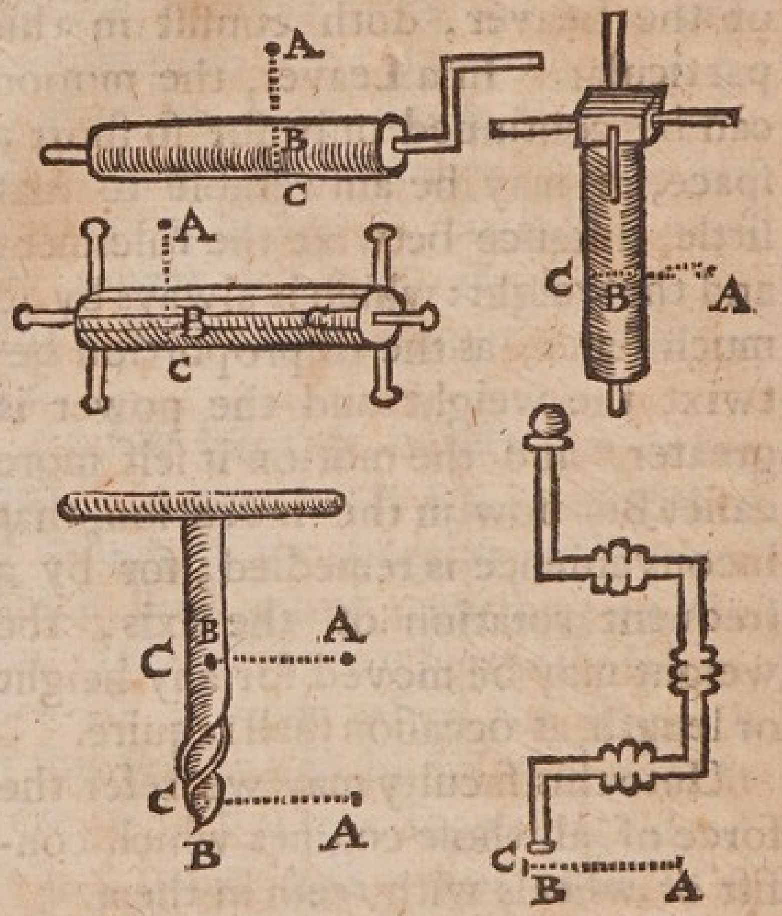
And ſo likewiſe is it for the other ſpokes or handles *E F G H*, at either of which, if we conceive any power, which ſhall move according to the ſame circumference wherein theſe handles are placed, then the ſtrength of this power will be all one, as if it were at *C*. But now ſuppoſing a dead weight hanging at any of them, (as at *E*,) then the diſproportion will vary. The power being ſo much leſs than that at *C*, by how much the line *A C*, is longer then *A I*. The weight *K*, being of the ſame force at *E*, as if it were hung at *I*, in which point the perpendicular of its gravity doth cut the Diameter.

The chief advantage which this in-

inſtrument doth beſtow, above that of the Leaver, doth conſiſt in this particular. In a Leaver, the motion can be continued only for ſo ſhort a ſpace, as may be anſwerable to that little diſtance betwixt the fulciment and the weight: which is always by ſo much leſſer, as the diſproportion betwixt the weight and the power is greater, and the motion it ſelf more eaſie. But now in this invention, that inconvenience is remedied; for by a frequent rotation of the axis, the weight may be moved for any height or length, as occaſion ſhall require.

Unto this faculty may we refer the force of all thoſe engines which conſiſt of wheels with teeth in them.

Hence alſo may we diſcern the reaſon why ſundry inſtruments in common uſe, are framed after the like form with the following figures.



All which are but ſeveral kinds of this third Mechanical faculty. In which the points *A B C*, do repreſent the places of the power, the fulciment, and the weight. The power being in the ſame proportion unto the weight, as *B C* is unto *B A*.

CAP.

CAP. VII.

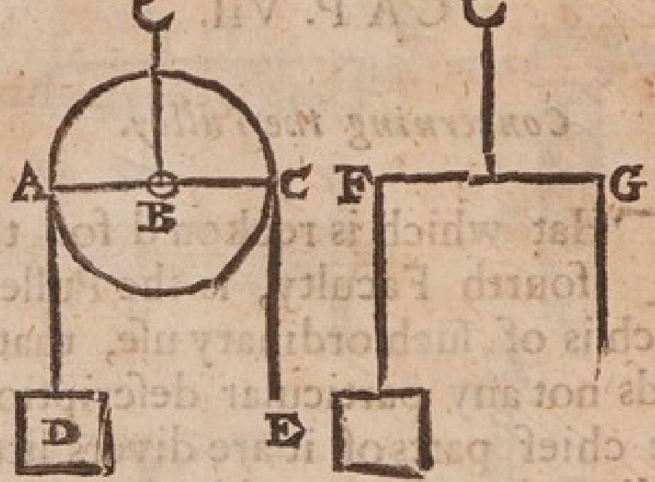
Concerning the Pulley.

THat which is reckon'd for the fourth Faculty, is the Pulley: which is of ſuch ordinary uſe, that it needs not any particular deſcription. The chief parts of it are divers little rundles, that are movable about their proper axes. Theſe are uſually divided according to their ſeveral ſituations, into the upper and lower. If an engine have two of theſe rundles above, and two below, it is uſually called δίσπαστος, if three τρίσπαστος, if many, πολύσπαστος.

Ariſt. Mechan. c.19.

The lower Pulleys only do give force to the motion. If we ſuppoſe a weight to hang upon any of the upper rundles, it will then require a power, that in it ſelf ſhall be fully equal for the ſuſtaining of it.

The



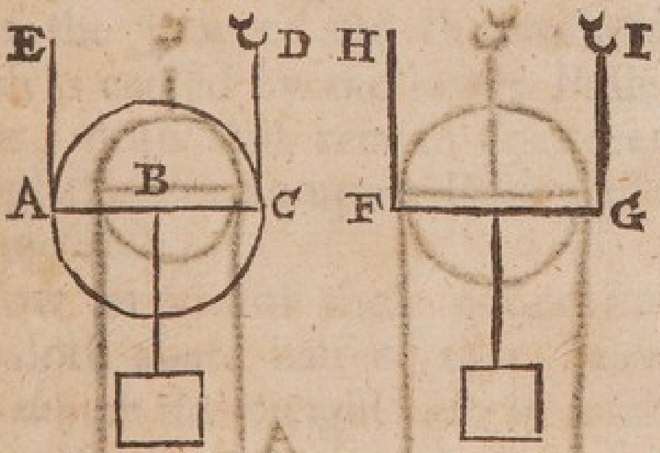
The Diameter *AC*, being as the beam of a ballance, of which *B* is the prop or center. Now the parts *A*, and *C*, being equally diſtant from this center, therefore the power at *E*, muſt be equal to the weight at *D*, it being all one as if the power and the weight were faſtned by two ſeveral ſtrings at the ends of the ballance *F G*.

Now all the upper Pulleys being of the ſame nature, it muſt neceſſarily follow, that none of them do in themſelves conduce to the eaſing of the power, or lightning the weight, but only for the greater convenien-

cy

cy of the motion, the cords by this means being more eaſily moved than otherwiſe they would.

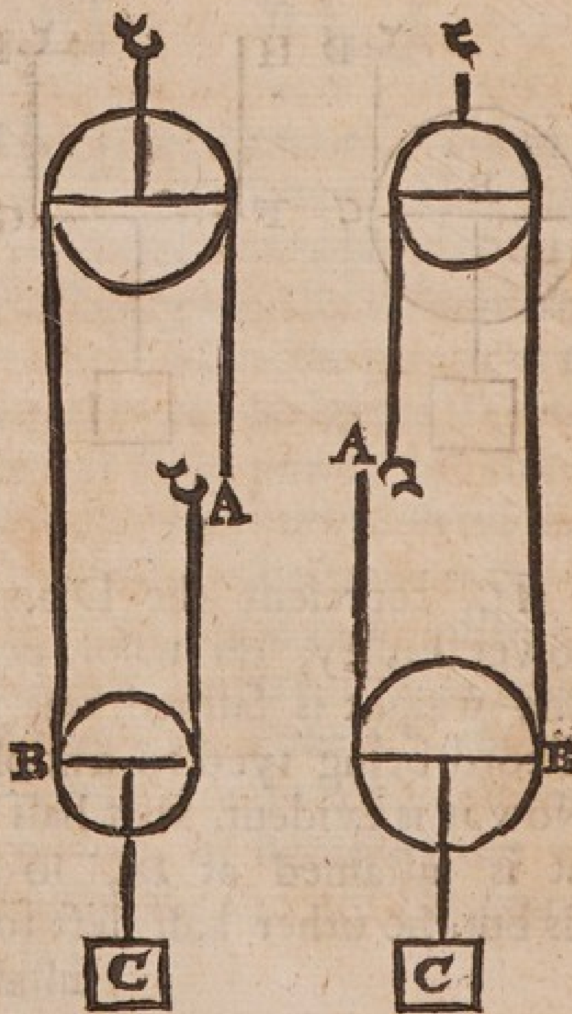
But now ſuppoſe the weight to be ſuſtained above the Pulley, as it is in all thoſe of the lower ſort; and then the power which ſupports it, need be but half as much as the weight it ſelf.



Let *A C*, repreſent the Diameter of a lower Pulley, on whoſe center at *B*. the weight is faſtned, one end of the cord being tyed to a hook at *D*. Now it is evident, that half the weight is ſuſtained at *D*, ſo that there is but the other half left to be ſuſtained

ſuſtained by the power at *E*. It being all one as if the weight were tyed unto the middle of the ballance *F G*, whoſe ends were upheld by two ſeveral ſtrings, *F H*, and *G I*.

And this ſame ſubduple proportion will ſtill remain, though we ſuppoſe an upper Pulley joyned to the lower, as in theſe two other figures.



Where the power at *A*, is equal to the weight at *B*: Now the weight at *B*, being but half the ponderoſity *C*, therefore the power at *A*, notwithſtanding the addition of the upper rundle, muſt be equivalent to half the weight; and as the upper Pulley alone doth not abate any thing of the weight, ſo neither being joined with the lower, and the ſame ſubduple difference betwixt the power and the weight, which is cauſed by the lower Pulley alone, doth ſtill remain unaltered, though there be an upper Pulley added unto it.

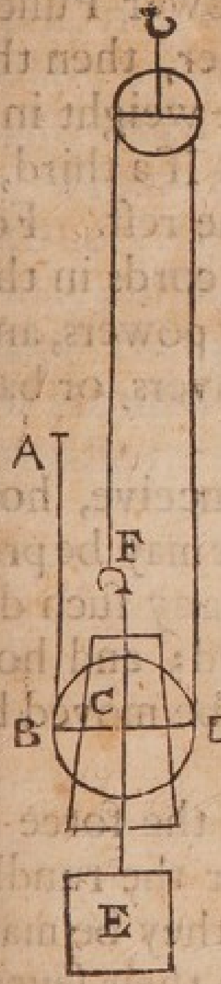
Now as one of theſe under Pulleys doth abate half of that heavineſs which the weight hath in it ſelf, and cauſe the power to be in a ſubduple proportion unto it, ſo two of them do abate half of that which remains, and cauſe a ſubquadruple proportion, betwixt the weight and the power; three of them a ſubſextuple, four a ſuboctuple: and ſo for five, or ſix, or as many as ſhall be required, they will all of them diminiſh the

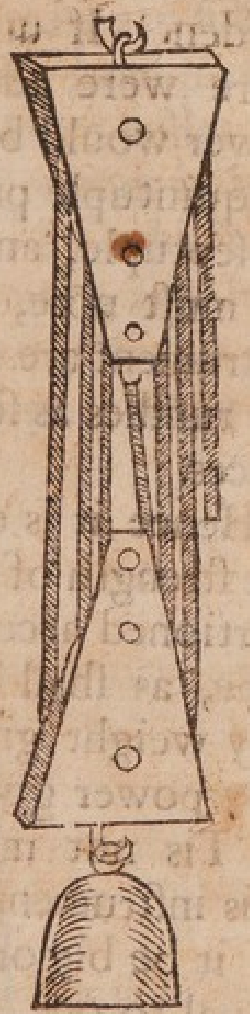
the weight according to this proportion.

Suppoſe the weight in it ſelf to be 1200 pound, the applying unto it one of theſe lower Pulleys, will make it but as 600, two of them as 300, three of them as 150, &c.

But now, if we conceive the firſt part of the ſtring to be faſtened unto the lower Pulley, as in this other figure at *F* ;

then





then the power at *A*, will be in a sub-triple proportion to the weight *E*, because the heavinesſ would be then equally divided unto the three points of the lower Diameter *B*, *C*, *D*, each of them ſupporting a like ſhare of the burden. If unto this lower Pulley there were added another, then the power would be unto the weight in a ſubquintuple proportion. If a third, a ſubſeptuple, and ſo of the reſt. For we muſt note, that the cords in this inſtrument are as ſo many powers, and the rundles as ſo many leavers, or bal-lances.

Hence it is eaſie to conceive, how the ſtrength of the power may be pro-portioned according to any ſuch de-gree, as ſhall be required; and how any weight given, may be moved by any power given.

'Tis not material to the force of this inſtrument, whether the rundles of it be big or little, if they be made equal to one another in their ſeveral orders; But it is moſt convenient, that the upper ſhould each of them increaſe as they are higher, and the other as they are lower, becauſe by this means the cords will be kept from tangling.

Theſe Pulleys may be multiplied ac-

according to ſundry different ſituations, not only when they are ſubordinate, as in the former examples, but alſo when they are placed collaterally.

From the former grounds it is eaſie to contrive a ladder, by which a man may pull himſelf up unto any height. For the performance of this, there is required only an upper and a lower rundle:

To

To the uppermoſt of theſe at *A*, there ſhould be faſtned a ſharp graple or cramp of iron, which may be apt to take hold of any place where it lights. This part being firſt caſt up and faſtned, and the ſtaff *DE*, at the nether end, being put betwixt the legs, ſo that a man may ſit upon the other *BC*, and take hold of the cord at *F*, it is evident that the weight of the perſon at *E*, will be but equal to half ſo much ſtrength at *F*; ſo that a man may eaſily pull himſelf up to the place required, by leaning but little more than half of his own weight on the ſtring *F*. Or if the Pulleys be multiplyed, this experiment may then be wrought with leſs labour.

CAP. VIII.

Of the Wedge.

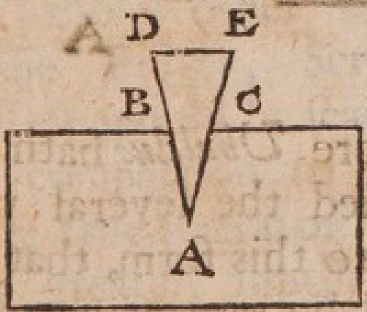
THE fift Mechanical faculty is the Wedge, which is a known inſtrument, commonly uſed in the cleaving

ving of wood. The efficacy and great ſtrength of it may be reſolved unto theſe two particulars:

1. The form of it.

2. The manner whereby the power is impreſſed upon it, which is by the force of blows.

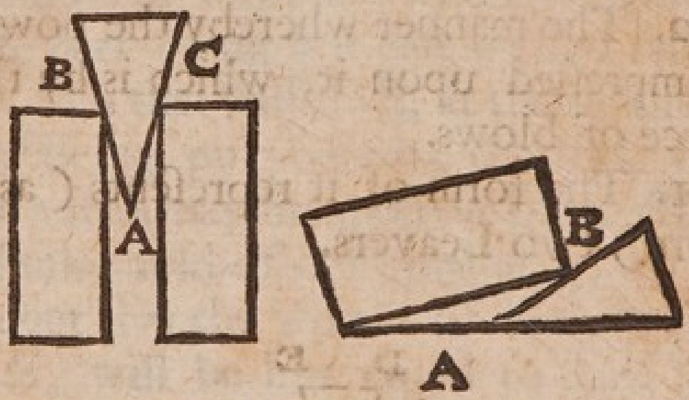
1. The form of it repreſents (as it were) two Leavers.



Each ſide *AD*, and *AE*, being one, the points *B C*, being inſtead of ſeveral props or fulciments; the weight to be moved, at *A*, and the power that ſhould move it, being applyed to the top *DE*, by the force of ſome ſtroak or blow, as *Ariſtotle* hath explained the ſeveral parts of this faculty. But now, becauſe this inſtrument may be ſo uſed that the

Mechan. c. 8.

point of it ſhall not touch the body to be moved, as in theſe other figures :



Therefore *Ubaldus* hath more exactly applied the ſeveral parts of it according to this form, that the point *A*, ſhould be as the common fulciment, in which both the ſides do meet, and (as it were) uphold one another ; the points *B*, and *C*, repreſenting that part of the Leavers where the weight is placed.

It is a general rule, that the more acute the angles of theſe wedges are, by ſo much more eaſie will their motion be ; the force being more eaſily impreſſed, and the ſpace wherein the body is moved, being ſo much the leſs.

The

The ſecond particular whereby this faculty hath its force, is the *manner* whereby the power is impreſt upon it, which is by a ſtroke or blow; the efficacy of which doth much exceed any other ſtrength. For though we ſuppoſe a wedge being laid on a peice of timber, to be preſſed down with never ſo great a weight; nay, though we ſhould apply unto it the power of thoſe other Mechanical engines, the Pulley, Screw, &c. yet the effect would be ſcarce conſiderable in compariſon to that of a blow. The true reaſon of which, is one of the greateſt ſubtilties in nature; nor is it fully rendred by any of thoſe who have undertaken the reſolution of it. *Ariſtotle*, *Cardan*,* and *Scaliger*, do generally aſcribe it unto the ſwiftneſs of that motion; But there ſeems to be ſomething more in the matter than ſo; for otherwiſe it would follow that the quick ſtroak of a light hammer, ſhould be of greater efficacy, than any ſofter and more gentle ſtriking of a great

* *Mecan. c.* 13. *Subtil. l.* 17 *Exercit.* 331.

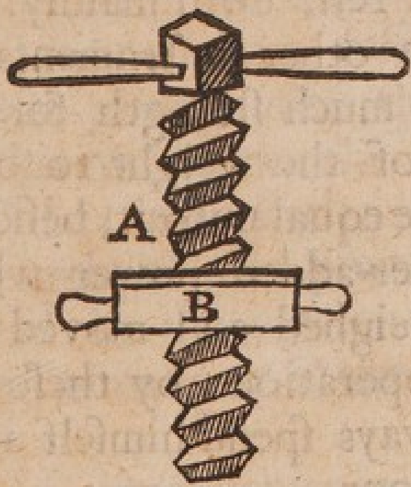
ſledge. Or according to this, how ſhould it come to paſs, that the force of an arrow or bullet diſcharged near at hand (when the impreſſion of that violence, whereby they are carried, is moſt freſh, and ſo in probability the motion at its ſwifteſt) is yet notwithſtanding much leſs than it would be at a greater diſtance? There is therefore further conſiderable, the quality of that inſtrument by which this motion is given, and alſo the conveniency of diſtance through which it paſſes.

Unto this faculty is uſually reduced the force of files, ſaws, hatchets, &c. which are as it were but ſo many wedges faſtned unto a Vectis or Leaver.

CAP. IX.
Of the Screw.

THat which is uſually recited for the ſixth and laſt Mechanick faculty, is the Screw, which is deſcribed to be a kind of wedge that is multiplied

plied, or continued by a helical revolution about a Cylinder, receiving its motion not from any ſtroak, but from a Vectis at one end of it. It is uſually diſtinguiſhed into two ſeveral kinds: the male, which is meant in the former deſcription; and the female, which is of a concave ſuperficies. *Pappus: Collect. Mathemat. lib.* 8.



The former is noted in the figure with the letter *A*, the other with *B*.

Ariſtotle himſelf doth not ſo much as mention this inſtrument, which yet notwithſtanding is of greater force and ſubtilty, than any of the reſt. It is chiefly applied to the ſqueezing or preſſing of things downwards,

wards, as in the preſſes for Printing, for wine, oyl, and extracting the juice from other fruits. In the performance of which, the ſtrength of one man may be of greater force, than the weight of a heavy mountain: It is likewiſe uſed for the elevating or lifting up of weights.

The advantage of this faculty above the reſt, doth mainly conſiſt in this: the other inſtruments doe require ſo much ſtrength for the ſupporting of the weight to be moved, as may be equal unto it, beſides that other ſuper-added power whereby it is out-weighed and moved; ſo that in the operations by theſe, a man does always ſpend himſelf in a continued labour.

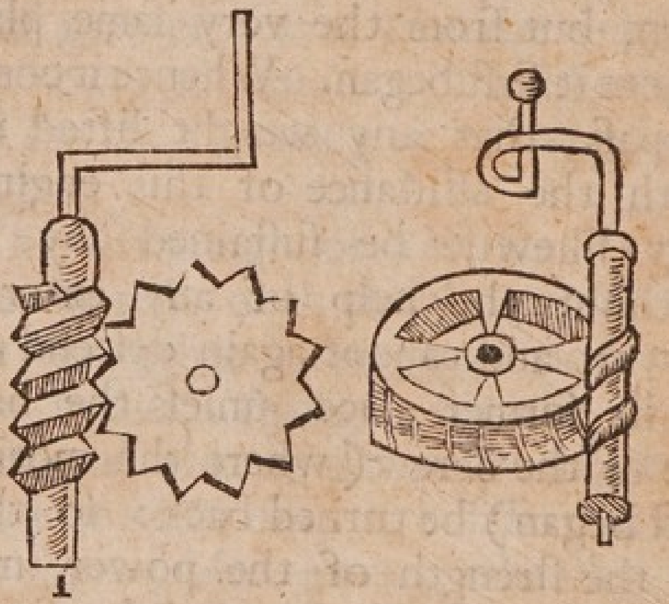
Thus (for example) a weight that is lifted up by a Wheel or Pulley, will of it ſelf deſcend, if there be not an equal power to ſuſtain it. But now in the compoſure of a Screw, this inconvenience is perfectly remedied; for ſo much force as is communicated unto this faculty, from the power

power that is applied unto it; is ſtill retained by the very frame and nature of the inſtrument it ſelf; ſince the motion of it cannot poſſibly return, but from the very ſame place where it firſt began. Whence it comes to paſs, that any weight lifted up, with the aſſiſtance of this engine, may likewiſe be ſuſtained by it, without the help of any external power, and cannot again deſcend unto its former place, unleſs the handle of the Screw (where the motion firſt began) be turned back: ſo that all the ſtrength of the power, may be imployed in the motion of the weight, and none ſpent in the ſuſtaining of it.

The chief inconvenience of this inſtrument is, that in a ſhort ſpace it will be ſcrewed unto its full length, and then it cannot be of any further uſe for the continuance of the motion, unleſs it be returned back, and undone again as at the firſt. But this is uſually remedied by another invention, commonly ſtyled a *perpe-*

tual

tual ſcrew, which hath the *motion* of a *wheel*, and the *force* of a *ſcrew*, being both infinite.



For the compoſure of which, inſtead of the female, or concave ſcrew, there muſt be a little wheel, with ſome notches in it, equivalent to teeth, by which the other may take hold of it, and turn it round, as in theſe other figures.

It is uſed in ſome Watches.

This latter engine does ſo far exceed all other contrivances to this purpoſe, that it may juſtly ſeem a wonder why it is not of as common uſe

use in these times and places, as any of the rest.

CAP. X.

An enquiry into the magnificent works of the Ancients, which much exceeding our later times, may seem to infer a decay in these Mechanical Arts.

THus have I briefly treated concerning the general principles of Mechanicks, together with the distinct proportions betwixt the weight and the power in each several faculty of it; Whence it is easie to conceive the truth and ground of those famous ancient monuments, which seem almost incredible to these following ages. And because many of them recorded by Antiquity, were of such vast labour and magnificence, and so mightily disproportionable to humane strength, it shall not therefore be impertinent unto the purpose I aim at, for to specifie some of of the moſt remarkable amongſt them, and to enquire into the means and occaſion upon which they were firſt attempted.

Amongſt the *Ægyptians*, we read of divers Pyramids, of ſo vaſt a magnitude, as time it ſelf in the ſpace of ſo many hundred years hath not yet devoured. *Herodotus* mentions one of them, erected by *Cleopes* an Ægyptian King, wherein there was not any one ſtone leſs than 30 foot long, all of them being fetched from *Arabia*. And not much after, the ſame Author relates, how *Amaſis* another Ægyptian, made himſelf a houſe of one entire ſtone, which was 21 cubits long, 14 broad, and 8 cubits high. The ſame *Amaſis* is reported to have made the ſtatue of a *Sphinx*, or Ægyptian Cat, all of one ſingle ſtone, whoſe length was 143 foot, its height 62 foot, the compaſs of this ſtatues head containing 102 foot. In one of the Ægyptian Temples conſecrated to *Jupiter*, there is related to be an Obelisk, conſiſting of 4 Smaragds

L.2.c.175

Plin. l. 36. ca. 12.

Plin. l. 37. cap. 5.

or

or Emeralds; the whole is 40 cubits high, 4 cubits broad at the bottom, and two at the top. *Seſoſtris* the King of *Ægypt* in a temple at *Memphis*, dedicated to *Vulcan*, is reported to have erected two ſtatues, one for himſelf, the other for his wife, both conſiſting of two ſeveral ſtones, each of which were 30 cubits high. *Diodor Sicul. Biblioth. l. 1. Sect. 2.*

Amongſt the Jews we read in ſacred Writ of *Solomons* Temple, which for its ſtate and magnificence might have been juſtly reckoned amongſt the other wonders of the world, wherein beſides the great riches of the materials, there were works too of as great labour. Pillars of braſs 18 cubits high, and 12 cubits round; great and coſtly ſtones for the foundation of it; *Joſephus* tells us, that ſome of them were 40 cubits, others 45 cubits long. And in the ſame Chapter he mentions the three famous Towers built by *Herod*, wherein every ſtone being of white marble, was 20 cubits long, 10 broad, and 5 high. And which was the greateſt won- 1 Kings 2. 15. cap. 5. v. 17. *De bello Juda. l. 6. c. 6.*

wonder, the old wall it ſelf was ſituated on a ſteep riſing ground, and yet the hills upon it, on the tops of which theſe Towers were placed, were about 30 cubits high, that 'tis ſcarce imaginable by what ſtrength ſo many ſtones of ſuch great magnitude ſhould be conveyed to ſo high a place.

Plin. l. 36. c. 14. Panciroll. Deperd. Tit. 32.

Amongſt the *Grecians* we read of the *Epheſian* Temple dedicated to *Diana*, wherein there were 127 columns, made of ſo many ſeveral ſtones, each of them 60 foot high, being all taken out of the quarries in *Aſia*. 'Tis ſtoried alſo of the brazen *Coloſſus*, or great Statue in the Iſland of *Rhodes*, that it was 70 cubits high. The thumbs of it being ſo big that no man could graſp one of them about with both his arms; when it ſtood upright, a ſhip might have paſſed betwixt the legs of it, with all its ſails fully diſplayed; being thrown down by an earth-quake, the braſs of it did load 900 Camels. But above all ancient deſigns to this purpoſe, that would have been moſt wonder-

Plin. l. 34. c. 3.

wonderful, which a Grecian Architect did propound unto *Alexander*, to cut the Mountain *Athos* into the form of a ſtatue, which in his right hand ſhould hold a Town capable of ten thouſand men, and in his left a Veſſel to receive all the water that flowed from the ſeveral ſprings in the Mountain. But whether *Alexander* in his ambition did fear that ſuch an Idol ſhould have more honour than he himſelf, or whether in his good husbandry, he thought that ſuch a *Microcoſme* (if I may ſo ſtyle it) would have coſt him almoſt as much as the conquering of this great world, or what ever elſe was the reaſon, he refuſed to attempt it. *Vitruv. Archit. l. 2.*

Amongſt the *Romans* we read of a brazen *Coloſſus*, made at the command and charges of *Nero*, which was 120 foot high; *Martial* calls it *Sydereus*, or ſtarry. *Suet. Ner.*

Hic ubi Sydereus proprius videt aſtra Coloſſus. And it is ſtoried of *M. Curio*, that he erected two *Theaters* ſuffici- *Pancirol. Deperd. Tit. 18.*

ently capacious of people, contrived movable upon certain hinges; Sometimes there were ſeveral plays and ſhows in each of them, neither being any diſturbance to the other; and ſometimes they were both turned about, with the people in them, and the ends meeting together, did make a perfect *Amphitheater:* ſo that the ſpectators which were in either of them, might joyntly behold the ſame ſpectacles.

*ae. Tit.*31. There were beſides at *Rome* ſundry *Obelisks*, made of ſo many intire ſtones, ſome of them 40, ſome 80, and others 90 cubits high. The chief of them were brought out of Ægypt, where they were dug out of divers quarries, and being wrought into form, were afterward (not without incredible labour, and infinite charges) conveyed unto *Rome*. In the year 1586, there was erected an old *Obelisk*, which had been formerly dedicated unto the memory of *Julius Cæſar*. It was one ſolid ſtone, being an Ophite or kind of ſpotted Marble. The height of it was 107 foot, the breadth of it

at

at the bottome was 12 foot, at the top 8. Its whole weight is reckoned to be 956148 pounds, besides the heavinesse of all those instruments that were used about it, which (as it is thought) could not amount to less then 1042824 pounds. It was transplaced at the charges of Pope *Sixtus* the fifth, from the left side of the *Vatican*, unto a more eminent place about a hundred foot off, where now it stands. The moving of this *Obelisk* is celebrated by the writings of above 56 several Authors, (saith *Monantholius*) all of them mentioning it, not without much wonder and praise. Now if it seem so strange and glorious an attempt to move this *Obelisk* for so little a space, what then may we think of the carriage of it out of *Egypt*, and divers other far greater works performed by Antiquity? This may seem to infer, that these Mechanical arts are now lost, and decayed amongst the many other ruins of time; which yet notwithstanding cannot be granted, without much ingrati-

Comment. in Mechan. Arist. c. 19.

tude to thoſe learned men, whoſe labours in this kind we enjoy, and may juſtly boaſt of. And therefore for our better underſtanding of theſe particulars, it will not be amiſs to enquire both *why*, and *how*, ſuch works ſhould be performed in thoſe former and ruder ages, which *are not*, and (as it ſhould ſeem) *cannot* be effected in theſe later and more learned times. In the examination of which, we ſhall find that it is not the want of art that diſables us for them, ſince theſe Mechanical diſcoveries are altogether as perfect, and (I think) much more exact now, than they were heretofore; but it is, becauſe we have not either the ſame *motives* to attempt ſuch works, or the ſame *means* to effect them as the Ancients had.

CAP.

CAP. XI.

That the Ancients had divers motives *and* means *for ſuch vaſt magnificent works, which we have not.*

THE *motives* by which they were excited to ſuch magnficent attempts, we may conceive to be chiefly three.

- *Religion.*
- *Policy.*
- *Ambition.*

1. *Religion.* Hence was it that moſt of theſe ſtately buildings were intended for ſome ſacred uſe, being either Temples or * Tombs, all of them dedicated to ſome of their Deities. It was an in-bred principle in thoſe ancient Heathen, that they could not chuſe but merit very much by being liberal in their outward ſervices. And therefore we read of *Crœſus*, that being overcome in a battel, and taken by *Cyrus*, he did revile the Gods of ingratitude, becauſe they had no better care of him, who had ſo frequently adored

* As Pyramids, Obelisks.

Herodot. *l.* 1.

adored them with coſtly oblations. And as they did conceive themſelves bound to part with their lives in defence of ther religion: ſo likewiſe to employ their utmoſt power and eſtate, about any ſuch deſign which might promote or advance it. Whereas now, the generality of men, eſpecially the wiſeſt ſort amongſt them, are in this reſpect of another opinion, counting ſuch great and immenſe labours to be at the beſt but glorious vanities. "The Temple of *Solomon* indeed was to be a type, and therefore it was neceſſary that it ſhould be ſo extraordinarily magnificent, otherwiſe perhaps a much cheaper ſtructure might have been as commendable and ſerviceable.

2. *Policy*, that by this means they might find out imployment for the people, who of themſelves being not much civilized, might by idleneſs quickly grow to ſuch a rudeneſs and barbariſm, as not to be bounded within any laws of government. Again, by this means the riches of the King- dom

Plin. l. 6. c. 12.

dom did not lye idly in their kings treaſuries, but was always in motion, which could not but be a great advantage and improvement to the Common-wealth. And perhaps ſome of them feared leſt if they ſhould leave too much money unto their ſucceſſors, it might be an occaſion to inſnare them in ſuch idle and vain courſes as would ruin their kingdoms. Whereas in theſe later ages none of all theſe politick incitements can be of any force, becauſe now there is imployment enough for all, and money little enough for every one.

3. *Ambition* to be known unto poſterity; and hence likewiſe aroſe that incredible labour and care they beſtowed to leave ſuch monuments behind them, as might ** continue for ever*, and make them famous unto all after ages: This was the reaſon of *Abſaloms* pillar ſpoken of in Scripture, *to keep his name in remembrance.* And doubtleſs this too was the end which many others of the Ancients have aimed at, in thoſe (as they thought)

* Pſal. 49. 21.

2 Sam. 18 18.

thought) everlaſting buildings.

But now theſe later ages are much more active and ſtirring: ſo that every ambitious man may find ſo much buſineſs for the preſent, that he ſhall ſcarce have any leiſure to trouble himſelf about the future. And therefore in all theſe reſpects, there is a great diſproportion betwixt the incitements of thoſe former and theſe later times unto ſuch magnificent attempts.

Again, as they differ much in their *motives* unto them, ſo likewiſe in the means of effecting them.

There was formerly more leiſure and opportunity, both for the great men to undertake ſuch works, and for the people to perfect them. Thoſe paſt ages were more quiet and peaceable, the Princes rather wanting imployment, than being over-preſt with it, and therefore were willing to make choice of ſuch great deſigns, about which to buſie themſelves: whereas now the world is grown more politick, and therefore more troublesome, every great man having other private and necessary business about which to imploy both his time and means. And so likewise for the common people, who then living more wildly without being confined to particular trades and professions, might be more easily collected about such famous imployments; whereas now, if a Prince have any occasion for an Army, it is very hard for him to raise so great a multitude, as were usually imployed about these magnificent buildings. We read of 360000men that were busied for twenty years in making one of the Egyptian Pyramids. And *Herodotus* tells us of 1000000 *Lib. 2.* men who were as long in building another of them. About the carriage of one stone for *Amasis* the distance of twenty days journey, there was for three years together imployed 2000 chosen men, Governours, besides many other under-labourers. 'Twas the opinion of * *Josephus* and *Nazianzen*, that these Pyramids were built by *Joseph* for granaries against the years

* *Antiq. l. 2. c. 5.*

years of famine. Others think that the brick made by the children of *Israel*, was imployed about the framing of them, because we read that the Tower of *Babel* did consist of brick or artificial stone, *Gen.* 11.3. And if these were the labourers that were busied about them, 'tis no wonder though they were of so vast a magnitude; for we read that the children of *Israel* at their coming out of *Egypt*, were numbred to be six hundred thousand, and three thousand, and five hundred and fifty men, *Numb.* 1.46. so many handfuls of earth would almost make a mountain, and therefore we may easily believe that so great a multitude in so long a space as their bondage lasted, for above four hundred years, might well enough accomplish such vast designs.

In the building of *Solomons* Temple, there were threescore and ten thousand that bare burdens, and fourscore thousand hewers in the mountains, 1 *Kings* 5. 15.

The *Ephesian* Temple was built by all

all *Asia* joyning together, the 127 pillars were made by so many Kings according to their several successions; the whole work being not finished under the space of two hundred and fifteen years. Whereas the transplacing of that Obelisk at *Rome* by *Sixtus* the fift, (spoken of before) was done in some few days by five or six hundred men; and as the work was much less than many other recorded by Antiquity, so the means by which it was wrought, was yet far less in this respect than what is related of them.

2. The abundance of wealth, which was then ingrossed in the possession of some few particular persons, being now diffused amongst a far greater number. There is now a greater equality amongst mankind, and the flourishing of Arts and Sciences hath so stirred up the sparks of mens natural nobility, and made them of such active and industrious spirits, as to free themselves in a great measure from that slavery, which those former and

wilder

wilder Nations were ſubjected unto.

In building one of the Pyramids, there was expended for the maintenance of the labourers with Radiſh and Onyons, no leſs than eighteen hundred talents, which is reckoned to amount unto 1880000 Crowns, or thereabouts. And conſidering the cheapneſs of theſe things in thoſe times and places, ſo much money might go farther than a ſum ten times greater could do in the maintenance of ſo many now.

In *Solomons* Temple we know how the extraordinary riches of that King, the general flouriſhing of the whole State, and the liberality of the people did joyntly concur to the building of the Temple. *Pecuniarum copia & populi largitus, majora dictu conabatur*, (ſaith *Joſephus*). The *Rhodian* Coloſſus is reported to have coſt three hundred talents the making. And ſo were all thoſe other famous Monuments of proportionable expence.

De bell. Jud. l. 6. cap. 6.

Pancirollus ſpeaking of thoſe Theaters that were erected at the charges

of

of ſome private Roman Citizens, ſaith thus: *Noſtro hoc ſæculo vel Rex ſatis haberet quod ageret ædificio ejuſmodi erigendo*; and a little after upon the like occaſion, *Res mehercule miraculoſa, quæ noſtris temporibus vix à potentiſſimo aliquo rege poſſit exhiberi.* *Deperd. Tit. 18.*

3. Add unto the two former conſiderations that exact *care* and indefatigable *induſtry* which they beſtowed in the raiſing of thoſe ſtructures: Theſe being the chief and only deſigns on which many of them did imploy all their beſt thoughts and utmoſt endeavours. *Cleopes* an Egyptian King is reported to have been ſo deſirous to finiſh one of the Pyramids, that having ſpent all about it he was worth, or could poſſibly procure, he was forced at laſt to proſtitute his own daughter for neceſſary maintenance. And we read of *Ramiſes* another King of *Egypt*, how that he was ſo careful to erect an Obelisk, about which he had imployed 20000 men, that when he feared leſt through the negligence of the artificers, or weakneſs of the engine, *Plin. l. 36. c. 9.*

gine, the ſtone might fall and break, he tyed his own ſon to the top of it, that ſo the care of his ſafety might make the workmen more circumſpect in their buſineſs. And what ſtrange matters may be effected by the meer diligence and labour of great multitudes, we may eaſily deſcern from the wild Indians, who having not the art or advantage of Engines, did yet by their unwearied induſtry remove ſtones of an incredible greatneſs. *Acoſta* relates that he himſelf meaſured one at *Tiaguanaco*, which was thirty eight foot long, eighteen broad, and ſix thick, and he affirms that in their ſtatelieſt Edifices, there were many other of much vaſter magnitude.

Hiſtor. Ind. l. 6. c. 14.

From all which conſiderations it may appear, that the ſtrangeneſs of thoſe ancient monuments above any that are now effected, does not neceſſarily infer any defect of art in theſe later ages. And I conceive, it were as eaſie to demonſtrate the Mechanical Arts in theſe times to be ſo far beyond the knowledge of former

ages;

ages, that had we but the ſame means as the Ancients had, we might effect far greater matters than any they attempted, and that too in a ſhorter ſpace, and with leſs labour.

CAP. XII.

Concerning the force of the Mechanick faculties, particularly the Ballance and Leaver. How they may be contrived to move the whole world, or any other conceivable weight.

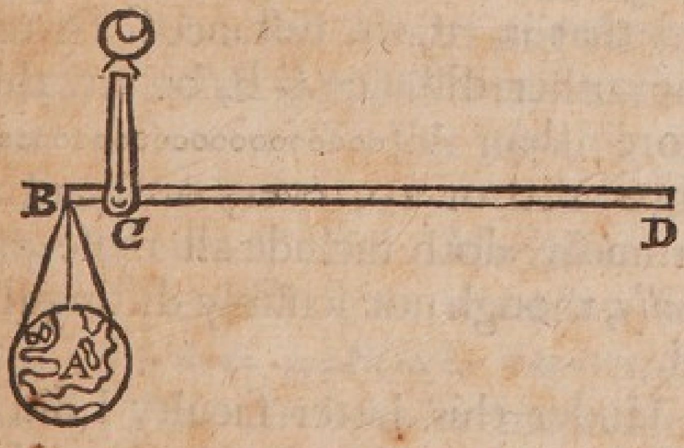
ALL theſe magnificent works of the Ancients before ſpecified, are ſcarce conſiderable in reſpect of art, if we compare them with the famous ſpeeches and acts of *Archimedes:* Of whom it is reported that he was frequently wont to ſay, how that he could move, *Datum pondus cum datâ potentiâ*, the greateſt conceivable weight with the leaſt conceivable power: and that if he did but know where to ſtand and faſten his inſtrument, he could move the world, all this

this great Globe of ſea and land; which *promiſes*, though they were altogether above the vulgar apprehenſion or belief, yet becauſe his *acts* were ſomewhat anſwerable thereunto, therefore the King of *Syracuſe* did enact a law whereby every man was bound to believe what ever *Archimedes* would affirm.

'Tis eaſie to demonſtrate the Geometrical truth of thoſe ſtrange aſſertions, by examining them according to each of the forenamed *Mechanick* faculties, every one of which is of infinite power.

To begin with the two firſt of them, the Ballance and the Leaver, (which I here joyn together, becauſe the proportions of both are wholly alike) 'tis certain, though there ſhould be the greateſt imaginable weight, and the leaſt imaginable power, (ſuppoſe the whole world, and the ſtrength of one man or infant) yet if we conceive the ſame diſproportion betwixt their ſeveral diſtances in the former faculties from the fulciment or center of gravity,

vity, they would both equiponderate. And if the diſtance of the power from the center, in compariſon to the diſtance of the weight, were but any thing more than the heavineſs of the weight is in reſpect of the power, it may then be evident from the former principles, that the power would be of greater force than the weight, and conſequently able to move it.



Thus if we ſuppoſe this great globe at *A*, to

 con-

contain 24000000000000000000000000 pounds, allowing a hundred pound for each cubical foot in it, (as *Stevinius* hath calculated) yet a man or child at *D*, whose strength perhaps is but equivalent to one hundred, or ten pounds weight, may be able to out-weigh and move it, if there be but a little greater dispropotion betwixt the two distances *C D*, and *C B*, than there is betwixt the heaviness of the weight, and the strength of the power; that is, if the distance *C D*, unto the other distance *C B*, be any thing more than 24000000000000000000000000 unto 100 or 10, every ordinary instrument doth include all these parts *really*, though not sensibly distinguished.

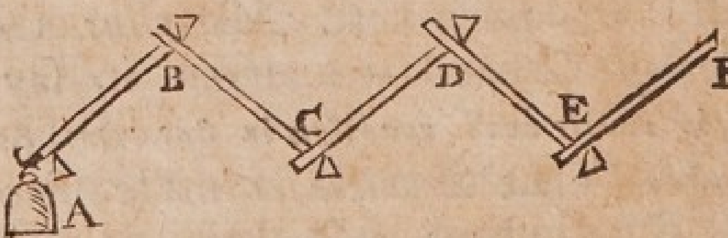
Static.l.3. prop. 10.

Under this latter faculty I did before mention that engine by which *Archimedes* drew up the *Roman* ships at the siege of *Syracuse*. This is usually styled *Tollenon*, being of the same form with that which is commonly used by Brewers and Dyers, for the drawing of water. It consists of two posts

Lipsius Poliorcet.l.1. Dialog.6.

posts, the one fastned perpendicularly in the ground, the other being jointed on cross to the top of it. At the end he fastned a strong hook or grapple of iron, which being let over the wall to the river, he would thereby take hold of the ships, as they passed under; and afterwards by applying some weight, or perhaps the force of Screws to the other end, he would thereby lift them into the open air, where having swinged them up and down till he had shaked out the men and goods that were in them, he would then dash the Vessels against the rocks, or drown them in their sudden fall: insomuch that *Marcellus* the *Roman* General was wont to say, *Plutarch. in his life.* ταῖς μὲν ναυσὶν αὐτοῦ κυαθίζειν ἐκ θαλάττης Ἀρχιμήδην, That *Archimedes* made use of his ships instead of Buckets, to draw water with.

This faculty will be of the same force, not only when it is continued in one, but also when it is multiplied in divers instruments, as may be conceived in this other form, which I do not mention as if it could be ſerviceable for any motion (ſince the ſpace by which the weight would be moved, will be ſo little as not to fall under ſenſe) but only for the better explication of this Mechanick principle, and for the right underſtanding of that force ariſing from multiplication in the other faculties, which do all depend upon this. The Wheel, and Pulley, and Screw, being but as ſo many Leavers of a circular form and motion, whoſe ſtrength may therefore be continued to a greater ſpace.



Imagine the weight *A*, to be an hundred thouſand pounds, and the diſtance of that point, wherein every Leaver touches either the weight or one another from the point where they touch the prop, to be but one

ſuch

ſuch part, whereof the remainder contains ten, then according to the former grounds 10000 at *B*, will equiponderate to *A*, which is 100000, ſo that the ſecond Leaver hath but 10000 pounds to move. Now becauſe this obſerves the ſame proportions with the other in the diſtances of its ſeveral points, therefore 1000 pounds at *C*, will be of equal weight to the former. And the weight at *C*, being but as a thouſand pound, that which is but as a hundred at *D*, will be anſwerable unto it; and ſo ſtill in the ſame proportion, that which is but 10 at *E*, will be equal to 100 at *D*; and that which is but one pound at *F*, will alſo be equal to ten at *E*. Whence it is manifeſt, that 1 pound at *F*, is equal to 100000 at *A*; and the weight muſt alwayes be diminiſhed in the ſame proportion as ten to one, becauſe in the multiplication of theſe Leavers, the diſtance of the point, where the inſtrument touches the weight, from that where it touches the prop, is but as one ſuch part whereof the remainder contains ten. But now if we imagine it to be as the thousandth part, then must the weight be diminished according to this proportion; and then in the same multiplication of Leavers, 1 l. will be equal to 1000 000 000 000 000 pounds: so that though we suppose the weight to be never so heavy, yet let the disproportion of distances be greater, or the Leavers more, and any little power may move it.

CAP. XIII.

Of the Wheel, by multiplication of which it is easie to move any imaginable weight.

THE Wheel or *axis in peritrochio*, was before demonstrated to be of equivalent force with the former faculties. If we conceive the same difference betwixt the Semidiameter of the wheels or spokes *A C*, and the Semidiameter of the axis *A B*, as there is betwixt the weight of the world,

See the figure cap 6 p. 38.

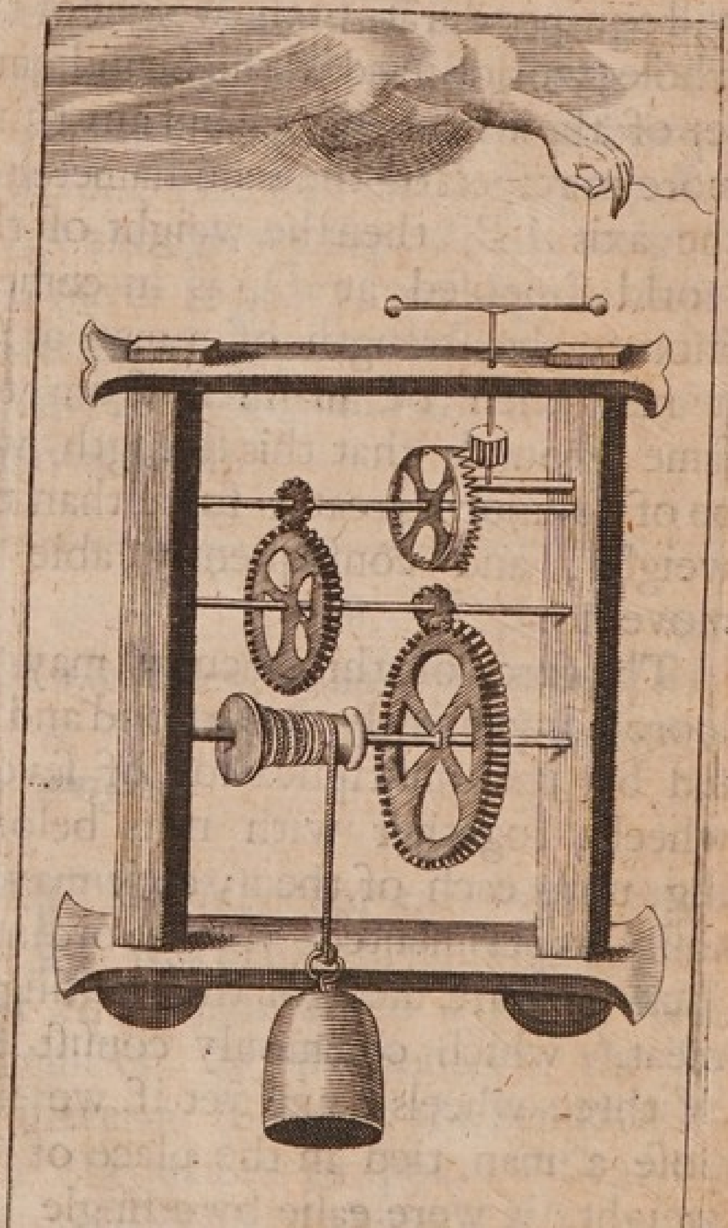
and the ſtrength of a man, it may then be evident, that this ſtrength of one man, by the help of ſuch an inſtrument, will equiponderate to the weight of the whole world. And if the Semidiameter of the wheel *A C*, be but any thing more in reſpect of the Semidiameter of the axis *A B*, then the weight of the world ſuppoſed at *D*, is in compariſon to the ſtrength of a man at *C*; it may then be manifeſt from the ſame grounds that this ſtrength will be of ſo much greater force than the weight, and conſequently able to move it.

The force of this faculty may be more conveniently underſtood and uſed by the multiplication of ſeveral wheels, together with nuts belonging unto each of them; as it may be eaſily experimented in the ordinary Jacks that are uſed for the roaſting of meat, which commonly conſiſt but of three wheels; and yet if we ſuppoſe a man tied in the place of the weight, it were eaſie by a ſingle hair faſtned unto the fly or ballance of the

An engine of many wheels is commonly called *Gloſſocomus.*

How to pull a man above ground with a ſingle hair.

Jack, to draw him up from the ground, as will be evident from this following figure.



Where ſuppoſe the length of the fly or ballance in compariſon to the breadth of its axis, to be as 10 to one, and ſo for the three other wheels in reſpect of the nuts that belong unto them; (though this difference be oftentimes leſs, as we may well allow it to be) withall ſuppoſe the weight (or a man tyed in the place of it) to be a hundred pounds: I ſay, according to this ſuppoſition, it is evident that the power at the ballance, which ſhall be equal to the weight, need be but as 1 to 10000. For the firſt axis is conceived to be but as the tenth part of its wheel, and therefore though the weight in it ſelf be as 10000, yet unto a power that hath this advantage, it is but as 1000, and therefore this thouſand unto the like power at the ſecond wheel, will be but as 100, and this 100 at the third but as 10; and laſtly, this ten at the ballance but as one. But the weight was before ſuppoſed to be 100, which to the firſt wheel will be but 10, to the ſecond as one, to the third as a deci-

mal,

mal, or one tenth, to the ſails as one hundredth part: ſo that if the hair be but ſtrong enough to lift $\frac{1}{10000}$ that is one ten thouſandth part of a man, or (which is all one) one hundreth part of a pound, it may as well ſerve by the help of this inſtrument for the drawing of him up. And though there be not altogether ſo great a diſproportion betwixt the ſeveral parts of a Jack, (as in many perhaps there is not); and though a man may be heavier than is here ſuppoſed, yet 'tis withall conſiderable that the ſtrength of a hair is able to bear much more than the hundredth part of a pound.

Coment. in Gen.c.1. v.10.art.6. De viribus motricibus Theor. 16.

Upon this ground *Merſennus* tells us out of *Solomon de Cavet*, that if there were an engine of 12 wheels each of them with teeth, as alſo the axes or nuts that belong unto them, if the Diameter of theſe wheels were unto each *axis*, as a hundred to one: and if we ſuppoſe theſe wheels to be ſo placed, that the teeth of the one might take hold of the axis that belongs unto the next, and that the axis of of the handle may turn the firſt wheel, and the weight be tyed unto the axis of the laſt, with ſuch an engine as this, ſaith he, a child (if he could ſtand any where without this earth) might with much eaſe move it towards him.

For according to the former ſuppoſition, that this Globe of ſea and land, did contain as many hundred pounds, as it doth cubical feet, *viz.* 240000000000000000000000000, it may be evident that any ſtrength, whoſe force is but equivalent to 3 pounds, will by ſuch an engine be able to move it.

Of this kind was that engine ſo highly extolled by *Stevinius*, which he calls *Pancration*, or *Omnipotent*, preferring it before the inventions of *Archimedes*. It conſiſted of wheels and nuts, as that before ſpecified is ſuppoſed. Hither alſo ſhould be referred the force of racks, which ſerve for bending of the ſtrongeſt bows, as alſo that little pocket-engine wherewith a man may break or wrench o-

De Statica proxi.

Rameli. Fig. 160.

pen

pen any dore, together with divers the like inſtruments in common uſe.

CAP. XIV.

Concerning the infinite ſtrength of Wheels, Pulleys, and Screws. That it is poſſible by the multiplication of theſe, to pull up any Oak by the roots with a hair, lift it up with a ſtraw, or blow it up with ones breath, or to perform the greateſt labour with the leaſt power.

FRom what hath been before delivered concerning the nature of the Pulley, it is eaſie to underſtand, how this faculty alſo may be proportioned betwixt any weight, and any power, as being likewiſe of infinite ſtrength.

'Tis reported of *Archimedes*, that with an engine of Pulleys, to which he applyed only his left hand, he lifted up * 5000 buſhels of corn at once, and drew a ſhip with all its lading

* 7000 ſaith *Zetzes Chiliad.* 2. *Hiſt.* 35.

ding upon dry land. This engine *Zetzes* calls *Trispatum*, or *Trispastum*, which signifies only a threefold Pulley; But herein he doth evidently mistake; for 'tis not possible that this alone should serve for the motion of so great a weight, because such an engine can but make a subsextuple, or at most a subseptuple proportion betwixt the weight and power, which is much too little to reconcile the strength of a man unto so much heaviness. Therefore *Ubaldus* doth more properly style it *Polyspaston*, or an instrument of many Pulleys: How many, were easie to find out, if we did exactly know the weight of those ancient measures; supposing them to be the same with our bushel in *England*, which contains 64 pints or pounds, the whole would amount to 320000 pounds, half of which would be lightned by the help of one Pulley, three quarters by two Pulleys, and so onward, according to this subduple, subquadruple, and subsextuple proportion: So that if we conceive the strength of

Praef. ad. Mechan.

of the left hand to be equivalent unto 20 or 40 pounds, it is is eaſie to find out howmany Pulleys are required to inable it for the motion of ſo great a weight.

Comment. inGen.c.1. v.10.art.6. Upon this ground *Merſennus* tells us, that any little child with an engine of an hundred double Pulleys, might eaſily move this great Globe of earth, though it were much heavier than it is. And in reference to this kind of engine (ſaith *Monantholius*) are we to underſtand that aſſertion of *Archimedes* (as he more immediately intended it) concerning the poſſibility of moving the world.

Præf. ad Mechan. Ariſtotle.

The Wedg was before demonſtrated to be as a double Vectis or Leaver, and therefore it would be needleſs to explain particularly how this likewiſe may be contrived of infinite force.

The Screw is capable of multiplication, as well as any of the other faculties, and may perhaps be more ſerviceable for ſuch great weights, than any of the reſt. *Archimedes* his

engine

engine of greateſt ſtrength, called *Chariſtion*, is by ſome thought to conſiſt of theſe. *Axes habebat cum infinitis cochleis.* And that other engine of his called *Helix* (mentioned by * *Athenæus*) wherewith he lifted *Hiero's* great ſhip into the ſea, without any other help, is moſt likely to be framed of perpetual ſcrews, ſaith *Rivaltus*.

Stevin. de Static. prax. See *Beſſon.*

* *Deipnoſophiſt. l. 5.* *Oper. exter Archimed.*

Whence it may evidently appear, that each of theſe Mechanick faculties are of infinite power, and may be contrived proportionable unto any conceivable weight: And that no natural ſtrength is any way comparable unto theſe artificial inventions

'Tis reported of *Sampſon*, that he could carry the gates of a City upon his ſhoulders, and that the ſtrongeſt bonds were unto him but as flax burnt with fire, and yet his hair being ſhaved off, all his ſtrength departed from him. We * read of *Milo*, that he could carry an Oxe upon his back, and yet when he tried to tear an Oak aſunder

Judg. 15.

* *A. Gel. Noct. Art. l. 15. c. 16.*

der that was ſomewhat riven before, having drawn it to its utmoſt, it ſuddenly joyned together again, catching his hands in the cleft, and ſo ſtrongly manacled him, that he became a prey to the wild beaſts.

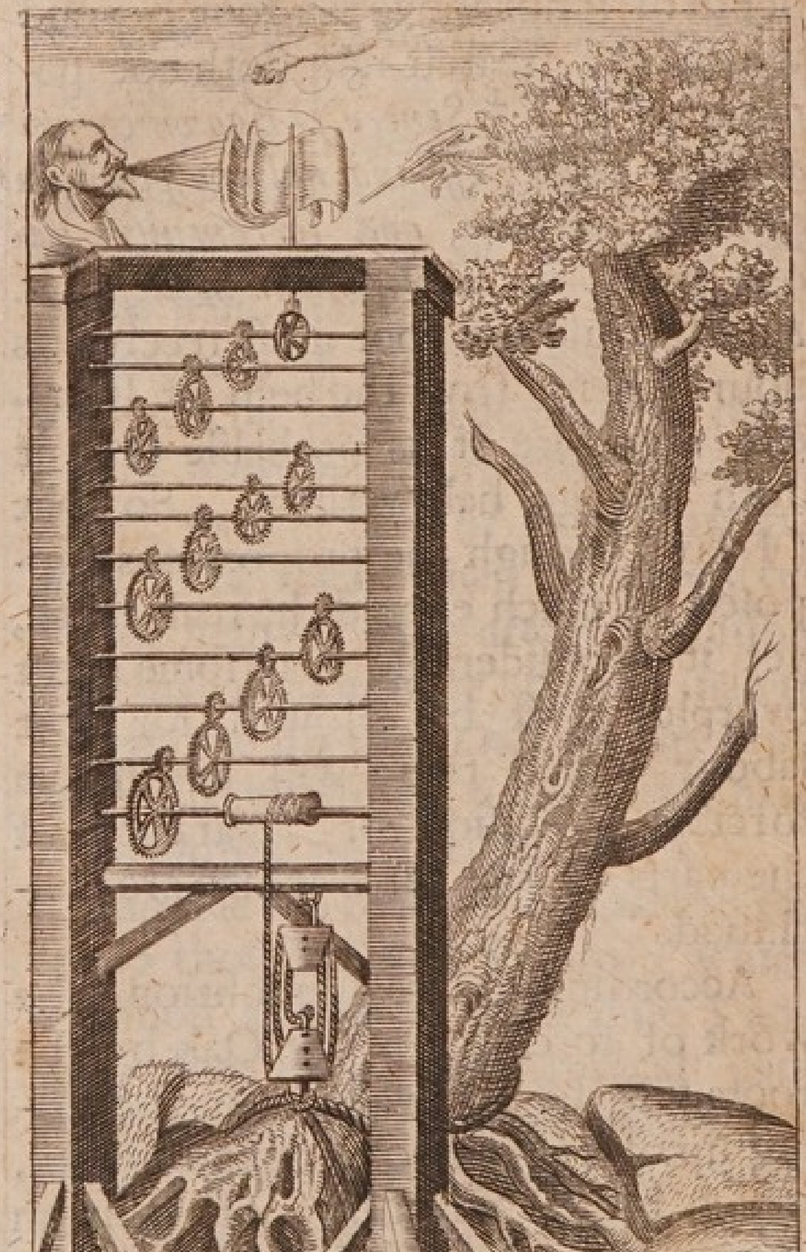
But now by theſe Mechanical contrivances, it were eaſie to have made one of *Sampſons* hairs that was ſhaved off, to have been of more ſtrength than all of them when they were on. By the help of theſe arts it is poſſible (as I ſhall demonſtrate) for any man to lift up the greateſt Oak by the roots with a ſtraw, to pull it up with a hair, or to blow it up with his breath.

Suppoſe the roots of an Oak to extend a thouſand foot ſquare, (which is almoſt a quarter of a mile) and forty foot deep, each cubical foot being a hundred pound weight; which though it be much beyond the extenſion of any tree, or the weight of the earth, the compaſs of the roots in the ground (according to common opinion) not extending further than the branches of it in the air, and the depth

depth of it not above ten foot, beyond which the greateſt rain doth not penetrate (ſaith * Seneca). *Ego vinearum diligens foſſor affirmo nullam pluviam eſſe tam magnam, quæ terram ultra decem pedes in altitudinem madefaciat.* And becauſe the root muſt receive its nouriſhment from the help of ſhowers, therefore it is probable that it doth not go below them. So that (I ſay) though the proportions ſuppoſed do much exceed the real truth, yet it is conſiderable that ſome great overplus muſt be allowed for that labour which there will be in the forcible divulſion or ſeparation of the parts of the earth which are continued.

* Nat. Qu. l. 3. c. 7.

According to this ſuppoſition, the work of forcing up the Oak by the roots will be equivalent to the lifting up of 400000000 pound weight, which by the advantage of ſuch an engine, as is here deſcribed, may be eaſily performed with the leaſt conceivable power.



The whole force of this engine doth consist in two double Pulleys, twelve wheels, and a sail. One of these Pulleys at the bottome will diminish half of the weight, so that it shall be but as 2000000000, and the other Pulley will abate ¾ three quarters of it: so that it shall be but as 1000000000. And because the beginning of the string being fastned unto the lower Pulley, makes the power to be in a subquintuple proportion unto the weight, therefore a power that shall be as 1000000000, that is, a subquadruple, will be so much stronger than the weight, and consequently able to move it. Now suppose the breadth of all the axes and nuts, to be unto the Diameters of the wheel as ten to one; and it will then be evident, that to a power at the first wheel, the weight is but as 100000000. To the second as 10000000. To the third as 1000000. To the fourth as 100000. To the fifth as 10000, To the sixth as 1000. To the seventh as a 100. To the eighth

See ch. 7.

as 10. To the ninth as 1. To the tenth as $\frac{1}{10}$ one decimal. To the eleventh as $\frac{1}{100}$. To the twelfth as $\frac{1}{1000}$. And the sails yet less. So that if the strength of the straw, or hair, or breath, be but equal to the weight of one thousandth part of a pound, it may be of sufficient force to pull up the Oak.

If in this engine we suppose the disproportion betwixt the wheels and nuts, to be as an hundred to one, then it is very evident, that the same strength of breath, or a hair, or a straw, would be able to move the whole world, as will be easily found by calculation. Let this great Globe of sea and land be imagined (as before) to weigh so many hundred pounds as it contains cubical feet; namely, 24000000000000000000000000 pounds. This will be to the first Pulley, 12000000000000000000000000. To the second less than 6000000000000000000000000. But for more easie and convenient reckoning, let it be supposed to be somewhat more, *viz.* 1000000000000000000000000.

This

This to the firſt wheel will be but as

	1000000000000000000000000.
To the ſecond as	100000000000000000000.
To the third as	1000000000000000000.
To the fourth as	10000000000000000.
To the fifth	100000000000000.
To the ſixth	1000000000000.
To the ſeventh	10000000000.
To the eighth	100000000.
To the ninth	1000000.
To the tenth	10000.
To the eleventh	100.
To the twelfth	1.
To the ſails as	$\frac{1}{100}$.

So that a power which is much leſs than the hundredth part of a pound, will be able to move the world.

It were needleſs to ſet down any particular explication, how ſuch Mechanical ſtrength may be applyed unto all the kinds of local motion; ſince this, in it ſelf, is ſo facile and obvious, that every ordinary artificer doth ſufficiently underſtand it.

The Species of local violent motion are by *Ariſtotle* reckoned to be theſe four.

Phys. l. 7. c. 3.

{ *Pulsio.*
Tractio.
Vectio.
Vertigo. }

Thrusting, Drawing, Carrying, Turning. Unto some of which all these artificial operations must necessarily be reduced, the strength of any power being equally appliable unto all of them; So that there is no work impossible to these contrivances, but there may be as much acted by this art, as can be fancied by imagination.

CAP. XV.

Concerning the proportion of slowness and swiftness in Mechanical motions.

HAving already discoursed concerning the *strength* of these Mechanical Faculties: it remains for the more perfect discovery of their natures, that we treat somewhat concerning those two differences of artificial motion:

Slow-

Slowneſs,
and
Swiftneſs.

Without the right underſtanding of which, a man ſhall be expoſed to many abſurd miſtakes, in attempting of thoſe things which are either in themſelves impoſſible, or elſe not to be performed with ſuch means as are applyed unto them. I may ſafely affirm, that many, if not moſt miſtakes in theſe Mechanical deſigns, do ariſe from a miſ-apprehenſion of that difference which there will be betwixt the ſlowneſs or ſwiftneſs of the weight and power, in compariſon to the proportion of their ſeveral ſtrengths.

Hence it is, that ſo many engines invented for mines and water-works do ſo often fail in the performance of that for which they were intended, becauſe the artificers many times do forget to allow ſo much time for the working of their engine, as may be proportionable to the difference betwixt the weight and power that belong unto them; whereas he that rightly underſtands the grounds of this art, may as eaſily find out the difference of ſpace and time, required to the motion of the weight and power, as he may their different ſtrengths; and not only tell how any power may move any weight, but alſo in what a ſpace of *time* it may move any ſpace or *diſtance.*

If it were poſſible to contrive ſuch an invention, whereby any conceivable weight may be moved by any conceivable power, both with the ſame quickneſs and ſpeed (as it is in thoſe things which are immediately ſtirred by the hand, without the help of any other inſtrument) the works of nature would be then too much ſubjected to the power of art: and men might be thereby incouraged (with the builders of *Babel*, or the rebel Gyants) to ſuch bold deſigns as would not become a created being. And therefore the wiſdom of Providence hath ſo confined theſe humane Arts, that what any invention

hath

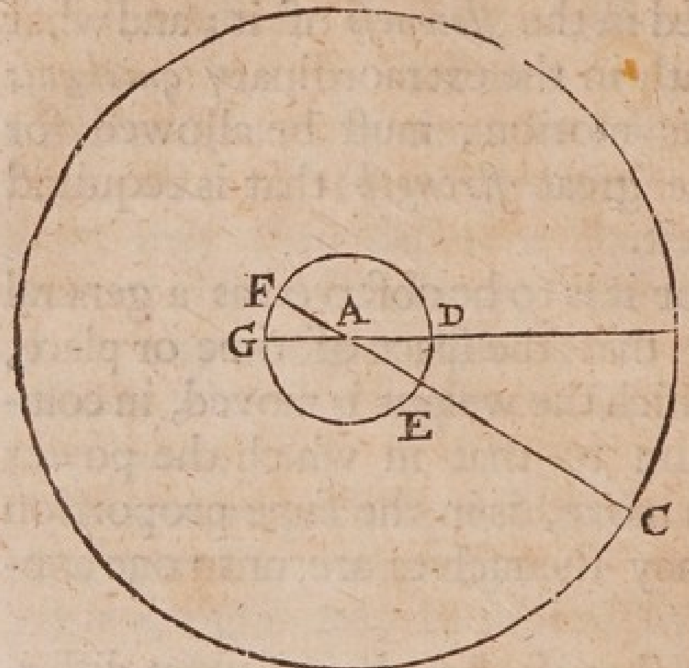
hath in the *ſtrength* of its motion, is abated in the *ſlowneſs* of it; and what it hath in the extraordinary *quickneſs* of its motion, muſt be allowed for in the great *ſtrength* that is required unto it.

For it is to be obſerved as a general rule, that the ſpace of time or place, in which the weight is moved, in compariſon to that in which the power doth move, is in the ſame proportion as they themſelves are unto one another.

So that if there be any great difference betwixt the ſtrength of the weight and the power, the ſame kind of difference will there be in the ſpaces of their motion.

To illuſtrate this by an example:

Let



Let the line *G AB*, repreſent a ballance or leaver, the weight being ſuppoſed at the point *G*, the fulciment at *A*, and the power ſuſtaining the weight at *B*. Suppoſe the point *G*, unto which the weight is faſtned, to be elevated unto *F*, and the oppoſite point *B*, to be depreſſed unto *C*; 'tis evident that the arch *F G*, or (which is all one) *D E*, doth ſhew the ſpace of the weight, and the arch *B C*, the motion of the power. Now both

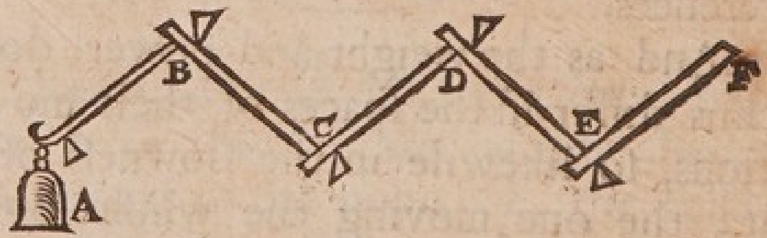
both theſe arches have the ſame proportion unto one another, as there is betwixt the weight and the power, or (which is all one) as there is betwixt their ſeveral diſtances from the fulciment. Suppoſe *A G*, unto *A B*, to be as one unto four, it may then be evident that *F G*, or *D E*, will be in the ſame proportion unto *B C*. For as any two Semidiameters are unto one another, ſo are the ſeveral circumferences deſcribed by them, as alſo any proportional parts of the ſame circumferences.

And as the weight and power do thus differ in the ſpaces of their motions, ſo likewiſe in the ſlowneſs of it; the one moving the whole diſtance *B C*, in the ſame time, wherein the other paſſes only *G F*. So that the motion of the power from *B* to *C*, is four times ſwifter then that of the weight from *G* to *F*. And thus will it be, if we ſuppoſe the diſproportions to be far greater, whether or no we conceive it, either by a *continuation* of the ſame inſtrument and

fa-

faculty, as in the former example, or by a *multiplication* of divers, as in Pulleys, Wheels, &c. By how much the power is in it ſelf leſs than the weight, by ſo much will the motion of the weight be ſlower than that of the power.

To this purpoſe I ſhall briefly touch at one of the Diagrams expreſſed before in the twelfth Chapter, concerning the multiplication of Leavers.



In which, as each inſtrument doth diminiſh the weight according to a decuple proportion, ſo alſo do they diminiſh the *ſpace* and *ſlowneſs* of its motion. For if we ſhould conceive the firſt Leaver *B*, to be depreſſed unto its loweſt, ſuppoſe ten foot, yet the weight *A*, would not be raiſed

ſed above one foot; but now the ſecond Leaver at its utmoſt could move but a tenth part of the firſt, and the third Leaver but a tenth part of the ſecond, and ſo of the reſt. So that the laſt Leaver *F*, being depreſſed, will paſs a *ſpace* 100000 greater, and by a motion, 100000 ſwifter than the weight at *A*.

Thus are we to conceive of all the other faculties, wherein there is conſtantly the ſame diſproportion betwixt the weight and power, in reſpect of the ſpaces and ſlowneſs of their motions, as there is betwixt their ſeveral gravities. If the power be unto the weight but as one unto a hundred, then the ſpace through which the weight moves, will be a hundred times leſs, and conſequently the motion of the weight a hundred times ſlower than that of the power.

So that it is but a vain and impoſſible fancy for any one to think that he can move a great weight with a little power in a little ſpace; but in all theſe Mechanical attempts, that advantage

vantage which is gotten in the ſtrength of the motion, muſt be ſtill allowed for in the ſlowneſs of it.

Though theſe contrivances do ſo extremely increaſe the power, yet they do proportionably protract the time. That which by ſuch helps one man may do in a hundred days, may be done by the immediate ſtrength of a hundred men in one day.

CAP. XVI.

That it is poſſible to contrive ſuch an artificial motion, as ſhall be of a ſlowneſs proportionable to the ſwiftneſs of the heavens.

IT were a pretty ſubtilty to enquire after, whether or no it be not poſſible to contrive ſuch an artificial motion, that ſhould be in ſuch a proportion ſlow, as the heavens are ſuppoſed to be ſwift.

For the exact reſolution of which, it would be requiſite that we ſhould firſt pitch upon ſome *medium*, or diffe-

different motion, by the diſtance from which, we may judge of the proportions on either ſide, whether ſlowneſs or ſwiftneſs. Now becauſe there is not any ſuch *natural medium*, which may be abſolutely ſtyled an indifferent motion, but that the ſwiftneſs and ſlowneſs of every thing, is ſtill proportioned either to the quantity of bodies, in which they are, or ſome other particular end for which they are deſigned; therefore we muſt take liberty to ſuppoſe ſuch a motion, and this we may conceive to be about 1000 paces, or a mile in an hour.

The ſtarry heaven, or 8th ſphear is thought to move 42398437 miles in the ſame ſpace: So that if it may be demonſtrated that it is poſſible to contrive ſuch a motion, which going on in a conſtant direct courſe, ſhall paſs but the 42398437 part of a mile in an hour, it will then be evident, that an artificial motion may be ſlow, in the ſame proportion as the heavens are ſwift.

Now

Now it was before manifested that according to the difference betwixt the weight and power, so will the difference be betwixt the slowness or swiftness of their motions; whence it will follow, that in such an engine, wherein the weight shall be 42398437 pounds, and the power that doth equiponderate it, but the 42398437 part of a pound (which is easie to contrive) in this engine the power being supposed to move with such a swiftness, as may be answerable to a mile an hour, the weight will pass but the 42398437 part of a mile in the same space, and so consequently will be proportionably slow unto the swiftness of the Heavens.

It is related by our Country-man *J. Dee*, that he and *Cardan* being both together in their travels, they did see an instrument which was at first sold for 20 talents of gold, wherein there was one wheel, which constantly moving round amongst the rest, did not finish one revolution under the space of seven thousand years.

Preface to *Euclid.*

But

But if we farther conſider ſuch an inſtrument of wheels as was mentioned before in the 14 chapter, with which the whole world might be eaſily moved, we ſhall then find that the motion of the weight by that, muſt be much more ſlow, than the heavens are ſwift. For though we ſuppoſe (ſaith *Stevinus*) the handle of ſuch an engine with 12 wheels to be turned about 4000 times in an hour, (which is as often as a mans pulſe doth beat) yet in ten years ſpace the weight by this would not be moved above $\frac{10512}{2400}$0000000000000000 parts of one foot, which is nothing near ſo much as a hairs breadth. And it could not paſs an inch in 1000000 years, ſaith *Merſennus.*

De ſtat. pract.

The truth of which we may more eaſily conceive, if we conſider the frame and manner of this 12 wheel'd engine. Suppoſe that in each axis or nut, there were ten teeth, and on each wheel a thouſand: then the ſails of this engine muſt be turned a hundred times, before the firſt wheel (reckon-

Phænom. Mechan. prop. 11.

I ing

ing downward) could be moved round once, and ten thouſand times before the ſecond wheel can finiſh one revolution, and ſo through the 12 wheels, according to this multiplyed proportion.

So that beſides the wonder which there is in the force of theſe Mechanical motions, the extreme ſlowneſs of them is no leſs admirable; If a man conſider that a body would remain in ſuch a conſtant direct motion, that there could not be one minute of time wherein it did not rid ſome ſpace, and paſs on further, and yet that this body in many years together ſhould not move ſo far as a hairs breadth.

Which notwithſtanding may evidently appear from the former inſtance. For ſince it is a natural principle, that there can be no penetration of bodies; and ſince it is ſuppoſed, that each of the parts in this engine do touch one another in their ſuperficies, therefore it muſt neceſſarily follow, that the weight does begin and

and continue to move with the power: and (however it is insensible) yet it is certain there must be such a motion so extremely slow, as is here specified. So full is this art of rare and incredible subtilties.

I know it is the assertion of *Cardan*, *Motus valde tardi, necessario quietes habent intermedias.* Extreme slow motions have necessarily some intermeditate stops and rests: But this is only said, not proved; and he speaks it from sensible experiments, which in this case are fallible. Our senses being very incompetent judges of the several proportions, whether greatness or littleness, slowness or swiftness, which there may be amongst things in nature. For ought we know, there may be some *Organical* bodies, as much less than ours, as the earth is bigger. We see what strange discoveries of extreme minute bodies, (as lice, wheel-worms, mites, and the like) are made by the *Microscope*, wherein their several parts (which are altogether invisible to the

De varietate rerum, l.9.c.47.

bare eye) will diſtinctly appear: and perhaps there may be other inſects that live upon them as they do upon us. 'Tis certain that our ſenſes are extremely diſproportioned for comprehending the whole compaſs and latitude of things. And becauſe there may be ſuch difference in the *motion* as well as in the *magnitude* of bodies; therefore though ſuch extreme ſlowneſs may ſeem altogether impoſſible to ſenſe and common apprehenſion, yet this can be no ſufficient argument againſt the reality of it.

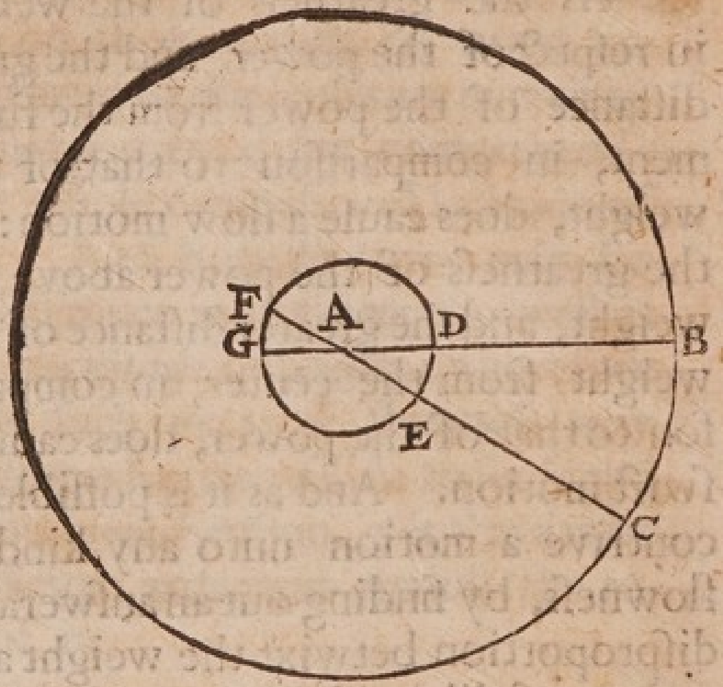
CAP. XVII.

Of ſwiftneſs, how it may be increaſed to any kind of proportion. Concerning the great force of Archimedes *his Engines. Of the Balliſta.*

BY that which hath been already explained concerning the ſlowneſs of motion, we may the better underſtand the nature of ſwiftneſs, both of them (as is the nature of oppo-

ſites,

ſites) being produced by contrary cauſes. As the greatneſs of the weight in reſpect of the power, and the great diſtance of the power from the fulciment, in compariſon to that of the weight, does cauſe a ſlow motion: So the greatneſs of the power above the weight, and the greater diſtance of the weight from the center, in compariſon to that of the power, does cauſe a ſwift motion. And as it is poſſible to contrive a motion unto any kind of ſlowneſs, by finding out an anſwerable diſproportion betwixt the weight and power: ſo likewiſe unto any kind of ſwiftneſs. For ſo much as the weight does exceed the power, by ſo much will the motion of the weight be ſlower; and ſo much as the power does exceed the weight, by ſo much will the motion of the weight be ſwifter.



In the Diagram ſet down before, if we ſuppoſe *F* to be the place of the power, and *C* of the weight, the point *A* being the fulciment or center, then in the ſame ſpace of time, wherein the power does move from *F* to *G*, the weight will paſs from *C* to *B*. Theſe diſtances having the ſame diſproportion unto one another, as there is betwixt *A F*, and *A C*, which is ſuppoſed to be quadruple. So that in this example, the weight will move four

four times ſwifter than the power. And according as the power does exceed the weight in any greater diſproportion, ſo will the ſwiftneſs of the weight be augmented.

Hence may we conceive the reaſon of that great force which there is in Slings, which have ſo much a greater ſwiftneſs, than a ſtone thrown from the hand, by how much the end of the Sling is farther off from the ſhoulder-joynt, which is the center of motion. The Sacred hiſtory concerning *Davids* victory over *Goliah*, may ſufficiently evidence the force of theſe. *Vegetius* relates that it was uſual this way to ſtrike a man dead, and beat the ſoul out of his body, without ſo much as breaking his armour, or fetching blood. *Membris integris læthale tamen vulnus important, & ſine invidia ſanguinis, hoſtis lapidis ictu intereat.*

1 Sam. 17. 49. *Lipſius Polior. l. 4. Dialog. 2.*

In the uſe of theſe, many of the Ancients have been of very exquiſite and admirable skill. We read of *ſeven hundred Benjamites left-handsd, that could*

Judges 20. 16.

sling a stone at a hairs breadth, and not miss. And there is the like storied of a whole Nation amongst the Indians, who from theirexcellency in this art were stiled *Baleares.* They were so strict in teaching this art unto their young ones, *Ut cibum puer à matre non accipit, nisi quem ipsâ monstrante percussit,* That the mother would not give any meat to her child, till (being set at some distance) he could hit it with slinging.

ἀπὸ τοῦ βάλλειν. *Diodor. Sicul.* Biblioth. *l.* 5. *L. Florus Hist. l.* 3. *cap.* 8. *Jo. Boemus Aubanus de moribus gentium, l.* 3. *c.* 26.

For the farther illustration of this subject, concerning the *swiftness* of motion, I shall briefly specifie some particulars concerning the engines of War used by the Ancients. Amongst these, the most famous and admirable were those invented by *Archimedes,* by which he did perform such strange exploits, as (were they not related by so many and such judicious Authors) would scarce seem credible even to these more learned ages. The acts of that famous Engineer, are largely set down by [a] *Polybius,* [b] *Tzetzes,* [c] *Proclus,* [d] *Plutarch,* [e] *Livy*

[a] *Histor. l.* 4
[b] *Histor. Chilias* 2. *histor.* 35.
[c] *l.* 1. 2. *c* 3.
[d] *Marcellus.*
[e] *Histor. l.* 24.

vy, and divers others. From the firſt of whom alone, we may have ſufficient evidence for the truth of thoſe relations. For beſides that he is an Author noted to be very grave and ſerious in his diſcourſe; and does ſolemnly promiſe in one place that he will relate nothing but what either he himſelf was an eye-witneſs of, or elſe what he had received from thoſe that were ſo; I ſay, beſides all this, it is conſiderable, that he himſelf was born not above thirty years after the ſiege of *Syracuſe*. And afterwards having occaſion to tarry ſome weeks in that City, when he travelled with *Scipio*, he might there perhaps ſee thoſe engines himſelf, or at leaſt take his information from ſuch as were eye-witneſſes of their force: So that there can be no colourable pretence for any one to diſtruſt the particulars related of them.

Hiſtor. l. 4. juxta initium.

In brief, the ſum of their reports is this: When the *Roman* forces under the conduct of *Marcellus*, had laid ſiege unto that famous City, (of which

which both by their former ſucceſſes, and their preſent ſtrength, they could not chuſe but promiſe themſelves a ſpeedy victory); yet the arts of this one Mathematician, notwithſtanding all their policies and reſolutions, did ſtill beat them back to their great diſadvantage. Whether they were near the wall or farther from it, they were ſtill expoſed to the force of his engines, ϰ̀ μακρὰν ἀφεϛῶτας, ϰ̀ συνέγγυς ὄντας, ὐ μόνον ἀπρἀκτȢς παρεσκεύαζε πρὸς τὰς ἰδίας ἐπιβολὰς, ἀλλὰ ϰ̀ διέφθειρε τȢ̀ς πλείϛȢς αὐτῶν. From the multitude of thoſe ſtones and arrows, which he ſhot againſt them, was he ſtyled ἑκατόγχειρ, or *Briareus*. Thoſe defenſive engines that were made by the *Romans* in the form of Penthouſes for to cover the aſſailants from the weapons of the beſieged, theſe would he preſently batter in pieces with great ſtones and blocks. Thoſe high towers erected in ſome of the ſhips, out of which the *Romans* might more conveniently fight with the defendants on the wall, theſe alſo were

Cal. Rhod. Ant. lect. l. 2. c. 16.
Pluteus
Teſtudo.

ſo

ſo broken by his engines, that no Cannon or other inſtrument of Gun-powder, (ſaith a learned man) had they been then in uſe, could have done greater miſchief. In brief, he did ſo moleſt them with his frequent and prodigious batteries, that the common ſoldiers were utterly diſcouraged from any hopes of ſucceſs.

Sir *Walt. Raleigh hiſtor. l. 5. c. 3 Sect* 16.

What was the particular frame and manner of theſe engines, cannot certainly be determined; but to contrive ſuch as may perform the like ſtrange effects, were not very difficult to any one who is throughly verſed in the grounds of this art. Though perhaps thoſe of *Archimedes* in reſpect of divers circumſtances, were much more exact and proper for the purpoſes to which they were intended, than the invention of others could be; He himſelf being ſo extraordinarily ſubtil and ingenious above the common ſort of men.

'Tis probable that the general kind of theſe engines, were the ſame with thoſe that were uſed after-

wards

wards amongst the *Romans* and other Nations. These were commonly divided into two sorts: styled

{ *Ballistæ.*
{ *Catapultæ.*

Both which names are sometimes used promiscuously; but according to their propriety † *Ballista* does signifie an engine for the shooting of stones, and *Catapulta* for darts or arrows.

Vid. Naudæum de Stud. Militar. l. 2

† ἀπὸ τοῦ βάλλειν, called also λιθόβολος. πετρόβολος. *Fundibalus. Petraria.*

The former of these was fitted either to carry divers lesser stones, or else one greatest one. Some of these engines made for great stones, have been proportioned to so vast and immense a weight, as may seem almost incredible: which occasioned that in *Lucan.*

Lib. 3.

At saxum quoties ingenti verberis ictu
Excutitur, qualis rupes quam vertice montis
Abscidit impulsu ventorum adjuta vetustas,
Frangit cuncta rumes; nec tantum corpora pressa
Exanimat, totos cum sanguine dissipat artus.

With these, they could easily batter down the walls and Towers of any Fort. So *Ovid.*

Quam

Quam grave balliſtæ mœnia pulſat onus.

And *Statius*—*Quo turbine bellica quondam.*

Librati ſaliunt portarum in clauſtra molares.

The ſtones that were caſt from theſe, were of any form, *Enormes & ſepulchrales*, Milſtones or Tomb-ſtones. Sometimes for the farther annoyance and terror of any beſieged place, they would by theſe throw into it dead bodies, either of men or horſes, and ſometimes only parts of them, as mens heads.

Lipſius Poliorcet. l. 3. Dial. 3.

Athenæus mentions one of theſe *Balliſtæ* that was proportiond unto a ſtone of three talents weight, each talent being 120 pounds (ſaith *Vitruvius*) ſo that the whole will amount to 360 pounds. But it is ſtoried of *Archimedes*, that he caſt a ſtone into one of *Marcellus* his ſhips, which was found to weigh ten talents. There is ſome difference amongſt* Authors, concerning what kind of talent this ſhould be underſtood, but it is certain that

Deipnoſoph. l. 5.

Archit. l. 10. c. ult.

λίθον δεκατάλαντον.

Plut. Marcell.

**Dav. Rivaltus Cômen in Archim. Oper. Ext.*

that in *Plutarchs* time, (from whom we have this relation) one talent did amount to 120 pounds (ſaith *Suidas*): according to which account, the ſtone it ſelf was of no leſs than twelve hundred pound weight. A weapon (one would think) big enough for thoſe rebel Gyants that fought againſt the gods. Now the greateſt Cannon in uſe, does not carry above 64 pound weight, which is far ſhort of the ſtrength in theſe Mathematical contrivances. Amongſt the Turks indeed, there have been ſometimes uſed ſuch powder-inſtruments, as may equal the force of thoſe invented by *Archimedes*. *Gab. Naudæus* tells us of one bullet ſhot from them at the ſiege of *Conſtantinople*, which was of above 1200 pound weight; This he affirms from the relation of an Archbiſhop, who was then preſent and did ſee it; the piece could not be drawn by leſs than a hundred and fifty yoak of oxen, which might almoſt have ſerved to draw away the Town it ſelf. But though there hath been perhaps ſome one

Naudæus de ſtudio. Milit. l. 2.

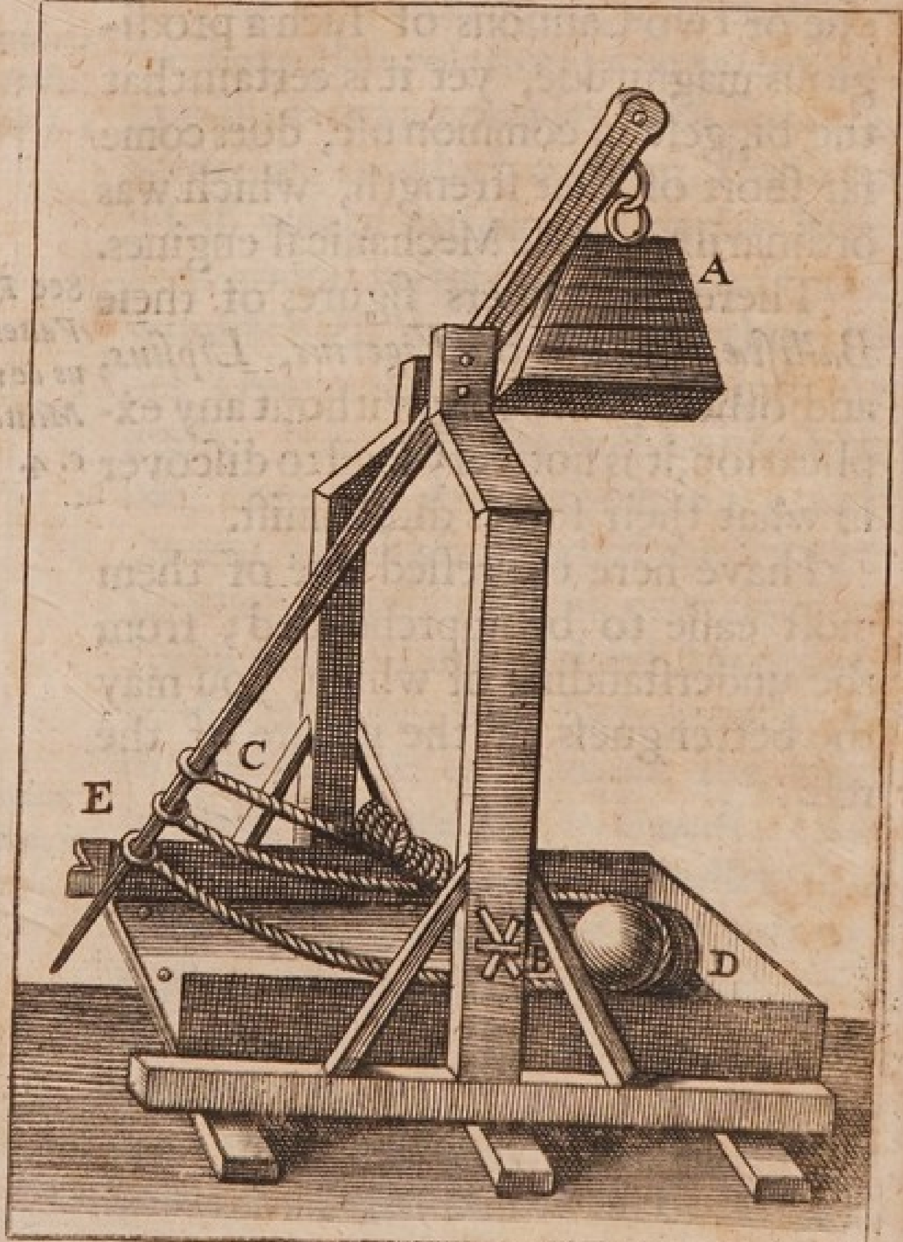
De Stud. Mil. l. 2.

one or two Cannons of ſuch a prodigious magnitude, yet it is certain that the biggeſt in common uſe, does come far ſhort of that ſtrength, which was ordinarily in theſe Mechanical engines.

There are divers figures of theſe *Balliſtæ*, ſet out by *Vigetius*, *Lipſius*, and others; but being without any explication, it is not very facil to diſcover in what their forces did conſiſt. See *Rob*: *Valteurius de re Milit.l.*10 *c*: 4.

I have here expreſſed one of them moſt eaſie to be apprehended; from the underſtanding of which, you may the better gueſs at the nature of the reſt.

That



That great box or cavity at *A*, is ſuppoſed to be full of ſome heavy weight, and is forced up by the turning

ning of the axis and ſpokes *BC*. The ſtone or bullet to be diſcharged being in a kind of ſling at *D*, which when the greater weight *A*, deſcends, will be violently whirled upwards, till that end of the ſling at *E*, coming to the top, will flye off, and diſcharge the ſtone as the skilful Artiſt ſhould direct it.

CAP. XVIII.

Concerning the Catapultæ, or Engines for Arrows.

THe other kind of engine was called *Catapultæ*, ἀπὸ τῆς πέλτης, which ſignifies a ſpear or dart, becauſe it was uſed for the ſhooting of ſuch weapons: ſome of theſe were proportioned unto ſpears of twelve cubits long; they did carry with ſo great a force, *ut interdum nimio ardore ſcintillant*, (ſaith *Ammianus*) that the weapons diſcharged from them were ſometimes (if you can believe it) ſet on fire by the ſwiftneſs of their motion.

In Greek καταπέλ-τῆς.

Athenæus, Deipnoſ. l. 5.

Lib. 23.

Lipſius Poliorcet. l. 3. *Dial.* 2.

Diod. Sic. Biblioth. l. 14. Sardus de Invent. Rerum. l. 2.

The first invention of these is commonly ascribed to *Dionysius* the younger, who is said to have made them amongst his other preparations against *Carthage*. But we have good reason to think them of more ancient use, because we read in Scripture that *Uzziah made in Jerusalem engines invented by cunning men to shoot arrows and great stones withall:* though it is likely these inventions were much bettered by the experience of after-ages.

2 Chron. 26. 15.

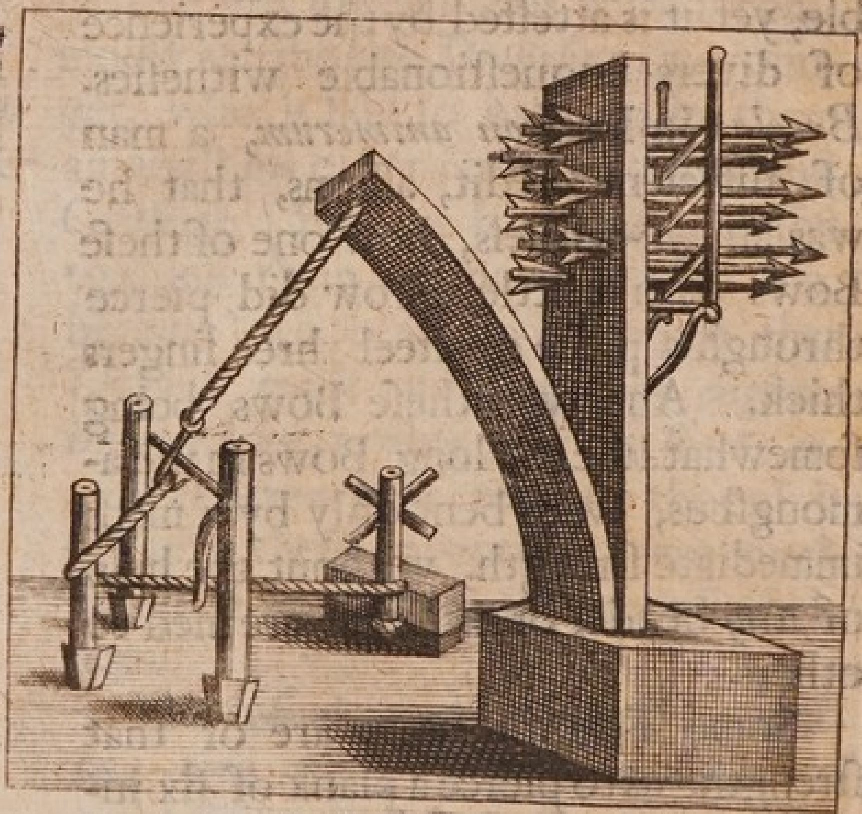
The usual form of these *Catapultæ*, was much after the manner of great Bows placed on Carriages, and wound up by the strength of several persons. And from that great force which we find in lesser Bows, we may easily ghess at the greater power of these other engines. 'Tis related of the Turkish Bow, that it can strike an arrow through a piece of steel or brass two inches thick; and being headed only with word, it pierces Timber of eight inches. Which though it may seem incredible,

Sir Fran. Bacon Nat. Hist. Exp. 704.

ble, yet it is atteſted by the experience of divers unqueſtionable witneſſes. *Barclay* in his *Icon animorum*, a man of ſufficient credit, affirms, that he was an eye-witneſs, how one of theſe Bows with a little arrow did pierce through a piece of ſteel three fingers thick. And yet theſe Bows being ſomewhat like the long Bows in uſe amongſt us, were bent only by a mans immediate ſtrength, without the help of any bender or rack that are uſed to others.

Some Turkiſh Bows are of that ſtrength, as to pierce a plank of ſix inches in thickneſs, (I ſpeak what I have ſeen) ſaith *M. Jo. Greaves* in his *Pyramodographia*. How much greater force then may we conceive to be impreſſed by the *Catapultæ*?

Theſe were ſometimes framed for the diſcharging of two or three arrows together, ſo that each of them might be directed unto a ſeveral aim. But it were as eaſie to contrive them after the like manner for the carriage of twenty arrows, or more, as in this figure.



Both these kinds of engines when they were used at the siege of any City, were commonly carried in a great wooden Turret (first invented by * *Demetrius*). It was driven upon four wheels at the bottom, each of its sides being forty five cubits, its height ninety. The whole was divided into nine several partitions, every one of which did contain divers engines for battery: from its use in the battering and taking of Cities it is stiled

* Who was before styled *Potorcetes.* This kind of Turret was first used at the siege of *Cyprus*, and is thus described by *Diodorus. Sicul. Biblioth. l. 20.*

ſtiled by the name of *Helepolis.*

He that would be informed in the nature of Bows, let him conſult *Merſennus De Balliſtica & Acontiſmologia*, where there are divers ſubtil inquiries and demonſtrations, concerning the ſtrength required to the bending of them to any diſtance. The force they have in the diſcharge according to ſeveral bents, the ſtrength required to be in the ſtringof them, the ſeveral proportions of ſwiftneſs and diſtance in an arrow ſhot vertically, or horizontally, or tranſverſally.

Thoſe ſtrange effects of the Turkiſh Bow (mentioned before) ſo much exceeding the force of others, which yet require far greater ſtrength for the bending of them, may probably be aſcribed either to the natural cauſe of *attraction by ſimilitude of ſubſtance* (as the Lord *Bacon* conjectures); For in theſe experiments the head of the arrow ſhould be of the ſame ſubſtance (whether ſteel or wood) with that which it pierces: Or elſe to that *juſt proportion* betwixt the weight of the arrow, and the ſtrength of the bow, which muſt needs much conduce to the force of it, and may perhaps be more exactly diſcovered in theſe, then it is commonly in others.

CAP. XIX.

A compariſon betwixt theſe ancient Engines, and the Gun-powder inſtruments now in uſe.

IT ſhall not be altogether impertinent to inquire ſomewhat concerning the advantages and diſadvantages betwixt thoſe Militay offenſive engines, uſed amongſt the Ancients, and thoſe of theſe later ages.

In which inquiry there are two particulars to be chiefly examined:

1. The force of theſe ſeveral contrivances, or the utmoſt that may be done by them.

2. Their price, or the greatneſs of the charges required unto them.

1. As for the force of theſe anci-

ent inventions, it may ſufficiently appear from thoſe many credible relations mentioned before; to which may be added that in *Joſephus*, which he ſets down from his own eye-ſight, being himſelf a chief Captain at the ſiege of *Jotapata*, where theſe events happened. He tells us that beſides the multitude of perſons, who were ſlain by theſe *Roman* Engines, being not able to avoid their force, by reaſon they were placed ſo far off, and out of ſight; beſides this, they did alſo carry ſuch great ſtones, with ſo great a violence, that they did therewith batter down their walls and Towers. A great-bellied woman walking about the City in the day-time, had her child ſtruck out of her womb, and carried half a furlong from her. A ſoldier ſtanding by his Captain *Joſephus*, on the wall, had his head ſtruck off by another ſtone ſent from theſe *Roman* Engines, and his brains carried three furlongs off. *De bello Judaico, l. 3. c. 9.*

To this purpoſe *Cardan* relates out of *Ammianus Marcellinus*, *Tanto* *De variet. l. 12. c. 58.*

impetu fertur lapis ut uno viso lapide quamvis intacti barbari fuerint ab eo, destiterunt à pugna & abierunt. Many foreign people being so amazed at the strange force of these Engines, that they durst not contest with those who were masters of such inventions. 'Tis frequently asserted, that bullets have been melted in the air, by that extremity of violent motion imprest from these slings.

Fundáque contorto transverberat aëra plumbo,
Et mediis liquidæ glandes in nubibus errant.

So *Lucan*, speaking of the same Engines.

Inde faces & saxa volant, spatioque solutæ.
Aëris & calidæ liquefactæ pondere glandes.

Which relations, though they may seem somewhat poetical and improbable, yet *Aristotle* himself (*De Cœlo, lib. 2. c. 7.*) doth suppose them as unquestionable. From whence it may be inferred, that the force of these Engines

gines does rather exceed than come ſhort of our Gun-powder inventions.

Add to this that opinion of a learned man (which I cited before) that *Archimedes* in the ſiege of *Syracuſe*, did more michief with his Engines, than could have been wrought by any Cannons, had they been then in uſe.

Sir Walt. Raleigh *Hiſt. l.* 5. *c.* 3. *Sect.* 16. See *Lipſins de militiâ Romanâ. l.* 5.

In this perhaps there may be ſome diſadvantage, becauſe theſe Mathematical Engines cannot be ſo eaſily and ſpeedily wound up, and ſo certainly levelled as the other may.

2. As for the price or charges of both theſe, it may be conſidered under three particulars:

1. Their making.
2. Their carriage or conveyance.
3. Their charge and diſcharging.

In all which reſpects, the Cannons now in uſe, are of much greater coſt than theſe other inventions.

1. The making or price of theſe Gun-powder inſtruments is extremely expenſive, as may be eaſily judged by the weight of their materials. A whole

Cannon

Cannon weighing commonly 8000 *l.* a half Cannon 5000, a Culverin 4500, a Demiculverin 3000; which whether it be in iron or braſs, muſt needs be very coſtly, only for the matter of them; beſides the farther charges required for the form and making of them, which in the whole muſt needs amount to ſeveral hundred pounds. Whereas theſe Mathematical inventions conſiſting chiefly of Timber, and Cords, may be much more cheaply made; The ſeveral degrees of them which ſhall anſwer in proportion to the ſtrength of thoſe other, being at the leaſt ten times cheaper; that is, ten Engines that ſhall be of equal force either to a Cannon or Demicannon, Culverin or Demiculverin, may be framed at the ſame price that one of theſe will amount to: So that in this reſpect there is a great inequality.

2. As for the Carriage or conveyance; a whole Cannon does require at the leaſt 90 men, or 16 horſes, for the draught of it; a half Cannon 56 men,

men, or 9 horſes; a Culverin 50, men, or 8 horſes; a Demiculverin 36 men, or 7 horſes; Suppoſing the way to be hard and plain, in which notwithſtanding the motion will be very ſlow. But if the paſſage prove riſing and ſteep, or rotten and dirty, then they will require a much greater ſtrength and charge for the conveyance of them. Whereas theſe other inventions are in themſelves more light (if there be occaſion for the draught of them) being eaſily taken aſunder into ſeverals parts. And beſides their materials are to be found every where, ſo that they need not be carried up and down at all, but may be eaſily made in the place where they are to be uſed:

3. The materials required to the charging of theſe Gun-powder inſtruments are very coſtly. A whole Cannon requiring for every charge 40 pounds of powder, and a bullet of 64 pounds; a half Cannon 18 pounds of powder, and a bullet of 24 pounds; a Culverin 16 pounds of powder, and

a bullet of 19 pounds; a Demiculverin 9 pounds of powder, and a bullet of 12 pounds: whereas those other Engines may be charged only with ſtones, or (which may ſerve for terrour) with dead bodies, or any ſuch materials as every place will afford without any coſt.

So then, put all theſe together; If it be ſo that thoſe ancient inventions did not come ſhort of theſe other in regard of force, and if they do ſo much excel them in divers others reſpects; It ſhould ſeem then, that they are much more commodious than theſe latter inventions, and ſhould be preferred before them. But this enquiry cannot be fully determined without particular experience of both.

CAP.

CAP. XX.

That it is possible to contrive such an artificial motion, as may be equally swift with the supposed motion of the heavens.

FOR the conclusion of this Discourse, I shall briefly examine (as before concerning slowness) whether it be possible to contrive such an artificial motion, as may be equal unto the supposed swiftness of the heavens. This question hath been formerly proposed and answered by *Cardan*, where he applies it unto the swiftness of the Moons Orb; but that Orb being the lowest of all, and consequently of a dull and sluggish motion, in comparison to the rest; therefore it will perhaps be more convenient to understand the question concerning the eighth sphere or starry heaven. *De Variet. Rerum l. 9. c. 47.*

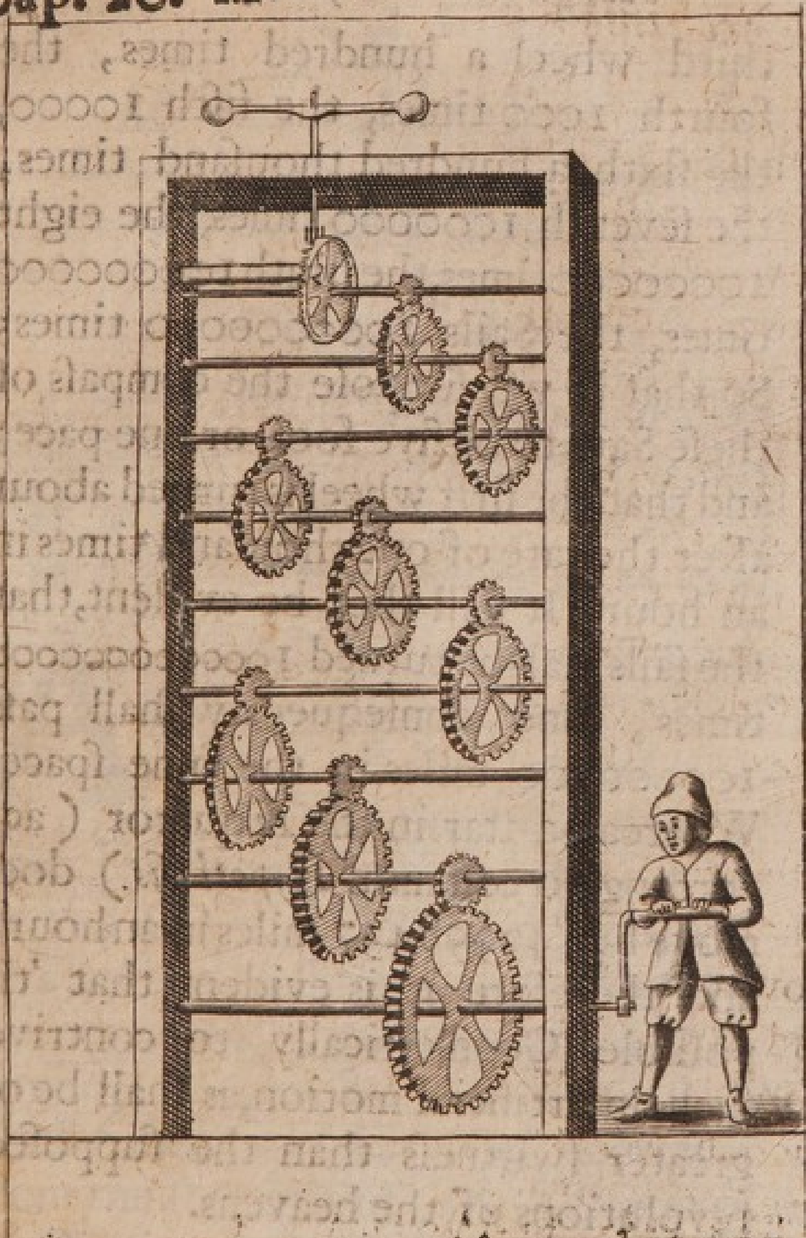
For the true resolution of this, it should be first observed, that a material substance is altogether incapable

ble of ſo great a celerity, as is uſually aſcribed to the Celeſtiall Orbs, (as I have proved elſewhere). And therefore the quæry is not to be underſtood for any real and experimental, but only notional and Geometrical contrivance.

The earth a Planet, prop. 9.

Now that the ſwiftneſs of motion may be thus increaſed, according to any conceivable proportion, will be manifeſt from what hath been formerly delivered concerning the grounds and nature of ſlowneſs and ſwiftneſs. For according as we ſhall ſuppoſe the power to exceed the weight; ſo may the motion of the weight be ſwifter than that of the power.

But to anſwer more particularly: Let us imagine every wheel in this following figure to have an hundred teeth in it, and every nut ten:



It may then be evident, that one revolution of the first wheel, will turn the nut, and consequently the second wheel on the same axis ten times, the third wheel a hundred times, the fourth 1000 times, the fifth 10000, the ſixth a hundred thouſand times, the ſeventh 1000000 times, the eight 10000000 times, the ninth 100000000 times, the Sails 1000000000 times; So that if we ſuppoſe the compaſs of theſe Sails to be five foot, or one pace; and that the firſt wheel is turned about after the rate of one thouſand times in an hour: It will then be evident, that the ſails ſhall be turned 1000000000000 times, and conſequently ſhall paſs 100000000 miles in the ſame ſpace. Whereas a ſtar in the Æquator (according to common *Hypotheſis*) does move but 42398437 miles in an hour; and therefore it is evident that 'tis poſſible Geometrically to contrive ſuch an artificial motion, as ſhall be of greater ſwiftneſs than the ſuppoſed revolutions of the heavens.

DÆDA-

DÆDALUS: OR, Mechanical Motions.

The Second Book.

CHAP. I.

The divers kind of Automata, *or Self-movers. Of Mills, and the contrivance of several motions by rarified air. A brief digression concerning wind-guns*

Amongst the variety of artificial motions, those are of most use and pleasure, in which, by the application of some continued strength, there is bestowed a regular and lasting motion.

These we call the αὐτόματα, or *self-movers:* which name in its utmost latitude, is sometimes ascribed unto those motions that are contrived from the strength of living creatures, as Chariots, Carts, &c. But in its strictness and propriety, it is only appliable unto such inventions, wherein the motion is caused either by somthing that belongs unto its own frame, or else by some external inanimate agent.

Whence these αὐτόματα are easily distinguishable into two sorts:

1. Those that are moved by something which is extrinsecal unto their own frame, as Mills by water or wind.

2. Those that receive their motion from something that does belong to the frame it self, as Clocks, Watches, by weights, springs, or the like.

Of both which sorts there have been many excellent inventions: In the recital of them, I shall insist chiefly on such as are most eminent for their rarity and subtilty.

Amongst the αὐτόματα that receive their motion from some external agent, those of more common use are Mills.

And first, the Water-mills, which are thought to be before the other, though neither the first Author, nor so much as the time wherein they were invented is fully known. And therefore *Polydor Virgil* refers them amongst other fatherless inventions. *Pliny* indeed doth mention them, as being commonly used in his ti me: and yet others

De invent. Rerum, l. 3 *c.* 18.

Nat. Hist. l. 18. *c.* 10.

others affirm, that *Bellisarius* in the reign of *Justinian*, did first invent them: Whence *Pancirollus* concludes, that it is likely their use was for some space intermitted, and being afterwards renewed again, they were then thought to be first discovered. *De Repert. Tit. 22.*

However 'tis certain, that this invention hath much abridged and advantaged the labours of men, who were before condemned unto this slavery, as now unto the Galleys. And as the force of waters hath been useful for this, so likewise may it be contrived to divers other purposes. Herein doth the skill of an artificer chiefly consist, in the application of these common motions unto various and beneficial ends, making them serviceable not only for the grinding of corn, but for the preparing of iron or other oar, the making of paper, the elevating of water, or the like. *Ad Pistrinum.*

To this purpose also are the Mills that are driven by wind, which are so much more convenient than the other, by how much their situations may be more easie and common. The motions of these may likewise be accommodated to as various uses as the other, there being scarce any labour, to the performance of which an ingenious artificer cannot apply them. To the sawing of Timber, the plowing of land, or any other the like service, which cannot be dispatched the ordinary way, without much toil and tediousness. And it is a wonderful thing to consider, how much mens labours might be eased and contracted in sundry particulars, if such as were well skilled in the principles and practises of these Mechanical experiments, would but thorowly apply their studies unto the inlargement of such inventions.

There are some other motions by wind or air, which (though they are not so common as the other), yet may prove of excellent curiosity, and singular use. Such was that musical instrument invented by *Cornelius Dreble*, which being set in the sun-shine, would of it self render a soft and pleasant

Marcell. Vrankhein. Epist. ad Joh. Ernestum.

pleaſant harmony, but being removed into the ſhade would preſently become ſilent. The reaſon of it was this: the warmth of the ſun, working upon ſome moiſture within it, and rarifying the inward air unto ſo great an extenſion, that it muſt needs ſeek for a vent or iſſue, did thereby give ſeveral motions unto the inſtrument.

Like that ſtatue of *Memnon*, in *Egypt*, which makes a ſtrange noiſe whenever the ſun begins to ſhine upon it.

Tacit. Annal. 2. *Strabo* affirms that he had both ſeen and heard it.

Somewhat of this nature are the *Eolipiles*, which are concave Veſſels, conſiſting of ſome ſuch material as may indure the fire, having a ſmall hole, at which they are filled with water, and out of which (when the Veſſels are heated) the air doth iſſue forth with a ſtrong and laſting violence. Theſe are frequently uſed for the exciting and contracting of heat in the melting of glaſſes or metals. They may alſo be contrived to be ſerviceable for ſundry other pleaſant uſes, as for the moving of ſails in a chimney corner, the motion of which ſails may be applied to the turning of a ſpit, or the like.

But there is a better invention to

this purpoſe mentioned in *Cardan*, whereby a ſpit may be turned (without the help of weights) by the motion of the air that aſcends the Chimney; and it may be uſeful for the roaſting of many or great joynts: for as the fire muſt be increaſed according to the quantity of meat, ſo the force of the inſtrument will be augmented proportionably to the fire. In which contrivance there are theſe conveniences above the Jacks of ordinary uſe.

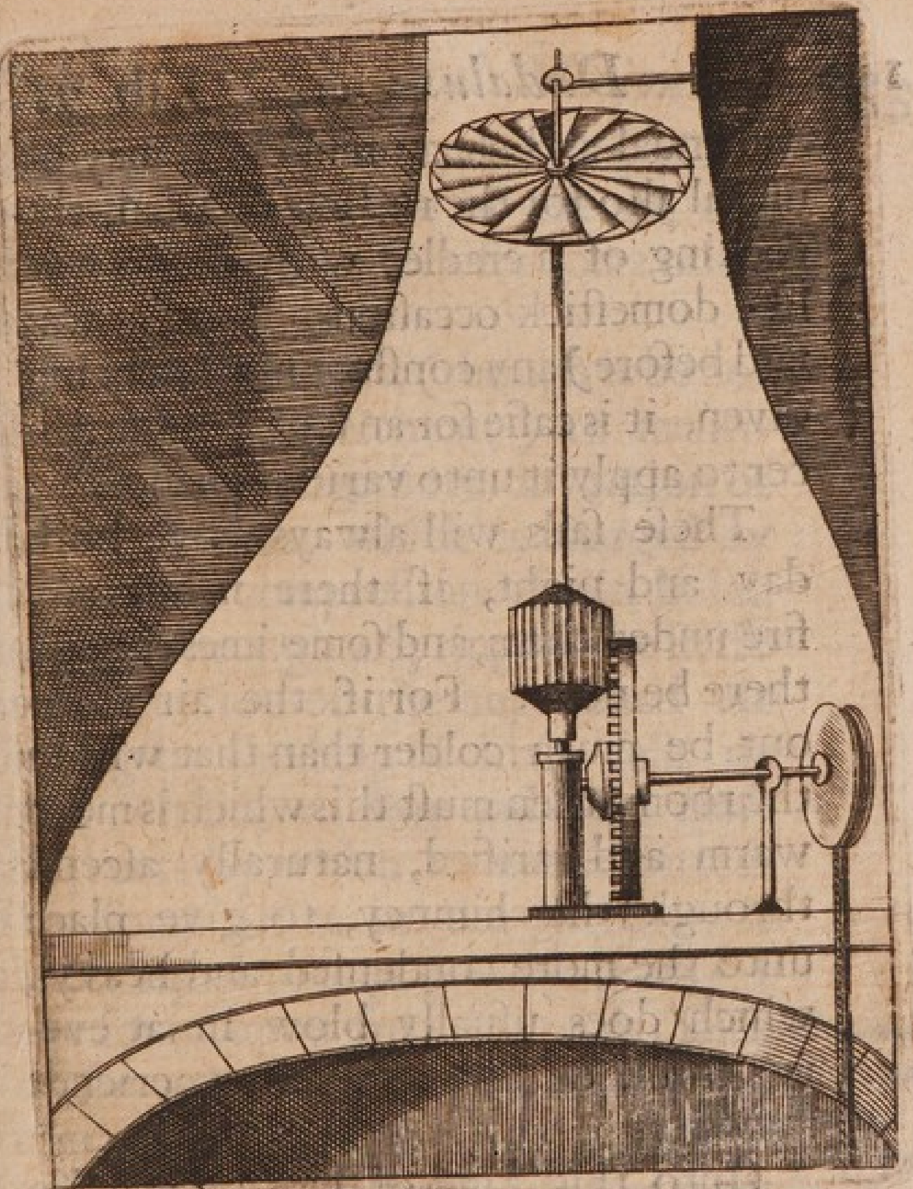
De Variet. Rerum, l. 12, c. 58.

1. It makes little or no noiſe in the motion.

2. It needs no winding up, but will conſtantly move of it ſelf, while there is any fire to rarifie the air.

3. It is much cheaper than the other inſtruments that are commonly uſed to this purpoſe. There being required unto it only a pair of ſails, which muſt be placed in that part of the Chimney where it begins to be ſtraightned, and one wheel, to the axis of which the ſpit line muſt be faſtned, according to this following Diagram.

The



The motion of theſe ſails may likewiſe be ſerviceable for ſundry other purpoſes, beſides the turning of a ſpit; for the chiming of bells or other muſical devices; and there cannot be any more pleaſant contrivance for continual and cheap muſick. It may be uſeful alſo for the reeling of yarn, the rocking of a cradle, with divers the like domeſtick occaſions. For (as was ſaid before) any conſtant motion being given, it is eaſie for an ingenious artificer to apply it unto various ſervices.

Theſe ſails will always move both day and night, if there is but any fire under them, and ſometimes though there be none. For if the air without be much colder than that within the room, then muſt this which is more warm and rarified, naturally aſcend through the chimney, to give place unto the more condenſed and heavy, which does uſually blow in at every chink or cranny, as experience ſhews.

Unto this kind of motion may be reduced all thoſe repreſentations of living creatures, whether birds, or beaſts, invented by *Cteſibius*, which were for the moſt part performed by the motion of air, being forced up either by *rarefaction*, with fire, or elſe by *compreſſion*, through the fall

of

of ſome heavier body, as water, which by poſſeſſing the place of the air, did thereby drive it to ſeek for ſome other vent.

I cannot here omit (though it be not altogether ſo pertinent) to mention that late ingenious invention of the winde-gun, which is charged by the forcible compreſſion of air, being injected through a Syringe; the ſtrife and diſtention of the impriſoned air ſerving by the help of little falls or ſhuts within, to ſtop and keep cloſe the vents by which it was admitted. The force of it in the diſcharge is almoſt equal to our powder-guns. I have found upon frequent trials (ſaith *Merſennus*) that a leaden bullet ſhot from one of theſe Guns againſt a ſtone wall, the ſpace of 24 paces from it, will be beaten into a thin plate. It would be a conſiderable addition to this experiment which the ſame Author mentions a little after, whereby he will make the ſame charge of air to ſerve for the diſcharge of ſeveral arrows or bullets after one another,

Phænomena pneumatica, prop. 32.

nother, by giving the air only ſo much room, as may immediatly ſerve to impreſs a violence in ſending away the arrow or bullet, and then ſcrewing it down again to its former confinement, to fit it for another ſhooting. But againſt this there may be many conſiderable doubts, which I cannot ſtand to diſcuſs.

CAP. II.

Of a ſailing Chariot, that may without horſes be driven on the land by the wind, as ſhips are on the ſea.

THE force of wind in the motion of ſails may be applied alſo to the driving of a Chariot, by which a man may ſail on the land as well as by a ſhip on the water. The labour of horſes or other beaſts, which are uſually applied to this purpoſe, being artificially ſupplied by the ſtrength of winds.

That ſuch Chariots are commonly uſed in the Champion plains of *China*, is frequently affirmed by divers credible Authors. *Boterus* mentions that they have been tried alſo in *Spain*, though

De incremento Urbium, l. 1. c. 10.

though with what ſucceſs he doth not ſpecifie. But above all other experiments to this purpoſe, that ſailing Chariot at *Sceveling* in *Holland*, is more eminently remarkable. It was made by the direction of *Stephinus*, & is celebrated by many Authors. * *Walchius* affirms it to be of ſo great a ſwiftneſs for its motion, and yet of ſo great a capacity for its burden. *Ut in medio freto ſecundis ventis commiſſas naves, velocitate multis paraſangis poſt ſe relinquat, & paucarum horarum ſpatio, viginti aut triginta milliaria Germanica continuo curſu emetiatur, concreditoſq; ſibi plus minus vectores ſex aut decem, in petitum locum transferat, faciLlimo illius ad clavum qui ſedet nutu, quaquæ verſum minimo labore velis commiſſum, mirabile hoc continenti currus navigium dirigentis.* That it did far exceed the ſpeed of any ſhip, though we ſhould ſuppoſe it to be carried in the open ſea with never ſo proſperous wind: and that in ſome few hours ſpace it would convey 6 or 10 perſons 20 or 30 German miles, and all this with very little labour of him that ſitteth at the Stern, who

* *Fabularum decas, Fab. 9.*

who may eaſily guide the courſe of it as he pleaſeth.

That eminent inquiſitive man *Peireskius*, having travelled to *Sceveling* for the ſight and experience of this Chariot, would frequently after with much wonder mention the extreme ſwiftneſs of its motion. *Commemorare ſolebat ſtuporem quo correptus fuerat cum vento tranſlatus citatiſſimo non perſentiſcere tamen, nempe tam citus erat quam ventus.* Though the wind were in it ſelf more ſwift and ſtrong, yet to paſſengers in this Chariot it would not be at all diſcernable, becauſe they did go with an equal ſwiftneſs to the wind it ſelf. Men that ran before it, ſeeming to go backwards; things which ſeem at a great diſtance being preſently overtaken and left behind. In two hours ſpace it would paſs from *Sceveling* to *Putten*, which are diſtant from one another above 14 *Horaria milliaria* (ſaith the ſame Author) that is more than two and forty miles.

Pet. Gaſſendus. Vita Peireſkii, l. 2.

Grotius is very copious and elegant in the celebrating of this invention, and the

the Author of it, in divers Epigrams.

Ventivolam Tiphys deduxit in æquora navim, *Grotii Poemata, Ep. 19.*
Jupiter in ſtellas, æthereamque domum
Interreſtre ſolum virtus Stevinia, nam nec
Tiphy tuum fuerat, nec Jovis iſtud opus.

And in another place,

Impoſuit plauſtro vectantem carbaſa, malum
An potius navi, ſubdidit ille rotas? *Ep. 5.*
—Scandit æquas navis currus ruit aere prono;
Et merito dicas hic volat, illa natat.

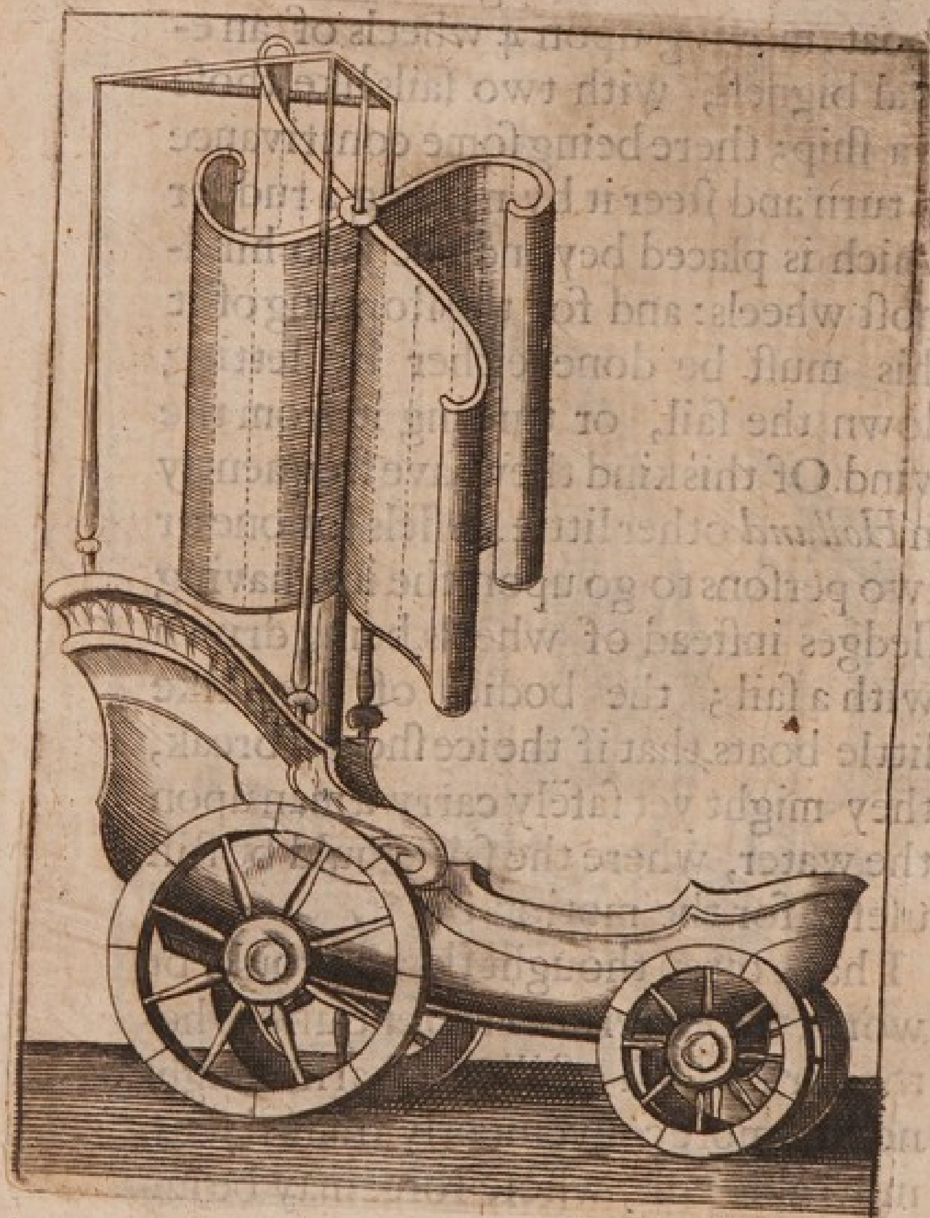
Theſe relations did at the firſt ſeem unto me, (and perhaps they will ſo to others) ſomewhat ſtrange and incredible. But upon farther enquiry I have heard them frequently atteſted from the particular eye-ſight and experience of ſuch eminent perſons, whoſe names I dare not cite in a buſineſs of this nature, which in thoſe parts is ſo very common, and little obſerved.

I have not met with any Author who doth treat particularly concerning the manner of framing this Chariot, though *Grotius* mentions an elegant deſcription of it in copper by one *Geynius*: and *Hondius* in one of his large Maps of *Aſia*, does give another conjectural deſcription of the like Chariots uſed in *China*. *Epig. 20. & 21.*

The form of it is related to be very ſimple and plain, after this manner:

The body of it being ſomewhat like a boat, moving upon 4 wheels of an e-qual bigneſs, with two ſails like thoſe in a ſhip; there being ſome contrivance to turn and ſteer it by moving a rudder which is placed beyond the two hind-moſt wheels: and for the ſtopping of it this muſt be done either by letting down the ſail, or turning it from the wind. Of this kind they have frequently in *Holland* other little Veſſels for one or two perſons to go upon the ice, having ſledges inſtead of wheels, being driven with a ſail; the bodies of them like little boats, that if the ice ſhould break, they might yet ſafely carry a man upon the water, where the ſail would be ſtill uſeful for the motion of it.

I have often thought that it would be worth the experiment to enquire, whe-ther or no ſuch a ſailing-Chariot might not be more conveniently framed with moveable ſails, whoſe force may be im-preſt from their motion, equivalent to thoſe in a wind-mill. Their foremoſt wheels (as in other Chariots) for the greater facility, being ſomewhat lower than the other, anſwerable to this figure.



In which the ſails are ſo contrived, that the wind from any Coaſt will have a force upon them to turn them about, and the motion of theſe ſails muſt needs turn the wheels, and conſequently carry on the Chariot it ſelf to any place (though fully againſt the wind) whither it ſhall be directed.

The chief doubt will be, whether in ſuch a contrivance every little ruggedneſs or unevenneſs of the ground, will not cauſe ſuch a jolting of the Chariot as to hinder the motion of its ſails. But this perhaps (if it ſhould prove ſo) is capable of ſeveral remedies.

I have often wondred, why none of our Gentry who live near great Plains, and ſmooth Champions, have attempted any thing to this purpoſe. The experiments of this kind being very pleaſant, and not coſtly: what could be more delightful or better husbandry, than to make uſe of the *wind* (which coſts nothing, and eats nothing) inſtead of *horſes*? This being very eaſie to be effected by thoſe, the convenience of whoſe habitations doth accommodate them for ſuch experiments.

CAP. III.

Concerning the fixed Automata, *Clocks, Spheres, repreſenting the heavenly motions: The ſeveral excellencies that are moſt commendable in ſuch kind of contrivances.*

THE ſecond kind of αὐτόματα were deſcribed to be ſuch Engines, as did receive a regular and laſting motion from ſomething belonging to their own frame, whether weights, or ſprings, &c.

They are uſually diſtinguiſhed into αὐτόματα.

$\begin{cases} \text{στάτα, fixed and ſtationary.} \\ \text{ὑπάγοντα, moveable and tranſient.} \end{cases}$

1. The fixed are ſuch as move only according to their ſeveral parts, and not according to their whole frame; In which, though each wheel hath a diſtinct rotation, yet the whole doth ſtill remain unmoved. The chiefeſt kind

kind of theſe are the Clocks and Watches in ordinary uſe, the framing of which is ſo commonly known by every Mechanick, that I ſhall not trouble the Reader with any explication of it. He that deſires fuller ſatiſfaction, may ſee them particularly deſcribed by * *Cardan*, † D. *Flood*, and others.

The firſt invention of theſe (ſaith *Pancirollus*) was taken from that experiment in the multiplication of wheels mentioned in *Vitruvius*, where he ſpeaks of an inſtrument whereby a man may know how many miles or paces he doth go in any ſpace of time, whether or no he do paſs by water in a boat or ſhip, or by land in a Chariot or Coach: they have been contrived alſo into little pocket-inſtruments, by which after a man hath walked a whole day together, he may eaſily know how many ſteps he hath taken. I forbear to enter upon a larger explication of theſe kind of Engines, becauſe they are impertinent unto the chief buſineſs that

* *De Variet. Rer. l.* 9. *c.* 47.

† *Tract.* 2. *part.* 7. *l.* 1. *cap.* 4.

Repert. Tit. 10. *Architect. l.* 10. *c.* 14.

I have propoſed for this diſcourſe. The Reader may ſee them more particularly deſcribed in the above-cited place of *Vitruvius*, in * *Cardan.* † *Beſſonius*, and others; I have here only mentioned them, as being the firſt occaſion of the chiefeſt αὐτόματα that are now in uſe.

*Subtil.

† *Thearum inſtrumentorum. Weeker de ſecret. l. 15. c. 32.*

Of the ſame kind with our Clocks and Watches (though perhaps more elaborate and ſubtil) was that ſphere invented by *Archimedes*, which did repreſent the heavenly motions: the diurnal and annual courſes of the ſun, the changes and aſpects of the Moon, &c. This is frequently celebrated inthe writings of the Ancients, particularly in that known *Epigram* of *Claudian*:

Mentioned by *Cicero. Tuſcul. Quæſt. l. 1. item De Nat. Deorum l. 2.*

Jupiter in parvo cum cerneret æthera vitro,
Riſit, & ad Superos talia dicta dedit;
Huccine mortalis progreſſa potentia curæ?
Jam mens in fragili luditur orbe labor.
Jura poli, rerumque fidem, legeſque Deorum,
Ecce Syracuſius tranſtulit arte ſenex.
*Incluſius variis famulatur * ſpiritus aſtris,*
Et vivum certis motibus urget opus.

* The ſecret force from which the motion was impreſſed.

Per-

Percurrit proprium mentitus Signifer annum;
Et ſimulata novo Cynthia menſe redit.
Jamq; ſuum volvens audax induſtria mundum
Gaudet, & humanâ ſidera mente regit.
Quid falſo inſontem tonitru Salmonea miror?
Æmula naturæ parva reperta manus.

Excellently Tranſlated by
T. Randolph.

Jove ſaw the heavens fram'd in a little *glaſs*,
And laughing, to the gods theſe words did paſs;
Comes then the power of mortal cares ſo far?
In brittle orbs my labours acted are.
The ſtatutes of the Poles, the faith of things,
The laws of Gods, this *Syracuſian* brings
Hither by art: Spirits inclos'd attend
Their ſeveral ſpheres, and with ſet motions bend
The living work: each year the feigned Sun,
Each month returns the counterfeited Moon.
And viewing now her world, bold induſtry
Grows proud, to know the heavens his ſubjects be.
Believe, *Salmoneus* hath falſe thunders thrown,
For a poor hand is natures rival grown.

But that this Engine ſhould be made of glaſs, is ſcarce credible. *Lactantius* mentioning the relation of it, affirms it to conſiſt of braſs, which is more likely. It may be the outſide or caſe was glaſs, and the frame it ſelf of braſs. *Cœlius Rhodoginus*, ſpeaking of the wondrous art in the contrivance of

Inſtit. l. 2. c. 5.

Ant. q. eſt l. 2. c. 16.

of this Sphere, breaks out into this quære, *Nonne igitur miraculorum omnium maximum miraculum est homo?* He might have said *Mathematicus:* And another to this purpose, *Sic manus ejus naturam, ut natura ipsa manum imitata putetur. Pappus* tells us, that *Archimedes* writ a Book *de Sphæropœia* concerning the manner of framing such Engines, and after him *Posidonius* composed another discourse on the same subject, though now either the ignorance or the envy of time hath deprived us of both those works. And yet the art it self is not quite perished, for we read of divers the like contrivances in these latter times. *Agrippa* affirms that he himself had seen such a sphere, and *Ramus* tels us how he beheld two of them in *Paris*, the one brought thither amongst other spoils from *Sicily*, and the other out of *Germany.* And it is commonly reported, that there is yet such a sphere at *Strasburgh* in *Germany.* * *Rivaltus* relates how *Marinus Burgesius* a *Norman* made two of them in *France* for the King.

Guid. Ubaldus præf ad Mechan

Collect. Mathem. Præm, ad l. 8.

De Vanit. Scient. cap. 22. Schol. Math. l. 1. So *Cardan* 100, *l.* 17. *Monanth. in Mecha. Arist. com. c. 1.* Dr. Hackwel, *Apol. l. 2. c. 10. sect. 1.*

* *De vitâ Archimedes.*

And

And perhaps theſe latter (ſaith he) were more exact than the former, becauſe the heavenly revolutions are now much better underſtood then before. And beſides, it is queſtionable, whether the uſe of ſteel-ſprings was known in thoſe ancient times; the application of which unto theſe kind of ſpheres muſt needs be much more convenient then weights.

'Tis related alſo of the Conſul *Boethius*, that amongſt other Mathematical contrivances, (for which he was famous) he made a ſphere to repreſent the Suns motion, which was ſo much admired, and talked of in thoſe times, that *Gundibaldus* King of *Burgundie*, did purpoſely ſend over Embaſſadors to *Theodoricus* the Emperour, with intreaties that he would be a means to procure one of theſe ſpheres from *Boethius*; the Emperor thinking hereby to make his kingdom more famous and terrible unto foreign Nations, doth write an Epiſtle to *Boethius*, perſwading him to ſend this inſtrument. *Quoties non ſunt credituri*

Caſſiodor. Chron. Pet. Bertius præf. ad Conſolat. Philoſ.

quod viderint? Quoties hanc veritatem luſoria ſomnia putabunt? Et quando fuerint à ſtupore converſi, non audebunt ſe æquales nobis dicere, apud quos ſciunt ſapientes talia cogitaſſe. So much were all theſe kind of inventions admired in thoſe ruder and darker times; whereas the inſtruments that are now in uſe amongſt us (though not ſo much extolled) yet do altogether equal (if not exceed) the other both in uſefulneſs and ſubtilty. The chiefeſt of theſe former Engines receiving their motion from weights, and not from ſprings, which (as I ſaid before) are of later and more excellent invention.

Polyd. Virgil. de invent. rerum l. 2. c. 5. Cardan Subt. l. 17.

The particular circumſtances for which the *Automota* of this kind, are moſt eminent, may be reduced to theſe four.

1. The laſtingneſs of their motion, without needing any new ſupply; for which purpoſe there have been ſome Watches contrived to continue without winding up for a week together, or longer.

2. The

2. The eaſineſs and ſimplicity of their compoſition; Art it ſelf being but the facilitating and contracting of ordinary operations, therefore the more eaſie and compendious ſuch inventions are, the more artificial ſhould they be eſteemed. And the addition of any ſuch unneceſſary parts, as may be ſupplied ſome other way, is a ſure ſign of unskilfulneſs and ignorance. Thoſe antiquated Engines that did conſiſt of ſuch a needleſs multitude of wheels, and ſprings, and ſcrews, (like the old *hypotheſis* of the heavens) may be compared to the notions of a confuſed knowledg, which are always full of perplexity and complications, and ſeldom in order; whereas the inventions of art are more regular, ſimple and perſpicuous, like the apprehenſions of a diſtinct and thoroughly informed judgment. In this reſpect the manner of framing the ordinary *Automata*, hath been much bettered in theſe latter times above the former, and ſhall hereafter perhaps be yet more advantaged.

Theſe

Theſe kind of experiments (like all other humane arts) receiving additions from every days experiment.

To this purpoſe there is an invention conſiſting only of one hollow orb or wheel, whereby the hours may be as truly diſtinguiſhed, as by any ordinary clock or watch. This wheel ſhould be divided into ſeveral cavities, through each of which ſucceſſively either ſand or water muſt be contrived to paſs; the heavineſs of theſe bodies (being always in the aſcending ſide of the wheel) muſt be counterpoiſed by a plummet that may be faſtned about the pulley on the axis: this plummet will leiſurely deſcend, according as the ſand by running out of one cavity into the next, doth make the ſeveral parts of the wheel lighter or heavier, and ſo conſequently there will be produced an equal and laſting motion, which may be eaſily applied to the diſtinction of hours.

3. The multitude and variety of thoſe ſervices for which they may be

be uſeful. Unto this kind may we refer thoſe Watches, by which a man may tell not only the hour of the day, but the minute of the hour, the day of the month, the age and aſpects of the Moon, &c. Of this nature likewiſe was that larum mentioned by *Walchius*, which though it were but two or three inches big, yet would both wake a man, and of it ſelf light a candle for him at any ſet hour of the night. And thoſe weights or ſprings which are of ſo great force as to turn a mill, (as ſome have been contrived) may be eaſily applied to more various and difficult labours.

Fab. 9.

Ramel. ſig. 130.

4. The littleneſs of their frame. *Nunquam ars magis quam in minimis nota eſt* (ſaith *Aquinas*). The ſmalneſs of the Engine doth much commend the skill of the Artificer; to this purpoſe there have been Watches contrived in the form and quantity of a Jewel for the ear, where the ſtriking of the minutes may conſtantly whiſper unto us, how our lives do ſlide away

Jacks no bigger than a walnut, to turn any joint of meat.

De subtil. l. 2. item l. 17.

away by a swift succession. *Cardan* tells us of a Smith who made a Watch in the Jewel of a ring, to be worn on the finger, which did shew the hours, (*non solum sagitta, sed ictu*) not only by the hand, but by the finger too (as I may say) by pricking it every hour.

CAP. IV.

Of the movable and Gradient Automota, representing the motions of living creatures, various sounds, of birds, or beasts, and some of them articulate.

THus much of those Automata, which were said to be fixed and stationary.

The other kind to be enquired after, are those that are movable and transient, which are described to be such engines as move not only according to their several parts, but also according to their whole frames. These are again distinguishable into two sorts :

1. *Gra-*

1. *Gradient.*
2. *Volant.*

1. The *Gradient* or *ambulatory*, are such as require some *basis* or bottom to uphold them in their motions. Such were those strange inventions (commonly attributed to *Dædalus*) or self-moving statues, which (unless they were violently detained) would of themselves run away, * *Aristotle* affirms that *Dædalus* did this by putting quick-silver into them. But this would have been too gross a way for so excellent an Artificer; it is more likely that he did it with wheels and weights. Of this kind likewise were *Vulcans Tripodes*, celebrated by *Homer*, that were made to move up and down the house, and fight with one another. He might as well have contrived them into Journey-men statues, each of which with a hammer in his hand should have worked at the forge.

Plato in Menone. Arist. Polit. l.1.c.3.

* *De Anima.l.1.c.3.*

Iliad. 18.

There have been also chariots driven by the force of a spring contrived within them.

But amongst these fighting images, that in *Cardan* may deserve a mention, which holding in its hand a golden apple, beautified with many costly Jewels;

De Variet. rerum. l. 12. *c.*58.

Jewels; if any man offered to take it, the ſtatue preſently ſhot him to death. The touching of this apple ſerving to diſcharge ſeveral ſhort bows, or other the like inſtruments that were ſecretly couched within the body of the image. By ſuch a treachery was King *Chennetus* murdered (as *Boethius* relates).

It is ſo common an experiment in theſe times to repreſent the perſons and actions of any ſtory by ſuch ſelf-moving images, that I ſhall not need to explain the manner how the wheels and ſprings are contrived within them.

Fab. 9. There have been other inventions to move on the water. *Navigium ſponte mobile, ac ſui remigii autorm, faciamnullo negotio,* ſaith *Scaliger, Exerc.* 326.

Amongſt theſe gradient *Automata,* that iron Spider mentioned in *Walchius,* is more eſpecially remarkable, which being but of an ordinary bigneſs, beſides the outward ſimilitude, (which was very exact) had the ſame kind of motions with a living ſpider, and did creep up and down as if it had been alive. It muſt needs argue a wonderfull art, and acurateneſs, to contrive all the inſtruments requiſite for ſuch a motion in ſo ſmall a frame.

There hath been alſo other motions contrived from Magnetical qualities, which will ſhew the more wonderful, becauſe there is no apparent reaſon of their motion, there being not the leaſt contiguity or dependance upon any other body that may occaſion it; but it is all one as if they ſhould move up and down in the open air. Get a glaſs ſphere, fill it with ſuch liquors as may be clear of the ſame colour, immixable, ſuch as are oyl of Tartar, and ſpirit of wine: In which, it is eaſie ſo to poiſe a little globe or other ſtatue, that it ſhall ſwim in the center. Under this glaſs ſphere, there ſhould be a loadſtone concealed, by the motion of which, the ſtatue (having a needle touched within it) will move up and down, and may be contrived to ſhew the hour or ſign. See ſeveral inventions of this kind in *Kircher de arte Magnetica, l.* 2.

There have been ſome artificial images, which beſides their ſeveral poſtures in walking up and down, have

have been made alſo to give ſeveral ſounds, whether of birds, as Larks, Cuckooes,&c. or beaſts,as Hares,Foxes. The voices of which creatures ſhall be rendered as clearly and diſtinctly, by theſe artificial images, as they are by thoſe natural living bodies, which they repreſent.

There have been ſome inventions alſo which have been able for the utterance of articulate ſounds, as the ſpeaking of certain words. Such are ſome of the *Egyptian* idols related to be. Such was the brazen head made by Fryer *Bacon*, and that ſtatue in the framing of which *Albertus Magnus* beſtowed thirty years, broken by *Aquinas*, who came to ſee it, purpoſely that he might boaſt, how in one minute he had ruined the labour of ſo many years.

Cœl. Rhod. lect. Ant. l. 2. *c.* 17. *Maiolus Colloq*,

Now the ground and reaſon how theſe ſounds were contrived, may be worth our inquiry.

Firſt then, for thoſe of birds or beaſts, they were made from ſuch pipes or calls, as may expreſs the ſeveral

veral tones of thoſe creatures which are repreſented: theſe calls are ſo commonly known and uſed, that they need not any further explication.

But now about articulate ſounds there is much greater difficulty. *Walchius* thinks it poſſible entirely to preſerve the voice, or any words ſpoken, in a hollow trunk, or pipe, and that this pipe being rightly opened, the words will come out of it in the ſame order wherein they were ſpoken. Somewhat like that cold Countrey, where the peoples diſcourſe doth freeze in the air all winter, and may be heard in the next Summer, or at a great thaw. But this conjecture will need no refutation. Fab. 9.

The more ſubſtantial way for ſuch a diſcovery, is by marking how nature her ſelf doth imploy the ſeveral inſtruments of ſpeech, the tongue, lips, throat, teeth, &c. To this purpoſe the Hebrews have aſſigned each letter unto its proper inſtrument. And beſides, we ſhould obſerve what inarticulate ſounds do reſemble any of the particular letters. Thus we may note the trembling of water to be like the letter *L*, the quenching of hot things to the letter *Z*, the ſound of ſtrings, unto the letter *Ng*, the jirking of a ſwitch the letter *Q*, &c. By an exact obſervation of theſe particulars, it is (perhaps) poſſible to make a ſtatue ſpeak ſome words.

Bacon *Nat. Hiſt.* Exper. 199 200.

CAP. V.

Concerning the poſſibility of framing an Ark for ſubmarine Navigations. The difficulties and conveniences of ſuch a contrivance.

IT will not be altogether impertinent unto the diſcourſe of theſe gradient *Automata*, to mention what *Merſennus* doth ſo largely and pleaſantly deſcant upon, concerning the making of a ſhip, wherein men may ſafely ſwim under water.

Tract. de Magnetis proprietatibus.

That ſuch a contrivance is feaſible and may be effected, is beyond all queſtion, becauſe it hath been already dy experimented here in *England* by *Cornelius Dreble*; but how to improve it unto publick uſe and advantage, ſo as to be ſerviceable for remote voyages, the carrying of any conſiderable number of men, with proviſions and commodities, would be of ſuch excellent uſe as may deſerve ſome further inquiry.

Concerning which there are two things chiefly conſiderable :

The { many difficulties with their remedies. / great conveniences. }

1. The difficulties are generally reducible to theſe three heads.

1. The letting out, or receiving in any thing, as there ſhall be occaſion, without the admiſſion of water. If it have not ſuch a convenience, theſe kind of voyages muſt needs be very dangerous and uncomfortable, both by reaſon of many noiſome offenſive things, which ſhould be thruſt out, and many other needful things which ſhould be received in. Now herein will conſiſt the difficulty, how to con-

trive the opening of this veſſel ſo, that any thing may be put in or out, and yet the water not ruſh into it with much violence, as it doth uſually in the leak of a ſhip.

In which caſe this may be a proper remedy; let there be certain leather bags made of ſeveral bigneſſes, which for the *matter* of them ſhould be both *tractable* for the uſe and managing of them, and *ſtrong* to keep out the water; for the *figure* of them, being long and open at both ends. Anſwerable to theſe, let there be divers windows, or open places in the frame of the ſhip, round the ſides of which one end of theſe bags may be fixed, the other end coming within the ſhip being to open and ſhut as a purſe. Now if we ſuppoſe this bag thus faſtned, to be tyed cloſe about towards the window, then any thing that is to be ſent out, may be ſafely put into that end within the ſhip, which being again cloſe ſhut, and the other end looſened, the thing may be ſafely ſent out without the admiſſion of any water.

So again, when any thing is to be taken in, it muſt be firſt received into that part of the bag towards the window, which being (after the thing is within it) cloſe tyed about, the other end may then be ſafely opened. It is eaſie to conceive, how by this means any thing or perſon may be ſent out, or received in, as there ſhall be ocaſion; how the water, which will perhaps by degrees leak into ſeveral parts, may be emptied out again, with divers the like advantages. Though if there ſhould be any leak at the bottom of the Veſſel, yet very little water would get in, becauſe no air could get out.

2. The ſecond difficulty in ſuch an Ark will be the *motion* or *fixing* of it according to occaſion; The *directing* of it to ſeveral places, as the voyage ſhall be deſigned, without which it would be very uſeleſs, if it were to remain only in one place, or were to remove only blindfold, without any certain direction; And the contrivance of this may ſeem very diffi-

cult, becauſe theſe ſubmarine Navigators will want the uſual advantages of winds and tides for motion, and the ſight of the heavens for direction.

But theſe difficulties may be thus remedied ; As for the *progreſſive* motion of it, this may be effected by the help of ſeveral Oars, which in the outward ends of them, ſhall be like the fins of a fiſh to contract and dilate. The paſſage where they are admitted into the ſhip being tyed about with ſuch leather bags (as were mentioned before) to keep out the water. It will not be convenient perhaps that the motion in theſe voyages ſhould be very ſwift, becauſe of thoſe obſervations and diſcoveries to be made at the bottom of the ſea, which in a little ſpace may abundantly recompence the ſlowneſs of its progreſs.

If this Ark be ſo ballaſt as to be of equal weight with the like magnitude of water, it will then be eaſily movable in any part of it.

As for the *aſcent* of it, this may be eaſily contrived, if there be ſome great

weight

weight at the bottom of the ſhip (being part of its ballaſt) which by ſome cord within may be looſned from it; As this weight is let lower, ſo will the ſhip aſcend from it (if need be) to the very ſurface of the water; and again, as it is pulled cloſe to the ſhip, ſo will it *deſcend.*

For *direction* of this Ark, the Mariners needle may be uſeful in reſpect of the *latitude* of places; and the courſe of this ſhip being more regular than others, by reaſon it is not ſubject to Tempeſts or unequal winds, may more certainly guide them in judging of the *longitude* of places.

3. But the greateſt difficulty of all will be this, how the air may be ſupplied for reſpiration: How conſtant fires may be kept in it for light, and the dreſſing of food; how thoſe viciſſitudes of rarefaction and condenſation may be maintained.

It is obſerved, that a barrel or cap, whoſe cavity will contain eight cubical feet of air, will not ſerve a Urinator or Diver for reſpiration, above one quarter of an hour ; the breath which is often ſucked in and out, being ſo corrupted by the mixture of vapours, that nature rejects it as unſerviceable. Now in an hour a man will need at leaſt 360 reſpirations, betwixt every one of which there ſhall be 10 ſecond minutes, and conſequently a great change and ſupply of air will be neceſſary for many perſons, and any long ſpace.

And ſo likewiſe for the keeping of fire ; a cloſe Veſſel containing ten cubical feet of air, will not ſuffer a wax candle of an ounce to burn in it above an hour before it be ſuffocated, though this proportion (ſaith *Merſennus*) doth not equally increaſe for ſeveral lights, becauſe four flames of an equal magnitude will be kept alive the ſpace of 16 ſecond minutes, though one of theſe flames alone in the ſame Veſſel will not laſt above 25, or at moſt 30 ſeconds, which may be eaſily tried in large glaſs bottles, having wax candles lighted in them, and with their mouths inverted in water.

For

For the reſolution of this difficulty, though I will uot ſay that a man may by cuſtome (which in other things doth produce ſuch ſtrange incredible effects) be inabled to live in the open water as the fiſhes do, the inſpiration and expiration of water ſerving inſtead of air, this being uſual with many fiſhes that have lungs; yet it is certain that long uſe and cuſtome may ſtrengthen men againſt many ſuch incoveniences of this kind, which to unexperienced perſons may prove very hazardous: and ſo it will not perhaps be unto theſe ſo neceſſary, to have the air for breathing ſo pure and defecated as is required for others.

But further, there are in this caſe theſe three things conſiderable.

1. That the Veſſel it ſelf ſhould be of a large capacity, that as the air in it is corrupted in one part, ſo it may be purified and renewed in the other: or if the meer refrigeration of the air would fit it for breathing, this might be ſomewhat helped with

bellows, which would cool it by motion.

2. It is not altogether improbable, that the lamps or fires in the middle of it, like the reflected beams in the first Region, rarefying the air, and the circumambient coldneſs towards the ſides of the Veſſel, like the ſecond Region, cooling and condenſing of it, would make ſuch a viciſſitude and change of air, as might fit it for all its proper uſes.

3. Or if neither of theſe conjectures will help, yet *Merſennus* tells us in another place, that there is in *France* one *Barricus* a Diver, who hath lately found out another art, whereby a man might eaſily continue under water for ſix hours together; and whereas ten cubical feet of air will not ſerve another Diver to breathe in, for half an hour, he by the help of a cavity, not above one or two foot at moſt, will have breath enough for ſix hours, and a lanthorn ſcarce above the uſual ſize to keep a candle burning as long as a man pleaſe, which

Harmon. l.4. prop.6. Monit.

(if

(if it be true, and were commonly known) might be a ſufficient help againſt this greateſt difficulty.

As for the many advantages and conveniences of ſuch a contrivance, it is not eaſie to recite them.

1. 'Tis *private*; a man may thus go to any coaſt of the world inviſibly, without being diſcovered or prevented in his journey.

2. 'Tis *ſafe*; from the uncertainty of *Tides*, and the violence of *Tempeſts*, which do never move the ſea above five or ſix paces deep. From *Pirates* and *Robbers* which do ſo infeſt other voyages; From ice and great froſts, which do ſo much endanger the paſſages towards the Poles.

3. It may be of very great advantage againſt a Navy of enemies, who by this means may be undermined in the water and blown up.

4. It may be of ſpecial uſe for the relief of any place that is beſieged by water, to convey unto them inviſible ſupplies: and ſo likewiſe for the ſurpriſal of any place that is acceſſible by water.

5. It

5. It may be of unſpeakable benefit for ſubmarine experiments and diſcoveries: as,

The ſeveral proportions of ſwiftneſs betwixt the aſcent of a bladder, cork, or any other light ſubſtance, in compariſon to the deſcent of ſtones or lead. The deep caverns and ſubterraneous paſſages where the ſea-water in the courſe of its circulation, doth vent it ſelf into other places, and the like. The nature and kinds of fiſhes, the ſeveral arts of catching them, by alluring them with lights, by placing divers nets about the ſides of this Veſſel, ſhooting the greater ſort of them with guns, which may be put out of the ſhip by the help of ſuch bags as were mentioned before, with divers the like artifices and treacheries, which may be more ſucceſſively practiſed by ſuch who live ſo familiarly together. Theſe fiſh may ſerve not only for food, but for fewel likewiſe, in reſpect of that oyl which may be extracted from them; the way of dreſſing meat by lamps, being in many reſpects the moſt convenient for ſuch a voyage.

The many freſh ſprings that may probably be met with in the bottom of the ſea, will ſerve for the ſupply of drink and other occaſions.

But above all, the diſcovery of ſubmarine treaſures is more eſpecially conſiderable, not only in regard of what hath been drowned by wrecks, but the ſeveral precious things that grow there, as Pearl, Coral Mines, with innumerable other things of great value, which may be much more eaſily found out, and fetcht up by the help of this, than by any other uſual way of the Urinators.

To which purpoſe, this great Veſſel may have ſome leſſer Cabins tyed about it, at various diſtances, wherein ſeveral perſons, as Scouts, may be lodged for the taking of obſervations, according as the Admiral ſhall direct them. Some of them being frequently ſent up to the ſurface of the water, as there ſhall be occaſion.

All kind of arts and manufactures may be exercifed in this Veffel. The obfervations made by it, may be both written, and (if need were) printed here likewife. Several Colonies may thus inhabit, having their Children born and bred up without the knowledg of land, who could not chufe but be amazed with ftrange conceits upon the difcovery of this upper world.

I am not able to judge what other advantages there may be fuggefted, or whether experiment would fully anfwer to thefe notional conjectures. But however, becaufe the invention did unto me feem ingenious and new, being not impertinent to the prefent enquiry, therefore I thought it might be worth the mentioning.

CAP. VI.

Of the volant Automata, Archytas *his Dove, and* Regiomontanus *his Eagle. The possibility and great usefulness of such inventions.*

THE *volant* or flying *Automata* are such Mechanical contrivances, as have a self-motion, whereby they are carried aloft in the open air, like the flight of Birds. Such was that wooden Dove made by *Archytas*, a Citizen of *Tarentum*, and one of *Plato's* acquaintance. And that wooden Eagle framed by *Regiomontanus* at *Noremberg*, which by way of triumph, did fly out of the City to meet *Charles* the fift. This later Author is also reported to have made an iron fly, *Quæ ex artificis manu egressa, convivas circumvolitavit, tandemque veluti defessa in Domini manus reversa est,* which when he invited any of his friends, would fly to each of them round the table, and at length (as being weary) return unto its Master.

Diog. Laer. l. 8.

Pet. Crinitus de honest. discip. l. 17. c. 12.

Ramus Schol. Mathem. l. 2.

Dubartas 6days 1w.

J. Dee Preface to *Euclid.*

Cardan

De Variet. rerum lib. 12. c. 58.

Cardan ſeems to doubt the poſſibility of any ſuch contrivance ; his reaſon is, becauſe the inſtruments of it muſt be firm, and ſtrong, and conſequently they will be too heavy to be carried by their own force ; but yet (ſaith he) if it be a little helped in the firſt riſing; and if there be any wind to aſſiſt it in the flight, then there is nothing to hinder, but that ſuch motions may be poſſible. So that he doth in effect grant as much as may be ſufficient for the truth and credit of thoſe ancient relations ; and to diſtruſt them without a ſtronger argument, muſt needs argue a blind and perverſe incredulity. As for his objection concerning the heavineſs of the materials in ſuch an invention, it may be anſwered, that it is eaſie to contrive ſuch ſprings and other inſtruments, whoſe ſtrength ſhall much exceed their heavineſs. Nor can he ſhew any cauſe why theſe Mechanical motions may not be as ſtrong, (though not ſo laſting) as the natural ſtrength of living creatures.

Scaliger

Scaliger conceives the framing of ſuch volant *Automata*, to be very eaſie. *Volantis columbæ machinulam, cujus autorem Archytam tradunt, vel facillime profiteri audeo.* Thoſe ancient motions were thought to be contrived by the force of ſome included air: So *Gellius*, *Ita erat ſcilicet libramentis ſuſpenſum, & aurâ ſpiritus incluſâ atque occultâ conſitum, &c.* As if there had been ſome lamp, or other fire within it, which might produce ſuch a forcible rarefaction, as ſhould give a motion to the whole frame.

Subtil. Exercit. 326.

Noct. Attic. l. 10. cap. 12. where he thinks it ſo ſtrange an invention that he ſtyles *Res abhorrens à fide*

But this may be better performed by the ſtrength of ſome ſuch ſpring as is commonly uſed in watches; this ſpring may be applied unto one wheel, which ſhall give an equal motion to both the wings; theſe wings having unto each of them another ſmaller ſpring by which they may be contracted and lifted up: So that being forcibly depreſſed by the ſtrength of the great and ſtronger ſpring, and lifted up again by the other two. According to this ſuppo-

Athan. Kircher de Magnete l. 2. par. 4. Poem: doth promiſe a large diſcourſe concerning theſe kind of inventions in another Treatiſe which he ſtyles *Oedipus Aegyptiacus.*

ſition, it is eaſie to conceive how the motion of flight may be performed and continued.

The wings may be made either of *ſeveral ſubſtances joyned,* like the feathers in ordinary fowl, as *Dædalus* is feigned to contrive them, according to that in the Poet,

Ovid. Metam. l. 8.

--Ignotas animum dimittit in artes,
Naturamque novat, nam ponit in ordine pennas
A minimo cœptas longam breviore ſequente,
Ut clivo creviſſe putes, &c.

Or elſe of *one continuate ſubſtance,* like thoſe of Bats. In framing of both which, the beſt guidance is to follow (as neer as may be) the direction of nature; this being but an imitation of a natural work. Now in both theſe, the ſtrength of each part is proportioned to the force of its imployment. But nothing in this kind can be perfectly determined without a particular trial.

Though the compoſing of ſuch motions may be a ſufficient reward to any ones induſtry in the ſearching af-

after them, as being in themſelves of excellent curioſity; yet there are ſome other inventions depend upon them of more general benefit and greater importance. For if there be any ſuch artificial contrivances that can fly in the air, (as is evident from the former relations, together with the grounds here ſpecified, and I doubt not, may be eaſily effected by a diligent and ingenious artificer) then it will clearly follow, that it is poſſible alſo for a man to fly himſelf: It being eaſie from the ſame grounds to frame an inſtrument, wherein any one may ſit, and give ſuch a motion unto it as ſhall convey him aloft through the air. Then which there is not any imaginable invention that could prove of greater benefit to the world, or glory to the Author. And therefore it may juſtly deſerve their enquiry, who have both leiſure and means for ſuch experiments.

But in theſe practical ſtudies, unleſs a man be able to go to the tryal of things, he will perform but little. In ſuch matters,

Horace. --*Studium ſine divite venâ,*

(as the Poet ſaith) a general ſpeculation, without particular experiment, may conjecture at many things, but can certainly effect nothing. And therefore I ſhall only propoſe unto the world, the Theory and general grounds that may conduce to the eaſie and more perfect diſcovery of the ſubject in queſtion, for the encouragement of thoſe that have both minds and means for ſuch experiments. This ſame Scholars fate,

Res anguſta domi, and
--*curta ſupellex.*

is that which hinders the promoting of learning in ſundry particulars, and robs the world of many excellent inventions. We read of *Ariſtotle,* that he was allowed by his pupil *Alexander* 800 talents a year, for the payment of Fiſhers, Fowlers, and Hunters, who were to bring him in ſeveral creatures, that ſo by his particular experience of their parts and diſpoſitions, he might be more fitly prepared

pared to write of their natures. The reason why the world hath not many *Aristotles* is, because it hath so few *Alexanders*.

Amongst other impediments of any strange invention or attempts, it is none of the meanest discouragements, that they are so generally derided by common opinion, being esteemed only as the dreams of a melancholy and distempered fancy. *Eusebius* speaking with what necessity every thing is confined by the laws of nature, and the decrees of providence, so that nothing can go out of that way, unto which naturally it is designed; as a fish cannot reside on the land, nor a man in the water, or aloft in the air, infers, that therefore none will venture upon any such vain attempt, as passing in the air, ἢ μελαγχολίας νοσήματα ἂν πειράσοι, unless his brain be a little crazed with the humour of melancholy; whereupon he advises that we should not in any particular endeavour to transgress the bounds of nature, μηδὲ ἄπτερον ἔχοντα τὸ σῶμα, τὰ τῶν

Contra Hierocl. confut. l. 1.

πτηνῶν ἀπομιμεῖσθαι, and since we are naturally destitute of wings, not to imitate the flight of Birds. That saying of the Poet,

Virgil. Æneid. l. 6.

Demens qui nimbos & non imitabile fulmen, &c.

hath been an old censure applied unto such as ventured upon any strange or incredible attempt.

Hence may we conceive the reason, why there is so little intimation in the writings of antiquity, concerning the possibility of any such invention. The Ancients durst not so much as mention the art of flying, but in a fable.

Dædalus, ut fama est, fugiens Minoïa regna,
Præpetibus pennis ausus se credere cælo,
Insuetum per iter gelidas enavit ad arctos, &c.

It was the custom of those former ages, in their overmuch gratitude, to advance the first Authors of any useful discovery, amongst the number of their gods. And *Dædalus*, being so famous amongst them for ſundry Mechanical inventions (eſpecially the ſails of ſhips) though they did not for theſe place him in the heavens, yet they have promoted him as near as they could, feigning him to fly aloft in the air, when as he did but fly in a ſwift ſhip, as *Diodorus* relates the Hiſtorical truth, on which that fiction is grounded.

So *Euſebius* too.

CAP. VII.

Concerning the Art of flying. The ſeveral ways whereby this hath been or may be attempted.

I Have formerly in two other * Diſcourſes mentioned the poſſibility of this art of flying, and intimated a further inquiry unto it, which is a kind of engagement to ſome fuller diſquiſitions and conjectures to that purpoſe.

* World in the Moon, cap. 14. Mercury, or the ſecret and ſwift Meſſenger c. 4

There are four ſeveral wayes whereby this flying in the air, hath been or may be attempted. Two of them by the ſtrength of other things, and two of them by our own ſtrength.

1. By ſpirits or Angels.

2. By the help of fowls.

3. By wings faſtned immediately to the body.

4. By a flying chariot.

Zanch. de oper. pars 1. l. 4. 1. For the firſt we read of divers that have paſſed ſwiftly in the air, by the help of ſpirits and Angels, whether good Angels, a * *Elias* was carried into heaven in a fiery chariot: as † *Philip* was conveyed to *Azotus*, and *Habbacuck* from Jewry to Babylon, and back again immediately: Or by evil Angels, as our Saviour was carried by the Devil to the top of a high mountain, and to the pinacle of the Temple. Thus witches are commonly related to paſs unto their uſual meetings in ſome remote place; and as they do ſell windes unto Mariners, ſo likewiſe are they ſometimes hired to carry men ſpeedily through the open air. *Acoſta* affirms that ſuch kind of paſſages are uſual amongſt divers Sorcerers with the Indians at this day.

* 2 Kings 2. 11.

† Acts 8. 39.

Dan. Apoc. 39.

Luke 4.

Eraſtus de Lamiis.

Hiſt. Ind. l. 5. c. 26.

So

So *Kepler* in his Aſtronomical dream doth fancy a Witch to be conveyed unto the Moon by her Familiar.

Simon Magus was ſo eminent for miraculous ſorceries, that all the people in *Samaria*, from the leaſt to the greateſt, did eſteem him *as the great power of God.* And ſo famous was he at *Rome*, that the Emperour erected a ſtatue to him with this Inſcription, *Simoni Deo Sancto.* 'Tis ſtoried of this Magician, that having challenged Saint *Peter* to do miracles with him, he attempted to fly from the Capitol to the Aventine hill. But when he was in the midſt of the way, Saint *Peters* prayers did overcome his ſorceries, and violently bring him to the ground, in which fall having broke his thigh, within a while after he died.

Acts 8. 10.

Hegeſip. l. 3. *c.* 2.

Pol. Virgil. de Inven. Rerum. l. 8 *c.* 3.

Pet. Crinitus de Honeſtâ Diſciplin. l. 8. *c.* 1. miſtruſts this relation as fabulous. *Non enim Lucas hoc omiſiſſet.*

But none of all theſe relations may conduce to the diſcovery of this experiment, as it is here enquired after, upon *natural* and *artificial* grounds.

2. There are others who have con-

conjectured a poſſibility of being conveyed through the air by the help of Fowls; to which purpoſe that fiction of the *Ganza's*, is the moſt pleaſant and probable. They are ſuppoſed to be great fowl of a ſtrong laſting flight, and eaſily tamable. Divers of which may be ſo brought up as to joyn together in carrying the weight of a man, ſo as each of them ſhall partake his proportionable ſhare of the burden; and the perſon that is carried may by certain reins direct and ſteer them in their courſes. However this may ſeem a ſtrange propoſal, yet it is not certainly more improbable, than many other arts, wherein the induſtry of ingenious men hath inſtructed theſe brute creatures. And I am very confident, that one whoſe genius doth enable him for ſuch kind of experiments, upon leiſure, and the advantage of ſuch helps as are requiſite for various and frequent trials might effect ſome ſtrange thing by this kind of enquiry.

'Tis reported as a cuſtom amongſt

the *Leucatians*, that they were wont upon a superstition to precipitate a man from some high cliffe into the Sea, tying about him with strings at some distance, many great fowls, and fixing unto his body divers feathers spread, to break the fall; which (saith the learned *Bacon*, if it were diligently and exactly contrived) would be able to hold up, and carry any proportionable weight; and therefore he advises others to think further upon this experiment, as giving some light to the invention of the art of flying.

Nat. Hist. experim. 886.

3. 'Tis the more obvious and common opinion that this may be effected by wings fastned immediately to the body, this coming nearest to the imitation of nature, which should be observed in such attempts as these. This is that way which *Fredericus Hermannus* in his little discourse *de Arte volandi*, doth only mention and insist upon. And if we may trust credible story, it hath been frequently attempted not without some success.

So the ancient British Bladuds.

'Tis

Erneſtus Burgravus in Panoplia Phyſico. Vultania. *Sturmius in Lat.; linguæ reſolut.*

'Tis related of a certain Engliſh Monk called *Elmerus*, about the Confeſſors time, that he did by ſuch wings fly from a Tower above a furlong; and ſo another from Saint *Marks* ſteeple in *Venice*; another at *Norinberge*; and *Busbequius* ſpeaks of a Turk in *Conſtantinople*, who attempted ſomething this way. Mr. *Burton* mentioning this quotation, doth believe that ſome new-fangled wit ('tis his Cynical phraſe) will ſome time or other find out this art. Though the truth is, moſt of theſe Artiſts did unfortunately miſcarry by falling down and breaking their arms or l gs, yet that may be imputed to their want of experience, and too much fear, which muſt needs poſſeſs men in ſuch dangerous and ſtrange attempts. Thoſe things that ſeem very difficult and fearful at the firſt, may grow very facil after frequent trial and exerciſe. And therefore he that would effect any thing in this kind, muſt be brought up to the conſtant practiſe of it from his youth. Trying

Melancholy, *Part.* 2. *Sect.* 1. *Mem.* 3.

ing first only to use his wings in running on the ground, as an Estrich or tame Geese will do, touching the earth with his toes; and so by degrees learn to rise higher, till he shall attain unto skill and confidence. I have heard it from credible testimony, that one of our own Nation hath proceeded so far in this experiment, that he was able by the help of wings in such a running pace, to step constantly ten yards at a time.

It is not more incredible that frequent practise and custom should inable a man for this, then for many other things which we see confirmed by experience. What strange agility and activeness do our common tumblers and dancers on the rope attain to by continual exercise? 'Tis related of certain Indians, that they are able when a horse is running in his full career, to stand upright on his back, to turn themselves round, to leap down, gethering up any thing from the ground, and immediatly to leap up again, to shoot exactly at any mark, the horse not inter-

Maffæus Hist. Ind. l. 1.

mitting

mitting his courſe. And ſo upon two horſes together, the man ſetting one of his feet upon each of them. Theſe things may ſeem impoſſible to others, and it would be very dangerous for any one to attempt them, who hath not firſt gradually attained to theſe arts, by long practiſe and trial ; and why may not ſuch practiſe enable him as well for this other experiment, as for theſe things ?

There are others who have invented wayes, to walk upon the water, as regularly and as firmly upon the land. There are ſome ſo accuſtomed to this element, that it hath been almoſt as natural to them, as to the fiſh ; men that could remain for above an hour together under water. *Pontanus* mentions one who could ſwim above a hundred miles together, from one ſhore to another, with great ſpeed, and at all times of the year. And it is ſtoried of a certain young man, a *Sicilian* by birth, and a *Diver* by profeſſion, who had ſo continually uſed himſelf to the water, that he could

Treatiſe of cuſtom.

not

not enjoy his health out of it. If at any time he ſtaid with his friends on the land, he ſhould be ſo tormented with a pain in his ſtomack, that he was forced for his health to return back again to Sea, wherein he kept his uſual reſidence; and when he ſaw any ſhips, his cuſtom was to ſwim to them for relief, which kind of life he continued till he was an old man, and dyed.

I mention theſe things to ſhew the great power of practiſe and cuſtom, which might more probably ſucceed in this experiment of flying (if it were but regularly attempted) than in ſuch ſtrange effects as theſe.

It is a uſual practiſe in theſe times, for our *Funambulones*, or Dancers on the Rope, to attempt ſomewhat like to flying, when they will with their heads forwards ſlide down a long cord extended; being faſtned at one end on the top of ſome high Tower, and the other at ſome diſtance on the ground, with wings fixed to their ſhoulders, by the ſhaking of which

they

they will break the force of their deſcent. It would ſeem that ſome attempts of this kind were uſual amongſt the *Romans*. To which that
*De gube. Dei. l. 6. expreſſion in * *Salvian* may refer, where amongſt other publick ſhews of the Theater, he mentions the *Petaminarii*:
Annot. in Salvi. which word (ſaith *Jo. Braſſicanus*) is ſcarce to be found in any other Author, being not mentioned either in *Julius Pollux*, or *Politian*. 'Tis probably derived from the Greek word πέταϑζ, which ſignifies to fly, and may refer to ſuch kind of Rope-dancers.

But now becauſe the arms extended, are but weak and eaſily wearied, therefore the motions by them are like to be but ſhort and ſlow, anſwerable it may be to the flight of ſuch domeſtick fowl, as are moſt converſant on the ground, which of themſelves we ſee are quickly weary, and therefore much more would the arm of a man, as being not naturally deſigned to ſuch a motion.

It were therefore worth the inquiry

ry to conſider whether this might not be more probably effected by the labour of the feet, which are naturally more ſtrong and indefatigable: In which contrivance the wings ſhould come down from the ſhoulders on each ſide as in the other, but the motion of them ſhould be from the legs, being thruſt out and drawn in again one after another, ſo as each leg ſhould move both wings, by which means a man ſhould (as it were) walk or climb up into the air: and then the hands and arms might be at leiſure to help and direct the motion, or for any other ſervice proportionable to their ſtrength. Which conjecture is not without good probability, and ſome ſpecial advantages above the other.

4. But the fourth and laſt way ſeems unto me altogether as probable, and much more uſeful than any of the reſt: And that is by a flying chariot, which may be ſo contrived as to carry a man within it; and though the ſtrength of a ſpring might per-

haps be ſerviceable for the motion of this engine, yet it were better to have it aſſiſted by the labour of ſome intelligent mover, as the heavenly Orbs are ſuppoſed to be turned. And therefore if it were made big enough to carry ſundry perſons together, then each of them in their ſeveral turns might ſucceſſively labour in the cauſing of this motion; which thereby would be much more conſtant and laſting, than it could otherwiſe be, if it did wholly depend on the ſtrength of the ſame perſon. This contrivance being as much to be preferred before any of the other, as ſwimming in a ſhip before ſwimming in the water.

CAP. VIII.

A reſolution of the two chief difficulties that ſeem to oppoſe the poſſibility of a flying Chariot.

THE chief difficulties againſt the poſſibility of any ſuch contrivance, may be fully removed in the reſolution

ſolution of theſe two *Quæries.*

1. Whether an engine of ſuch capacity and weight, may be ſupported by ſo thin and light a body as the air?

2. Whether the ſtrength of the perſons within it, may be ſufficient for the motion of it?

1. Concerning the firſt; when *Callias* was required by the men of *Rhodes*, to take up that great *Helepolis*, brought againſt them by *Demetrius*, (as he had done before unto ſome leſs, which he himſelf had made) He anſwered, that it could not be done. *Nonnulla enim ſunt quæ in exemplaribus videntur ſimilia, cum autem creſcere cœperunt, dilabuntur.* Because thoſe things that appear probable in leſſer models, when they are encreaſed to a greater proportion, do thereby exceed the power of art. For example, though a man may make an inſtrument to bore a hole an inch wide, or half an inch, and ſo leſs; yet to bore a hole of a foot wide, or two foot, is not ſo much as to be

Vitruvius Archit. l. 10. c. 22.

So Ramus Schol. Mathem. l. 1.

thought of. Thus, though the air may be able to uphold some lesser bodies, as those of birds; yet when the quantity of them is encreased to any great extension, it may justly be doubted, whether they will not exceed the proportion that is naturally required unto such kind of bodies.

To this I answer, That the engine can never be too big or too heavy, if the space which it possesses in the air, and the motive-faculty in the instrument be answerable to its weight. That saying of *Callias* was but a groundless shift and evasion, whereby he did endeavour to palliate his own ignorance and disability. The utmost truth which seems to be implied in it, is this; That there may be some bodies of so great a bigness, and gravity, that it is very difficult to apply so much force unto any particular instrument, as shall be able to move them.

Against the example, it may be affirmed and easily proved, that it is equally possible to bore a hole of any bigneſs, as well great as little, if we ſuppoſe the inſtrument, and the ſtrength, and the application of this ſtrength to be proportionable; But becauſe of the difficulty of theſe concurrent circumſtances in thoſe greater and more unuſual operations, therefore do they falſly ſeem to be abſolutely impoſſible.

So that the chief inference from this argument and example, doth imply only thus much, that it is very difficult to contrive any ſuch motive power, as ſhall be anſwerable to the greatneſs and weight of ſuch an inſtrument as is here diſcourſed of, which doth not at all impair the truth to be maintained; For if the poſſibility of ſuch a motion be yeilded, we need not make any ſcruple of granting the difficulty of it; It is this muſt add a glory to the invention; and yet this will not perhaps ſeem ſo very difficult to any one who hath but diligently obſerved the flight of ſome other birds, particularly of a Kite, how he will ſwim up and down in the air, ſometimes at a great height, and preſently again lower, guiding himſelf by his train, with his wings extended without any ſenſible motion of them; and all this when there is only ſome gentle breath of air ſtirring, without the help of any ſtrong forcible wind. Now I ſay, if that fowl (which is none of the lighteſt) can ſo very eaſily move it ſelf up and down in the air, without ſo much as ſtirring the wings of it; certainly then, it is not improbable, but that when all the due proportions in ſuch an engine are found out, and when men by long practiſe have arrived to any skill and experience, they will be able in this (as well as in many other things) to come very near unto the imitation of nature.

Sen. Nat. Qu. l. 3. c. 25. As it is in thoſe bodies which are carried on the water, though they be never ſo big, or ſo ponderous, (ſuppoſe equal to a City or a whole Iſland) yet they will always ſwim on the top, if they be but any thing lighter than ſo much water as is equal to them in bigneſs: So likewiſe is it in the bodies that are carried in the air. It is not their greatneſs (though never ſo immenſe) that can hinder their being ſupported in that light element, if we ſuppoſe them to be extended unto a proportionable ſpace of air. And as from the former experiments, *Archimedes* hath compoſed a ſubtil *ſcience* in his Book, *De inſidentibus humido*, concerning the weight of any heavy body, in reference to the water wherein it is: So from the particular trial of theſe other experiments, that are here inquired after, it is poſſible to raiſe a new ſcience, concerning the extenſion of bodies, in compariſon to the air, and motive faculties by which they are to be carried.

We ſee a great difference betwixt the ſeveral quantities of ſuch bodies as are commonly upheld by the air; not only little gnats, and flies, but alſo the Eagle and other fowl of vaſter magnitude. *Cardan* and *Scaliger* do unanimouſly affirm, that there is a bird

Subtil. l. 10
Exercit. 231.

bird amongst the *Indians* of so great a bigness, that his beak is often used to make a sheath or scabbard for a sword. And *Acosta* tells us of a fowl in *Peru* called *Condores*, which will of themselves kill and eat up a whole Calf at a time. Nor is there any reason why any other body may not be supported and carried by the air, though it should as much exceed the quantity of these fowl, as they do the quantity of a fly.

Histor. Nov. Orb. l. 4. c. 37.

Marcus Polus mentions a fowl in *Madagascar*, which he calls a *Ruck*, the feathers of whose wings are 12 paces, or threescore foot long, which can with as much ease soop up an Elephant, as our Kites do a Mouse. If this reletion were any thing credible, it might serve as an abundant proof for the present quæry. But I conceive this to be already so evident, that it needs not any fable for its further confirmation.

2. The other doubt was, whether the strength of the other persons within it, will be sufficient for the

moving

moving of this engine? I anſwer, the main difficulty and labour of it will be in the raiſing of it from the ground; near unto which, the earths attractive vigor is of greateſt efficacy. But for the better effecting of this, it may be helped by the ſtrength of winds, and by taking its firſt riſe from ſome mountain, or other high place. When once it is aloft in the air, the motion of it will be eaſie, as it is in the flight of all kind of birds, which being at any great diſtance from the earth, are able to continue their motion for a long time and way, with litlite labour or wearineſs.

'Tis certain from common relation and experience, that many birds do croſs the ſeas for divers hundred miles together: ſundry of them amongſt us, which are of a ſhort wing and flight, as Blackbirds, Nightingales, &c. do fly from us into *Germany*, and other remoter Countries. And Mariners do commonly affirm, that they have found ſome fowl above ſix hundred miles from any land. Now

Plin. l. 10. *c.* 23.

Now if we ſhould ſuppoſe theſe birds to labour ſo much in thoſe long journeys, as they do when they fly in our ſight, and near the earth, it were impoſſible for any of them to paſs ſo far without reſting. And therefore it is probable, that they do mount unto ſo high a place in the air, where the natural heavineſs of their bodies does prove but little or no impediment to their flight; Though perhaps either hunger, or the ſight of ſhips, or the like accident, may ſometimes occaſion their deſcending lower, as we may gheſs of thoſe birds, which Mariners have thus beheld; and divers others, that have been drowned and caſt up by the ſea.

Whence it may appear, that the motion of this Chariot (though it may be difficult at the firſt) yet will ſtill be eaſier, as it aſcends higher, till at length it ſhall become utterly devoid of gravity, when the leaſt ſtrength will be able to beſtow upon it a ſwift motion: as I have proved

more

more at large in another diſcourſe. World in the Moon, c. 14.

But then, (may ſome object) If it be ſuppoſed that a man in the æthereal air does loſe his own heavineſs, how ſhall he contribute any force towards the motion of this inſtrument?

I anſwer, The ſtrength of any living creature in theſe external motions, is ſomething really diſtinct from, and ſuperadded unto its naturally gravity: as common experience may ſhew, not only in the impreſſion of blows or violent motions, as a River-hawk will ſtrike a fowl with a far greater force, than the meer deſcent or heavineſs of his body could poſſibly perform: But alſo in thoſe actions which are done without ſuch help, as the pinching of the finger, the biting of the teeth, *&c.* all which are of much greater ſtrength than can proceed from the meer heavineſs of thoſe parts.

As for the other particular doubts, concerning the extreme thinneſs and coldneſs of this æthereal air, by reaſon of which it may ſeem to be

al-

altogether impaſſible, I have already reſolved them in the above-cited diſcourſe.

The uſes of ſuch a Chariot may be various: Beſides the diſcoveries which might be thereby made in the Lunary world; It would be ſerviceable alſo for the conveyance of a man to any remote place of this earth: as ſuppoſe to the *Indies* or *Antipodes*. For when once it was elevated for ſome few miles, ſo as to be above that Orb of Magnetick virtue, which is carried about by the earths diurnal revolution, it might then be very eaſily and ſpeedily directed to any particular place of this great Globe.

If the place which we intended were under the ſame parallel, why then the earths revolution once in twenty-four hours, would bring it to be under us; ſo that it would be but deſcending in a ſtraight line, and we might preſently be there. If it were under any other parallel, it would then only require that we ſhould direct it in the ſame Meridian, till we did come to that paral-

parallel; and then (as before) a man might eafily defcend unto it.

It would be one great advantage in this kind of travelling, that one fhould be perfectly freed from all inconveniences of ways or weather, not having any extremity of heat, or cold, or Tempefts to moleft him: This æthereal air being perpetually in an equal temper and calmnefs. *Pars fuperior mundi ordinatior eft nec in nubem cogitur, nec in tempeftatem impellitur, nec verfatur in turbinem, omni tumultu caret, inferiora fulminant.* The upper parts of the world are always quiet and ferene, no winds and bluftring there; they are thefe lower cloudy regions that are fo full of tempefts and combuftion.

Sen. de Ira l. 3. c. 6.

Pacem fumma tenens. Lucan.

As for the manner how the force of a fpring, or (inftead of that) the ftrength of any living perfon, may be applied to the motion of thefe wings of the Chariot, it may eafily be apprehended from what was formerly delivered.

There are divers other particulars

to be more fully enquired after, for the perfecting of ſuch a flying Chariot; as concerning the proportion of the wings both for their length and breadth, in compariſon to the weight which is to be carried by them, as alſo concerning thoſe ſpecial contrivances, whereby the ſtrength of theſe wings may be ſeverally applied either to aſcent, deſcent, progreſſive, or a turning motion; All which, and divers the like enquiries can only be reſolved by particular experiments. We know the invention of ſailing in ſhips does continually receive ſome new addition from the experience of every age, and hath been a long while growing up to that perfection, unto which it is now arrived. And ſo muſt it be expected for this likewiſe, which may at firſt perhaps ſeem perplexed with many difficulties and inconveniencies, and yet upon the experience of frequent tryals, many things may be ſuggeſted to make it more facil and commodious.

As well too long as too ſhort, too broad as too narrow, may be an impediment to the motion, by making it more difficult, ſlow and flaging.

He

He that would regularly attempt any thing to this purpoſe, ſhould obſerve this progreſs in his experiments, he ſhould firſt make enquiry what kind of wings would be moſt uſeful to this end; thoſe of a Bat being moſt eaſily imitable, and perhaps nature did by them purpoſely intend ſome intimation to direct us in ſuch experiments; that creature being not properly a bird, becauſe not amongſt the *Ovipara*, to imply that other kind of creatures are capable of flying as well as birds; and if any ſhould attempt it, that would be the beſt pattern for imitation.

After this he might try what may be effected by the force of ſprings in leſſer models, anſwerable unto *Archytas* his Dove, and *Regiomontanus* his Eagle: In which he muſt be careful to obſerve the various proportions betwixt the ſtrength of the ſpring, the heavineſs of the body, the breadth of the wings, the ſwiftneſs of the motion, &c.

From theſe he may by degrees aſcend to ſome larger eſſays. CAP.

CAP. IX.

Of a perpetual motion. The ſeeming facility and real difficulty of any ſuch contrivance. The ſeveral wayes whereby it hath been attempted, particularly by Chymiſtry.

IT is the chief inconvenience of all the *Automata* before mentioned, that they need a frequent repair of new ſtrength; the cauſes whence their motion does proceed, being ſubject to fail and come to a period; and therefore it would be worth our enquiry, to examine, whether or no there may be made any ſuch artificial contrivance, which might have the principle of moving from it ſelf; ſo that the preſent motion ſhould conſtantly be the cauſe of that which ſucceeds.

This is that great Secret in *Art*, which like the Philoſophers Stone in *Nature*, hath been the buſineſs and ſtudy of many more refined Wits, for divers ages together; and it may well be queſtioned, whether either of them as yet, hath ever been found out, though if this have, yet like the other, it is not plainly treated of by any Author.

Not but that there are ſundry diſcourſes concerning this ſubject, but they are rather *conjectures* than *experiments.* And though many inventions in this kind, may at firſt view bear a great ſhew of probability, yet they will fail, being brought to trial, and will not anſwer in practiſe what they promiſed in ſpeculation. Any one who hath been verſed in theſe experiments muſt needs acknowledge that he hath been often deceived in his ſtrongeſt confidence; when the imagination hath contrived the whole frame of ſuch an inſtrument, and conceives that the event muſt fallibly anſwer its hopes; yet then does it ſtrangely deceive in the proof, and diſcovers to us ſome defect, which we did not before take notice of.

Hence it is, that you ſhall ſcarce talk with any one who hath never ſo little ſmattering in theſe arts, but he will inſtantly promiſe ſuch a motion, as being but an eaſie atchievement, till further trial and experience hath taught him the difficulty of it. There being no enquiry that does more entice with the *probability*, and deceive with the *ſubtilty*. What one ſpeaks wittily concerning the Philoſophers Stone, may be juſtly applyed to this, that it is *Caſta meretrix*, a chaſte Whore, *Quia multos invitat, neminem admittit*, becauſe it allures many, but admits none.

I ſhall briefly recite the ſeveral ways whereby this hath been attempted, or ſeems moſt likely to be effected, thereby to contract and facilitate the enquiries of thoſe who are addicted to theſe kind of experiments; for when they know the defects of other inventions, they may the more eaſily avoid the ſame, or the like, in their own.

The ways whereby this hath been attempted, may be generally reduced to theſe three kinds:

1. By Chymical extractions.

2. By Magnetical virtues.

3. By the natural affection of gravity.

1. The discovery of this hath been attempted by Chymistry. *Paracelsus* and his followers have bragged, that by their separations and extractions, they can make a little world which shall have the same perpetual motions with this *Microcosme*, with the representation of all Meteors, Thunder, Snow, Rain, the courses of the sea in its ebbs and flows, and the like; But these miraculous promises would require as great a faith to belive them, as a power to perform them: And though they often talk of such great matters,

At nusquam totos inter qui talia curant,
Apparet ullus, qui re miracula tanta
Comprobet—

yet we can never see them confirmed by any real experiment; and then besides, every particular Author in that art, hath such a distinct language of his own, (all of them being so full of allegories and affected obſcurities) that 'tis very hard for any one (unleſs he be throughly verſed amongſt them) to find out what they mean, much more to try it.

Etten Mathem. Recreat. prob. 118.

One of theſe ways (as I find it ſet down) is this. Mix five ounces of ☿, with an equal weight of ♃, grind them together with ten ounces of ſublimate, diſſolve them in a Cellar upon ſome marble for the ſpace of four dayes, till they become like oyl-olive; diſtil this with fire of chaff, or driving fire, and it will ſublime into a dry ſubſtance: and ſo by repeating of theſe diſſolvings and diſtillings, there will be at length produced divers ſmall atomes, which being put into a glaſs well luted, and kept dry, will have a perpetual motion.

I cannot ſay any thing from experience againſt this; but methinks it does not ſeem very probable, becauſe things that are forced up to ſuch a vigorouſneſs and activity, as theſe ingredients ſeem to be by their frequent ſublimatings and diſtillings, are not likely to be of any duration; the more any thing is ſtretched beyond its uſual nature, the leſs does it laſt, violence and perpetuity being no companions. And then beſides, ſuppoſe it true, yet ſuch a motion could not well be applied to any uſe, which muſt needs take much from the delight of it.

Amongſt the Chymical experiments to this purpoſe may be reckoned up that famous motion invented by *Cornelius Dreble*, and made for King *James*; wherein was repreſented the conſtant revolutions of the Sun and Moon, and that without the help either of ſpring or weights. *Marcellus Vranckhein*, ſpeaking of the means whereby it was performed, he calls it, *Scintillula animæ magneticæ mundi, ſeu Aſtralis & inſenſibilis ſpiritus*; being that grand ſecret, for the diſcovery of which, thoſe Dictators of Philoſophy, *Democritus*, *Pythagoras*, *Plato*, did travel unto the Gymnoſophiſts, and *Indian* Prieſts.

Celebrated in an Epigram by *Hugo Grotius* 1. *Epi. Epiſt. ad Erneſtum de Lamp. Vitæ.*

Epist. ad Jacobum: Regem. The Author himſelf in his diſcourſe upon it, does not at all reveal the way, how it was performed. But there is one *Thomas Symme*, who was a familiar acquaintance of his, and did often pry into his works, (as he profeſſes himſelf) who affirms it to be done thus; *By extracting a fiery ſpirit out of the Mineral matter, joyning the ſame with his proper air, which included in the Axle-tree* (of the firſt moving wheel) *being hollow, carrieth the other wheels, making a continual rotation, except iſſue or vent be given in this hollow axle-tree, whereby the impriſoned ſpirit may get forth.*

Philoſophical dialogue. *Confer.* 2. *cap.* 3.

What ſtrange things may be done by ſuch extractions, I know not, and therefore dare not condemn this relation as is impoſſible; but methinks it ſounds rather like a chymical dream, than a Philoſophical truth. It ſeems this impriſoned ſpirit is now ſet at liberty, or elſe is grown weary, for the inſtrument (as I have heard) hath ſtood ſtill for many years. It is here conſiderable, that any force is weakeſt

near

near the center of a wheel; and therefore though ſuch a ſpirit might of it ſelf have an agitation, yet 'tis not eaſily conceivable how it ſhould have ſtrength enough to carry the wheels about with it. And then the abſurdity of the Authors citing this, would make one miſtruſt his miſtake; he urges it as a ſtrong argument againſt *Copernicus*, as if becauſe *Dreble* did thus contrive in an Engine, the revolution of the heavens, and the immovableneſs of the earth, therefore it muſt needs follow, that 'tis the heavens which are moved, and not the earth. If his relation were no truer than his conſequence, it had not been worth the citing.

CAP. X.

Of subterraneous lamps : divers historical relations concerning their duration for many hundred years together.

UNto this kind of Chymical experiments, we may moſt probably reduce thoſe perpetual lamps, which for many hundred years together have continued burning without any new ſupply in the ſepulchres of the Ancients, and might (for ought we know) have remained ſo for ever. All fire, and eſpecially flame, being of an active and ſtirring nature, it cannot therefore ſubſiſt without motion; whence it may ſeem, that this great enquiry hath been this way accompliſhed: And therefore it will be worth our examination to ſearch further into the particulars that concern this experiment. Though it be not ſo proper to the chief purpoſe of this diſcourſe, which concerns *Mechanical Geometry*, yet the ſubtilty and

and curiosity of it, may abundantly requite the impertinency.

There are sundry Authors who treat of this Subject~~ion~~ by the by, and in some particular passages, but none that I know of (except *Fortunius Licetus*) that hath writ purposely any set and large discourse concerning it: out of whom I shall borrow many of those relations and opinions, which may most naturally conduce to the present enquiry.

Lib. de re-conditis antiquorum lucernis.

For our fuller understanding of this, there are these particulars to be explained:

1. ὅτι, or *quod sit.*
2. διότι { *cur sit.* / *quomodo sit.* }

1. First then, for the ὅτι, or that there have been such lamps, it may be evident from sundry plain and undeniable testimonies: Saint *Austin* mentions one of them in a Temple dedicated to *Venus*, which was always exposed to the open weather, and could never be consumed or extinguished. To him assents the judicious

De Civit. Dei. l. 21. cap. 6.

cious *Zinchy.* *Pancyrollus* mentions a Lamp found in his time, in the ſepulcher of *Tullia*, *Cicero's* daughter, which had continued there for about 1550 years, but was preſently extinguiſhed upon the admiſſion of new air. And 'tis commonly related of *Cedrenus*, that in *Juſtinians* time there was another burning lamp found in an old wall at* *Edeſſa*, which had remained ſo for above 500 years, there being a Crucifix placed by it, whence it ſhould ſeem that they were in uſe alſo amongſt ſome Chriſtians.

De operibus Dei part. 1. l. 4. c. 12. Dedeperd. Tit. 35.

*Or *Antioch. Licetus de Lucernis, l. 1. c. 7.*

But more eſpecially remarkable is that relation celebrated by ſo many Authors, concerning *Olybius* his lamp, which had continued burning for 1500 years. The ſtory is thus: As a ruſtick was digging the ground by *Padua*, he found an Urn or earthen pot, in which there was another Urn, and in this leſſer, a lamp clearly burning; on each ſide of it there were two other Veſſels, each of them full of a pure liquor, the one of gold, the other of ſilver. *Ego Chymiæ artis, (ſi*

modo

modo vera poteſt eſſe ars Chymia) jurare auſim elementa & materiam omnium, (ſaith *Maturantius*, who had the poſſeſſion of theſe things after they were taken up). On the bigger of theſe Urns there was this inſcription:

Plutoni ſacrum munus ne attingite fures.
Ignotum eſt vobis hoc quod in orbe latet,
Namque elementa gravi clauſit digeſta labore
Vaſe ſub hoc modico, Maximus Olybius.
Adſit fæcundo cuſtos ſibi copia cornu,
Ne tanti pretium depereat laticis.

The leſſer Urn was thus inſcribed:

Abite hinc peſſimi fures,
Vos quid vultis, veſtris cum oculis emiſſitiis?
Abite hinc veſtro cum Mercurio
Petæſato Caduceatoque,
Donum hoc Maximum, Maximus Olybius
Plutoni ſacrum facit.

Whence we may probably conjecture that it was ſome Chymical ſe-

cret,

cret, by which this was contrived.

Mag. Natural. l. 12. c. ult. *Baptista Porta* tells us of another lamp burning in an old marble sepulcher, belonging to some of the ancient *Romans*, inclosed in a glass vial, found in his time, about the year 1550, in the Isle *Nesis*, which had been buried there before our Saviours coming.

Chron. Martin Fort. licet. de lucern. l. 1. c. 11. In the Tomb of *Pallas* the *Arcadian* who was slain by *Turnus* in the *Trojan* war, there was found another burning lamp in the year of our Lord 1401. Whence it should seem, that it had continued there for above two thousand and six hundred years: and being taken out, it did remain burning, notwithstanding either wind or water, with which some did strive to quench it; nor could it be extinguished till they had spilt the liquor that was in it.

Ludovicus Vives tells us of another lamp that did continue burning for 1050 years, which was found a little before his time.

Not. ad August. de Civit. Dei, l. 21. c. 6.

Such a lamp is likewise related to be

be ſeen in the ſepulcher of *Francis Roſicroſs*, as is more largely expreſſed in the confeſſion of that fraternity.

There is another relation of a certain man, who upon occaſion digging ſomewhat deep in the ground, did meet with ſomething like a dore, having a wall on each hand of it; from which having cleared the earth, he forced open the door; upon this there was diſcovered a fair Vault, and towards the farther ſide of it, the ſtatue of a man in Armour, ſiting by a table, leaning upon his left arm, and holding a ſcepter in his right hand, with a lamp burning before him; the floor of this Vault being ſo contrived, that upon the firſt ſtep into it, the ſtatue would erect it ſelf from its leaning poſture; upon the ſecond ſtep it did lift up the ſcepter to ſtrike, and before a man could approach near enough to take hold of the lamp, the ſtatue did ſtrike and break it to pieces; ſuch care was there taken that it might not be ſtoln away, or diſcovered.

Our learned *Cambden* in his deſcrip- *Pag. 572.*
tion

tion of *Yorkshire*, ſpeaking of the tomb of *Conſtantius Chlorus*, broken up in theſe later years, mentions ſuch a lamp to be found within it.

There are ſundry other relations to this purpoſe. *Quod ad lucernas attinet, illæ in omnibus fere monumentis inveniuntur*, (ſaith *Gutherius*). In moſt of the ancient Monuments there is ſome kind of lamp, (though of the ordinary ſort); But thoſe perſons who were of greateſt note and wiſdom, did procure ſuch as might laſt without ſupply, for ſo many ages together. *Pancirollus* tells us, that it was uſual for the Nobles amongſt the Romans, to take ſpecial care in their laſt wills, that they might have a lamp in their Monuments. And to this purpoſe they did uſually give liberty unto ſome of their ſlaves on this condition, that they ſhould be watchful in maintaining and preſerving it. From all which relations, the firſt particular of this enquiry, concerning the being or exiſtence of ſuch lamps, may ſufficiently appear.

De jure manium, l. 2. c. 32.

De perdit. Tit. 62.

CAP.

CAP. XI.

Several opinions concerning the nature and reaſon of theſe perpetual Lamps.

THere are two opinions to be anſwered, which do utterly overthrow the chief conſequence from theſe relations.

1. Some think that theſe lights ſo often diſcovered in the ancient tombs, were not fire or flame, but only ſome of thoſe bright bodies which do uſually ſhine in dark places.

2. Others grant them to be fire, but yet think them to be then firſt enkindled by the admiſſion of new air, when theſe ſepulchers were opened.

1. There are divers bodies (ſaith *Ariſtotle*) which ſhine in the dark, as rotten wood, the ſcales of ſome fiſhes, ſtones, the glow-worm, the eyes of divers creatures. *Cardan* tells us of a bird in new *Spain*, called *Cocoyum*, whoſe whole body is very bright, but his eyes almoſt equal to the light of

De anima, l. 2. c. 7.

Subtil. l. 9.

a

a candle, by which alone in a dark night one may both write and read; By theſe the *Indians* (ſaith he) uſe to eat their feaſting Suppers.

It is commonly related and believed, that a Carbuncle does ſhine in the dark like a burning coal, from whence it hath its * name. To which purpoſe there is a ſtory in *Ælian*, of a Stork, that by a certain woman was cured of a broken thigh, in gratitude to whom, this fowl afterwards flying by her, did let fall into her lap a bright Carbuncle, which (ſaith he) would in the night time ſhine as clear as a lamp. But this and the like old relations are now generally diſbelieved and rejected by learned men: *Doctiſſimorum omnium conſenſu, hujuſmodi gemmæ non inveniuntur*, ſaith *Boetius de Boot*) a man very much skill'd in, and inquiſite after ſuch matters; nor is there any one of name that does from his own eye-ſight or experience affirm the real exiſtence of any gem ſo qualified.

* *Carbo Pyropus*

Hiſtoria Animal. l. 8

De lapid. & Gemmis. l. 2. c. 8.

Some have thought that the light

in ancient tombs hath been occaſioned from ſome ſuch bodies as theſe. For if there had been any poſſibility to preſerve fire ſo long a ſpace, 'tis likely then that the *Iſraelites* would have known the way, who were to keep it perpetually for their ſacrifices.

Vide Licet. de lucern. l. 2.

But to this opinion it might be replyed, that none of theſe *Nocticula*, or night-ſhining bodies have been obſerved in any of the Ancient ſepulchres, and therefore this is a meer imaginary conjecture; And then beſides, ſome of theſe lamps have been taken out burning, and continued ſo for a conſiderable ſpace afterwards. As for the ſuppoſed conveniency of them, for the perpetuating of the holy fire amongſt the Jews, it may as well be feared leſt theſe ſhould have occaſioned their idolatry, unto which that Nation was ſo ſtrongly addicted upon every ſlight occaſion; nor may it ſeem ſtrange, if the providence of God ſhould rather permit this fire ſometimes to go out, that ſo by their earneſt prayers, being a-

gain renewed from heaven,(as it * some-
* Levit. 9. 24. 2 Chron. 7. 1. 1 King. 18. 38. times was) the peoples faith might be the better stirred up and strengthned by such frequent miracles.

De jure Mani. l. 2. c. 32. 2. It is the opinion of *Gutherius*, that these lamps have not continued burning for so long a space as they are supposed in the former relations; but that they were then first enflamed by the admission of new air, or such other occasion, when the sepulchres were opened: as we see in those fat earthy vapours of divers sorts, which are oftentimes enkindled into a flame. And 'tis said, that there are some Chymical ways, whereby iron may be so heated, that being closely luted in a glass, it shall constantly retain the fire for any space of time, though it were for a thousand years or more; at the end of which, if the glass be opened, and the fresh air admitted, the iron shall be as red hot as if it were newly taken out of the fire.

But for answer to this opinion, 'tis considerable that some Urns have had

inscrip-

inſcriptions on them, expreſſing that the lamps within them were burning, when they were firſt buried. To which may be added the experience of thoſe which have continued ſo for a good ſpace afterwards; whereas the inflamation of fat and viſcous vapours, does preſently vaniſh. The lamp which was found in the Iſle *Neſis*, did burn clearly while it was incloſed in the glaſs; but that being broken, was preſently exſtinguiſhed. As for that Chymical relation, it may rather ſerve to prove, that fire may continue ſo many ages, without conſuming any fuel.

So that notwithſtanding the oppoſite opinions, yet 'tis more probable that there have been ſuch lamps as have *remained burning*, without any new ſupply, for many hundred years together; which was the firſt particular to be explained.

2. Concerning the reaſon, why the Ancients were ſo careful in this particular; there are divers opinions. Some think it to be an expreſſion of *Cur ſint.*

their belief, concering the ſouls immortality, after its departure out of the body, a lamp amongſt the *Egyptians* being the *Hieroglyphick* of life. And therefore they that could not procure ſuch lamps, were yet careful to have the image and repreſentation of them ingraved on their Tombs.

Others conceive them to be by way of gratitude to thoſe infernal Deities, who took the charge and cuſtody of their dead bodies, *remaining* always with them in their Tombs, and were therefore called *Dii manes.*

Others are of opinion, that theſe lamps were only intended to make their ſepulchres more pleaſant and lightſome, that they might not ſeem to be impriſoned in a diſmal and uncomfortale place. True indeed, the dead body cannot be ſenſible of the light, no more could it of its want of burial; yet the ſame inſtinct which did excite it to the deſire of one, did alſo occaſion the other.

De Lucernis, l. 3. c. 8. *Licetus* concludes this ancient cuſtome to have a double end: 1. *Politick,*

litick, for the diſtinction of ſuch as were nobly born, in whoſe Monuments only they were uſed. 2. *Natural*, to preſerve the body and ſoul from darkneſs; For it was a common opinion amongſt them, that the ſouls alſo were much converſant about thoſe places where the bodies were buried.

CAP. XII.

The most probable conjecture how theſe lamps were framed.

THE greateſt difficulty of this enquiry doth conſiſt in this laſt particular, concerning the manner how, or by what poſſible means any ſuch perpetual flame may be contrived. *Quomodo ſint.*

For the diſcovery of which, there are two things to be more eſpecially conſidered.

1. The ſnuff or wiek, which muſt adminiſter unto the flame.

2. The oyl, which muſt nouriſh it.

For the firſt, it is generally granted that there are divers ſubſtances which will retain fire without conſuming: ſuch is that Mineral which they call the Salamanders-wool, ſaith our learned * Bacon. *Ipſe expertus ſum villos Salamandræ non conſumi*, ſaith † *Joachimus Fortius*. And * *Wecker* from his own knowledg affirms the ſame of *plumeallum*, that being formed into the likeneſs of a wiek, will adminiſter to the flame, and yet not conſume it ſelf. Of this nature likewiſe was that which the Ancients did call *Linum vivum*, or *Asbeſtinum*: of this they were wont to make garments that were not deſtroyed, but purified by fire; and whereas the ſpots or foulneſs of other cloaths are waſhed out, in theſe they were uſually burnt away. The bodies of the ancient Kings were wrapped in ſuch garments when they were put in the funeral-pile, that their aſhes might be therein preſerved, without the mixture of any other. The materials of them were not from any herb or vegetable,

* *Nat. hiſt. exper.* 774.
† *Lib. exper.*
* *De Secretis*, l. 3. c. 2.
Or *Linum Carpaſium Plutarch. de Oracul. defectu.*
Plin. Hiſt. l. 19. c. 1.

ble, as other textils, but from a ſtone called *Amiantus*, which being bruiſed by a hammer, and its earthy nature ſhaken out, retains certain hairy ſubſtances, which may be ſpun and woven as hemp or flax. *Pliny* ſays, that for the precioufneſs of it, it did almoſt equal the price of pearls. *Pancirollus* tells us, that it was very rare, and eſteemed precious in ancient times; but now is ſcarce found or known in any place, and therefore he reckons it amongſt the things that are loſt. But *L. Vives* affirms, that he hath often ſeen wieks made of it at *Paris*, and the ſame matter woven into a napkin at *Lovaine*, which was cleanſed by being burnt in the fire.

Deperd. Tit. 4.

In Auguſt. de Civit. Dei l. 21. c. 6.

'Tis probable from theſe various relations, that there was ſeveral ſorts of it, ſome of a more precious, others of a baſer kind, that was found in *Cyprus*, the deſerts of *India*, and a certain Province of *Aſia*: this being common in ſome parts of *Italy*, but is ſo ſhort and brittle, that it cannot be ſpun into a thred. And therefore is uſeful only for the wieks of perpetual lamps, ſaith *Boetius de Boot.* Some of this, or very like it, I have upon inquiry lately procured and experimented. But whether it be the ſtone *Asbeſtus*, or only *Plume-allum*, I cannot certainly affirm. For it ſeems they are both ſo very like, as to be commonly ſold for one another (ſaith the ſame Author). However, it does truly agree in this common quality aſcribed unto both, of being incombuſtible, and not conſumable by fire: But yet there is this inconvenience, that it doth contract ſo much fuliginous matter from the earthy parts of the oyl, (though it was tryed with ſome of the pureſt oyl, which is ordinary to be bought) that in a very few dayes it did choak and extinguiſh the flame. There may poſſibly be ſome chymical way ſo to purifie and defecate this oyl, that it ſhall not ſpend into a ſooty matter.

De lapid. & gemmis, l.2 c.204.

However if the liquor be of a cloſe and glutinous conſiſtency, it may burn without any ſnuff, as we ſee in Camphire, and ſome other bituminous ſubſtances. And it is probable that moſt of the ancient lamps were of this kind, becauſe the exacteſt relations (to my remembrance) do not mention any that have been found with ſuch wieks.

But herein will conſiſt the greateſt difficulty, to find out what invention there might be for their duration. Concerning which there are ſundry opinions.

Saint *Auſtin* ſpeaking of that Lamp in one of the Heathen Temples, thinks that it might either be done by Magick, the Devil thinking thereby to promote the worſhip and eſteem of that idol to which it was dedicated; or elſe that the art of man might make it of ſome ſuch material, as the ſtone *Asbeſtus*, which being once enkindled, will burn without being conſumed. As others (ſaith he) have contrived as great a wonder in appearance, from the natural virtue of another ſtone, making an iron-image ſeem to hang in the air, by rea-

De Civ. Dei l. 21. c. 6.

Zanch. de Operibus Dei, par. 1. l. 4. c. 12.

reaſon of two load-ſtones, the one being placed in the Cieling, the other in the floor.

Others are of opinion, that this may be effected in a hollow veſſel, exactly luted or ſtopped up in all the vents of it. And then, if a lamp be ſuppoſed to burn in it, but for the leaſt moment of time, it muſt continue ſo always, or elſe there would be a *Vacuum*, which nature is not capable of; If you ask, how it ſhall be nouriſhed, it is anſwered, that the oyl of it being turned into ſmoak and vapours, will again be converted into its former nature; For otherwiſe, if it ſhould remain rarified in ſo thin a ſubſtance, then there would not be room enough for that fume which muſt ſucceed it; and ſo on the other ſide, there might be ſome danger of the *Penetration* of bodies, which nature doth as much abhor. To prevent both which, as it is in the Chymical circulations, where the ſame body is oftentimes turned from liquor into vapour, and from vapour into liquor again; ſo

in

in this experiment, the ſame oyl ſhall be turned into fume, and that fume ſhall again convert into oyl. Always provided, that this oyl which nouriſhes the lamp, be ſuppoſed of ſo cloſe and tenacious a ſubſtance, that may ſlowly evaporate, and ſo there will be the more leiſure for nature to perfect theſe circulations. According to which contrivance, the lamp within this veſſel can never fail, being always ſupplyed with ſufficient nouriſhment. That which was found in the Iſle *Neſis*, incloſed in a glaſs vial, mentioned by *Baptiſta Porta*, is thought to be made after ſome ſuch manner as this.

Others conceive it poſſible to extract ſuch an oyl out of ſome Minerals, which ſhall for a long ſpace ſerve to nouriſh the flame of a lamp with very little or no expence of its own ſubſtance. To which purpoſe (ſay they) if gold be diſſolved into an unctuous humour; or if the radical moiſture of that metal were ſeparated, it might be contrived to burn (perhaps

VVolphang Lazius, l. 3. c. 18. *Camb. Brit.* p. 572.

(perhaps for ever, or at leaſt) for many ages together, without being conſumed. For if gold it ſelf (as experience ſhews) be ſo untameable by the fire, that after many meltings, and violent heats, it does ſcarce diminiſh; 'tis probable then, that being diſſolved into an oylie ſubſtance, it might for many hundred years together continue burning.

There is a little Chymical diſcourſe, to prove that *Urim* and *Thummim* is to be made by art; the Author of this Treatiſe affirms that place, *Gen.* 6. 16. where God tells *Noah*, *a window ſhalt thou make in the Ark*, to be very unfitly rendered in our Tranſlation a window, becauſe the Original word צֹהַר ſignifies properly ſplendor or light; and then beſides, the air being at that time ſo extremely darkned with the clouds of that exceſſive rain, a window could be but of very little uſe in regard of light, unleſs there were ſome other help for it; from whence he conjectures that both this ſplendor, and ſo likewiſe the Urim and Thummim, were artificial Chymical preparations of light, anſwerable to theſe ſubterraneous lamps; or in his own phraſe, it hath *the univerſal ſpirit fixed in a tranſparent body.*

It is the opinion of *Licetus* (who hath more axactly ſearched into the ſubtilties of this enquiry) that fire does not need any humour for the nouriſhment of it, but only to detain it from flying upwards. For being it ſelf one of the chief elements (ſaith he out of *Theophraſtus*) it were abſurd to think that it could not ſubſiſt without ſomething to feed it. As for that ſubſtance which is conſumed by it, this cannot be ſaid to foment or preſerve the ſame fire, but only to generate new. For the better underſtanding of this, we muſt obſerve, that there may be a threefold proportion betwixt fire, and the humour or matter of it. Either the humour does exceed the ſtrength of the fire, or the fire does exceed the humour; and according to both theſe, the flame doth preſently vaniſh. Or

De Lucernis, c. 20. 21.

elſe

elſe laſtly, they may be both equal in their virtues, (as it is betwixt the radical moiſture and natural heat in living creatures) and then neither of them can overcome or deſtroy the other.

Thoſe ancient lamps of ſuch long duration, were of this later kind. But now, becauſe the qualities of heat or cold, dryneſs or moiſture in the ambient air, may alter this equality of proportion betwixt them, and make one ſtronger than the other; therefore to prevent this, the Ancients did hide theſe lamps in ſome caverns of the earth, or cloſe monuments: And hence is it, that at the opening of theſe, the admiſſion of new air unto the lamp does uſually cauſe ſo great an inequality betwixt the flame and the oyl, that it is preſently extinguiſhed.

But ſtill the greateſt difficulty remains, how to make any ſuch exact proportion betwixt an unctuous humour, and ſuch an active quality, as the heat of fire; or this equality being

ing made, it is yet a further difficulty, how it may be preserved. To which purpose, *Licetus* thinks it possible to extract an inflameable oyl from the stone *Asbestus, Amiantus*, or the metal Gold, which being of the same pure and homogeneous nature with those bodies, shall be so proportioned unto the heat of fire, that it cannot be consumed by it, but being once inflamed should continue for many ages, without any sensible diminution.

If it be in the power of Chymistry to perform such strange effects as are commonly experimented in that which they call *aurum fulminans*, one scruple of which shall give a lowder blow, and be of greater force in descent, than half a pound of ordinary Gunpowder in ascent; why may it not be as feasible by the same art to extract such an oyl as is here enquired after: since it must needs be more difficult to make a fire which of its own inclination shall tend downwards, than to conrrive such an unctuous

ctuous liquor, wherein fire ſhall be maintained for many years without any new ſupply?

Thus have I briefly ſet down the relations and opinions of divers learned men concerning theſe perpetual lamps; of which, though there have been ſo many ſundry kinds, and ſeveral ways to make them, (ſome being able to reſiſt any violence of weathers, others being eaſily extinguiſhed by any little alteration of the air; ſome being incloſed round about within glaſs, others being open); yet now they are all of them utterly periſhed amongſt the other ruines of time; and thoſe who are moſt verſed in the ſearch after them, have only recovered ſuch dark conjectures, from which a man cannot clearly reduce any evident principle that may encourage him to a particular trial.

CAP. XIII.

Concerning ſeveral attempts of contriving a perpetual motion by Magnetical virtues.

THE ſecond way whereby the making of a perpetual motion hath been attempted, is by Magnetical virtues; which are not without ſome ſtrong probabilities of proving effectual to this purpoſe: eſpecially when we conſider that the heavenly revolutions, (being as the firſt pattern imitated and aimed at in theſe attempts) are all of them performed by the help of theſe qualities. This great Orb of earth, and all the other Planets being but as ſo many Magnetical Globes endowed with ſuch various and continual motions, as may be moſt agreable to the purpoſes for which they were intended. And therefore moſt of the Authors who treat concerning this invention, do agree, that the likelieſt way to effect it, is by theſe kind of qualities.

It was the opinion of *Pet. Peregrinus*, and there is an example pretended for it in *Bettinus* (*Apiar.* 9. *Progym.* 5. *pro.* 11). That a Magnetical Globe or Terella, being rightly placed upon its poles, would of it self have a constant rotation, like the diurnal motion of the earth; But this is commonly exploded, as being against all experience.

Gilbert. de Magnet. Calæus Philos. Magnet. l. 4. c. 20.

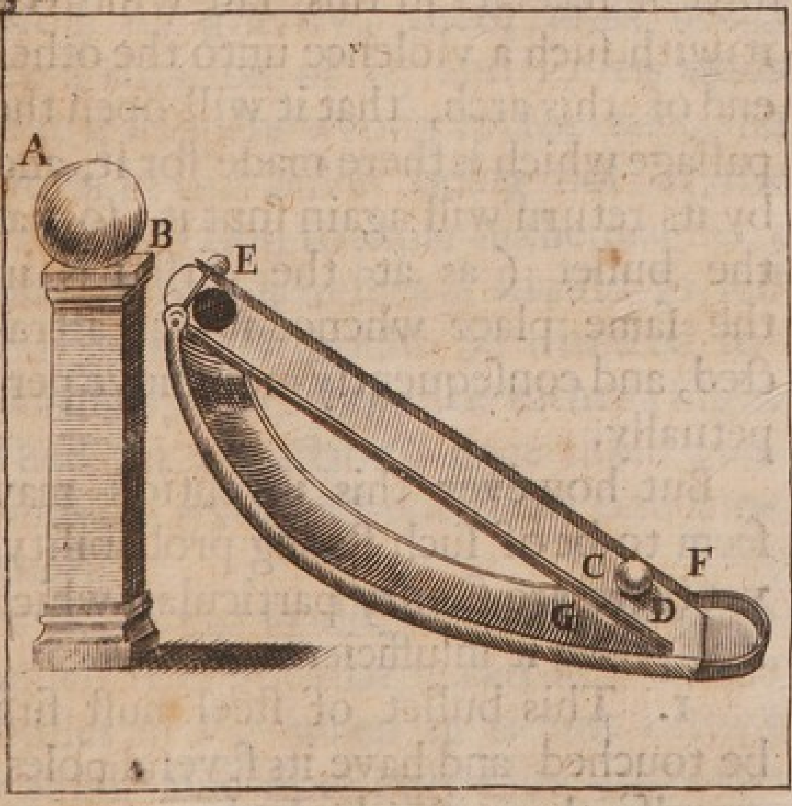
Others think it possible, so to contrive several pieces of steel, and a loadstone, that by their continual attraction and expulsion of one another, they may cause a perpetual revolution of a wheel; Of this opinion were [a] *Taisner* [b] *Pet. Peregrinus*, and [c] *Cardan*, out of *Antonius de Fantis*. But D. *Gilbert*, who was more especially versed in Magnetical experiments, concludes it to be a vain and groundless fancy.

Athanas. Kircher. de Arte Magnet. l. 1. par. 2. prop. 13. p. 4.

a *Tract. de motu continuo.*
b *De Rota perpetui motus. par. 2. c. 3.*
c *De Variet. rerum l. 9. c. 48.*
De magnet. l. 2. c. 35.

But amongst all these kind of inventions, that is most likely, wherein a loadstone is so disposed, that it shall draw unto it on a reclined plane, a bullet of steel; which steel, as it ascends

ſcends near to the loadſtone, may be contrived to fall down through ſome hole in the plane, and ſo to return unto the place from whence at firſt it began to move; and being there, the loadſtone will again attract it upwards, till coming to this hole it will fall down again: and ſo the motion ſhall be perpetual, as may be more eaſily conceivable by this figure.



Suppoſe the loadſtone to be repreſented at *A B*, which though it have not ſtrength enough to attract the bullet *C*, directly from the ground, yet may do it by the help of the plane *E F*. Now when the bullet is come to the top of this plane, its own gravity (which is ſuppoſed to exceed the ſtrength of the loadſtone) will make it fall into that hole at *E*: and the force it receives in this fall willcarry it with ſuch a violence unto the other end of this arch, that it will open the paſſage which is there made for it, and by its return will again ſhut it; ſo that the bullet (as at the firſt) is in the ſame place whence it was attracted, and conſequently muſt move perpetually.

But however this invention may ſeem to be of ſuch ſtrong probability, yet there are ſundry particulars which may prove it inſufficient; For,

1. This bullet of ſteel muſt firſt be touched and have its ſeveral poles, or elſe there can be little or no attraction of it. Suppoſe *C* in the ſteel to

to be anſwerable unto *A* in the ſtone; and to *B*; In the attraction, *C D* muſt always be directed anſwerable to *A B*, and ſo the motion will be more difficult, by reaſon there can be no rotation or turning round of the bullet, but it muſt ſlide up with the line *C D*, anſwerable to the axis *A B*.

2. In its fall from *E* to G, which is *motus elementaris*, and proceeds from its gravity, there muſt needs be a rotation of it, and ſo 'tis odds but it happens wrong in the riſe, the poles in the bullet being not in the ſame direction to thoſe in the magnet; and if in this reflux it ſhould ſo fall out, that *D* ſhould be directed towards *B*, there ſhould be rather a flight than an attraction, ſince thoſe two ends do *repell* and not draw one another.

3. If the loadſtone *A B*, have ſo much ſtrength that it can attract the bullet in *F*, when it is not turned round, but does only ſlide upon the plane, whereas its own gravity would roul it downwards: then it is evident,

the ſphere of its activity and ſtrength would be ſo increaſed when it approaches much nearer, that it would not need the aſſiſtance of the plane, but would draw it immediately to it ſelf without that help, and ſo the bullet would not fall down through the hole, but aſcend to the ſtone, and conſequently ceaſe its motion. For if the loadſtone be of force enough to draw the bullet on the plane, at the diſtance *F B*, then muſt the ſtrength of it be ſufficient to attract it immediatly unto it ſelf, when it is ſo much nearer as *E B.* And if the gravity of the bullet be ſuppoſed ſo much to exceed the ſtrength of the Magnet, that it cannot draw it directly when it is ſo near, then will it not be able to attract the bullet up the plane, when it is ſo much further off.

So that none of all theſe Magnetical experiments, which have been as yet diſcovered, are ſufficient for the effecting of a perpetual motion, though theſe kind of qualities ſeem moſt conducible unto it, and perhaps

haps hereafter it may be contrived from them.

CAP. XIV.

The ſeeming probability of effecting a continual motion by ſolid weights in a hollow wheel or ſphere.

THE third way whereby the making of a perpetual motion hath been attempted, is by the natural affection of gravity; when the heavineſs of ſeveral bodies is ſo contrived, that the ſame motion which they give in their deſcent, may be able to carry them up again.

But againſt the poſſibility of any ſuch invention, it is thus objected by *Cardan*; All ſublunary bodies have a direct motion either of aſcent or deſcent; which, becauſe it does refer to ſome term, therefore cannot be perpetual, but muſt needs ceaſe when it is arrived at the place unto which it naturally tends.

Subtil. l. 17 *De Var. Rerum. l.* 9 *c.* 48.

I anſwer, though this may prove

that there is no natural motion of any particular heavy body, which is perpetual; yet it doth not hinder but that is is poſſible from them to contrive ſuch an artificial revolution as ſhall conſtantly be the cauſe of it ſelf.

Thoſe bodies which may be ſerviceable to this purpoſe, are diſtinguiſhable into two kinds.

1. Solid and conſiſtent, as weights of metal, or the like.

2. Fluid or ſliding, as water, ſand, &c.

Both theſe ways have been attempted by many, though with very little or no ſucceſs. Other mens conjectures in this kind you may ſee ſet down by divers Authors. It would be too tedious to repeat them over, or ſet forth their draughts. I ſhall only mention two news ones, which (if I am not over partial) ſeem altogether as probable as any of theſe kinds that have been yet invented; and till experience had diſcovered their defect and inſufficiency, I did certainly

D. Flud. Tract. 2. part 7. l. 2. c. 4. & 7.

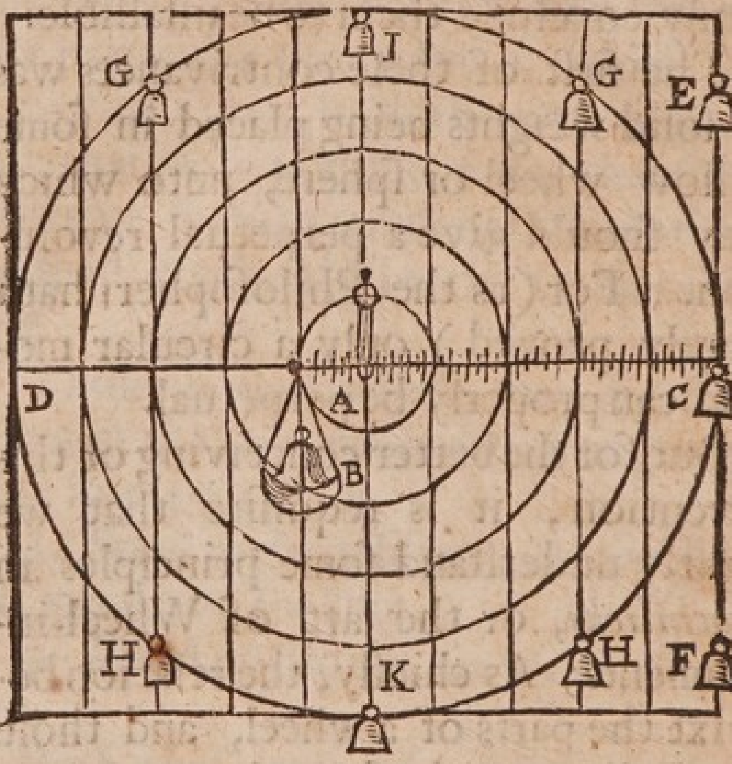
tainly

tainly conclude them to be infallible.

The first of these contrivances was by solid weights being placed in some hollow wheel or sphere, unto which they should give a perpetual revolution. For (as the Philosopher hath largely proved) only a circular motion can properly be perpetual. *Arist. Phis. l. 8, c. 12.*

But for the better conceiving of this invention, it is requisite that we rightly understand some principles in *Trochilicks*, or the art of Wheel-instruments; As chiefly, the relation betwixt the parts of a wheel, and those of a Ballance; the several proportions in the Semidiameter of a wheel, being answerable to the sides in a ballance, where the weight is multiplied according to its distance from the center. *Arist. Mechan. c. 2. De ratione libræ ad circulum.*

Thus



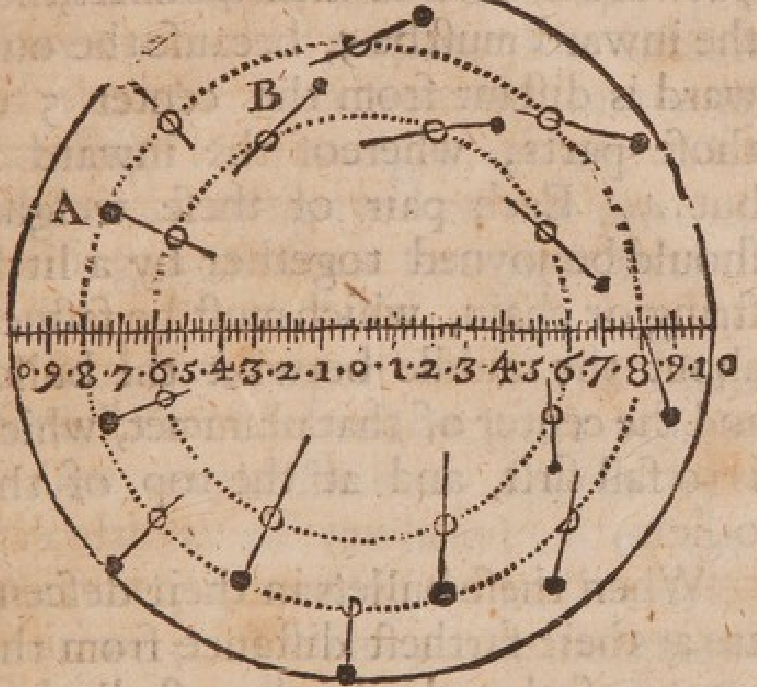
Thus ſuppoſe the center to be at *A*, and the Diameter of the wheel *D C*, to be divided into equal parts (as is here expreſſed) it is evident according to the former ground, that one pound at *C*, will equiponderate to five pound at *B*, becauſe there is ſuch a proportion betwixt their ſeveral diſtances from the Center. And it is not material whether or no theſe ſeveral weights be placed horizontally; for though *B* do hang lower than

than *C*, yet this does not at all concern the heavineſs, or though the plummet *C* were placed much higher than it is at *E*, or lower at *F*, yet would it ſtill retain the ſame weight which it had at *C*, becauſe theſe plummets (as is the nature of all heavy bodies) do tend downwards by a ſtraight line: So that their ſeveral gravities are to be meaſured by that part of the horizontal Semidiameter which is directly either below or above them. Thus when the plummet *C*, ſhall be moved either to *G* or *H*, it will loſe ⅗ of its former heavineſs, and be equally ponderous as if it were placed in the ballance at the number 3; and if we ſuppoſe it to be ſituated at *I* or *K*, then the weight of it will lie wholly upon the Center, and not at all conduce to the motion of the wheel on either ſide. So that the ſtraight lines which paſs through the diviſions of the diameter, may ſerve to meaſure the heavineſs of any weight in its ſeveral ſituations.

These things throughly conſidered, it

it ſeems very poſſible and eaſie for a man to contrive the plummets of a wheel, that they may be always heavier in their fall, than in their aſcent, and ſo conſequently that they ſhould give a perpetual motion to the wheel it ſelf: Since it is impoſſible for that to remain unmoved, as long as one ſide in it is heavier than the other.

For the performance of this, the weights muſt be ſo ordered, 1. That in their deſcent they may fall from the Center, and in their aſcent may riſe nearer to it. 2. That the fall of each plummet may begin the motion of that which ſhould ſucceed it. As in this following Diagram.



Where there are 16 plummets, 8 in the inward circle, and as many in the outward, (the equality being to ariſe from their ſituation, it is therefore moſt convenient that the number of them be even). The eight inward plummets are ſuppoſed to be in themſelves ſo much heavier than the other, that in the wheel they may be of equal weight with thoſe above them, and then the fall of theſe will be of ſufficient force to bring down

down the other. For example, if the outward be each of them 4 ounces, then the inward muſt be 5, becauſe the outward is diſtant from the center 5 of thoſe parts, whereof the inward is but 4. Each pair of theſe weights ſhould be joyned together by a little ſtring or chain, which muſt be faſtned about the middle betwixt the bullet and the center of that plummet, which is to fall firſt, and at the top of the other.

When theſe bullets in their deſcent are at their fartheſt diſtance from the center of the wheel, then ſhall they be ſtopped, and reſt on the pins placed to that purpoſe; and ſo in their riſing, there muſt be other pins to keep them in a convenient poſture and diſtance from the center, leſt approaching too near unto it, they thereby become unfit to fall, when they ſhall come to the top of the deſcending ſide.

This may be otherwiſe contrived with ſome different circumſtances; but they will all redound to the ſame effect.

effect. By ſuch an engine it ſeems very probable, that a man may produce a perpetual motion. The diſtance of the plummets from the center increaſing their weight on one ſide; and their being tyed to one another, cauſing a conſtant ſucceſſion in their falling.

But now, upon experience I have found this to be fallacious; and the reaſon may ſufficiently appear by a calculation of the heavineſs of each plummet, according to its ſeveral ſcituations; which may eaſily be done by thoſe perpendiculars that cut the diameter, (as was before explained, and is here expreſſed in five of the plummets on the deſcending ſide). From ſuch a calculation it will be evident, that both the ſides of this wheel will equiponderate, and ſo conſequently that the ſuppoſed inequality, whence the motion ſhould proceed, is but imaginary and groundleſs. On the deſcending ſide, the heavineſs of each plummet may be meaſured according to theſe numbers, (ſuppoſing the diameter

ameter of the wheel to be divided into twenty parts, and each of thoſe ſub-divided into four).

The outward plummets.			*The inward plummets.*		
7	0	*The ſum* 24.	1	0	*The ſum* 19
10	0		7	2	
7	0		7	2	
			3	0	

On the aſcending ſide the weights are to be reckoned according to theſe degrees,

The outward.			*The inward.*		
1	3	*The ſum* 24.	4	1	*The ſum* 19
7	2		7	0	
9	0		5	2	
5	3		2	1	
0	0				

The ſumme of which laſt numbers is equal with the former, and therefore both the ſides of ſuch a wheel, in this ſituation will equiponderate.

If

If it be objected, that the plummet *A* ſhould be contrived to pull down the other at *B*, and then the deſcending ſide will be heavier than the other.

For anſwer to this, it is conſiderable,

1. That theſe bullets towards the top of the wheel, cannot deſcend till they come to a certain kind of inclination.

2. That any lower bullet hanging upon the other above it, to pull it down, muſt be conceived, as if the weight of it were in that point where its ſtring touches the upper; at which point this bullet will be of leſs heavineſs in reſpect of the wheel, than if it did reſt in its own place: So that both the ſides of it in any kind of ſituation may equiponderate.

CAP. XV.

Of composing a perpetual motion by fluid weights. Concerning Archimedes *his water-screw. The great probability of accomplishing this inquiry by the help of that: with the fallibleness of it upon experiment.*

THat which I shall mention as the last way, for the trial of this experiment, is by contriving it in some water-instrument; which may seem altogether as probable and easie as any of the rest, because that element by reason of its fluid and subtil nature (whereby of its own accord it searches out the lower and more narrow passages) may be most pliable to the mind of the artificer. Now the usual means for the ascent of water is either by *Suckers* or *Forces*, or something equivalent thereunto; Neither of which may be conveniently applied unto such a work as this, because there is required unto each of them so much or more strength, as may be answerable

ble to the full weight of the water that is to be drawn up; and then beſides, they move for the moſt part by fits and ſnatches, ſo that it is not eaſily conceivable, how they ſhould conduce unto ſuch a motion which by reaſon of its perpetuity muſt be regular and equal.

But amongſt all other ways to this purpoſe, that invention of *Archimedes* is incomparably the beſt, which is uſually called *Cochlea*, or the *Water-ſcrew*, being framed by the Helical revolution of a cavity about a Cylinder. We have not any diſcourſe from the Author himſelf concerning it, nor is it certain whether he ever writ any thing to this purpoſe. But if he did, yet as the injury of time hath deprived us of many other his excellent works; ſo likewiſe of this, amongſt the reſt.

Athenæus ſpeaking of that great ſhip built by *Hiero*, in the framing of which there were 300 Carpenters employed for a year together, beſides many other hirelings for carriages, *Dipnoſoph. l. 5.*

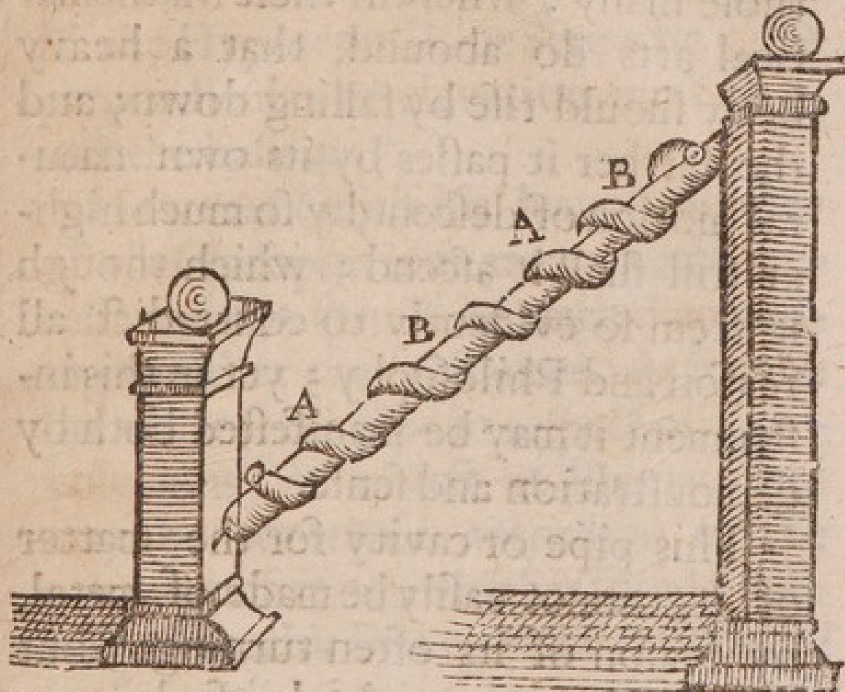
and ſuch ſervile works, mentions this inſtrument as being inſtead of a pump for that vaſt ſhip; by the help of which, one man might eaſily and ſpeedily drain out the water, though it were very deep.

Bibliotb. l. 1. *Diodorus Siculus* ſpeaking of this engine, tells us, that *Archimedes* invented it when he was in *Egypt*, and that it was uſed in that Country for the draining thoſe pits and lower grounds, whence the waters of *Nilus* could not return. Φιλοτέχνου δ' ὄντος τοῦ ὀργάνου καθ' ὑπερβολήν, (ſaith the ſame Author). It being an engine ſo ingenious and artificial, as cannot *Cardan. Subt. l.* 1: *De ſapient. l.* 5. be ſufficiently expreſſed or commended. And ſo (it ſhould ſeem) the Smith in *Millain* conceived it to be, who having without any teaching or information found it out, and therefore thinking himſelf to be the firſt inventor, fell mad with the meer joy of it.

Architect. l. 10. *c.* 11. The nature and manner of making this, is more largely handled by *Vitruvius.*

The

The Figure of it isafter this manner.



Where you ſee there is a Cylinder *A A*, and a ſpiral cavity or pipe twining about it, according to equal revolutions *B B*. The axis and centers of its motions are at the points *C D*, upon which being turned, it will ſo happen that the ſame part of the pipe which was now lowermoſt, will preſently become higher, ſo that the water does aſcend by deſcending; aſcending in compariſon to the whole inſtrument, and deſcending in reſpect of its ſeveral parts. This being one of the ſtrangeſt wonders amongſt thoſe many, wherein theſe Mathematical arts do abound, that a heavy body ſhould riſe by falling down; and the farther it paſſes by its own natural motion of deſcent, by ſo much higher ſtill ſhall it aſcend; which though it ſeem ſo evidently to contradict all reaſon and Philoſophy; yet in this inſtrument it may be manifeſted both by demonſtration and ſenſe.

This pipe or cavity for the matter of it, cannot eaſily be made of metal, by reaſon of its often turnings; but for trial, there might be ſuch a cavity, cut in a column of wood, and afterwards covered over with tin plate.

For the form and manner of making this ſcrew, *Vitruvius* does preſcribe theſe two rules:

1. That there muſt be an equality obſerved betwixt the breadth of the pipe, and the diſtance of its ſeveral circumvolutions.

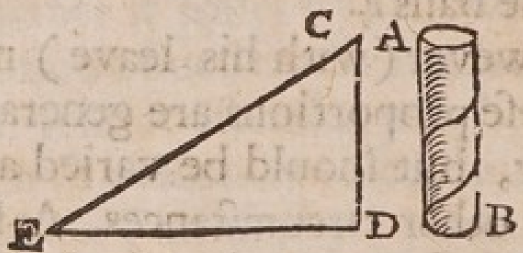
2. That there muſt be ſuch a proportion

portion betwixt the length of the instrument, and its elevation, as is anſwerable to the *Pythagorical Trigon.* If the Hypotenuſal, or Screw be 5, the perpendicular or elevation muſt be 3, and the baſis 4.

David Rivalt. Com. in Archim. opera. extern.

However (with his leave) neither of theſe proportions are generally neceſſary, but ſhould be varied according to other circumſtances. As for the breadth of the pipe in reſpect of its revolutions, it is left at liberty, and may be contrived according to the quantity of water which it ſhould contain. The chief thing to be conſidered is the obliquity or cloſeneſs of theſe circumvolutions. For the nearer they are unto one another, the higher may the inſtrument be erected; there being no other guide for its true elevation but this.

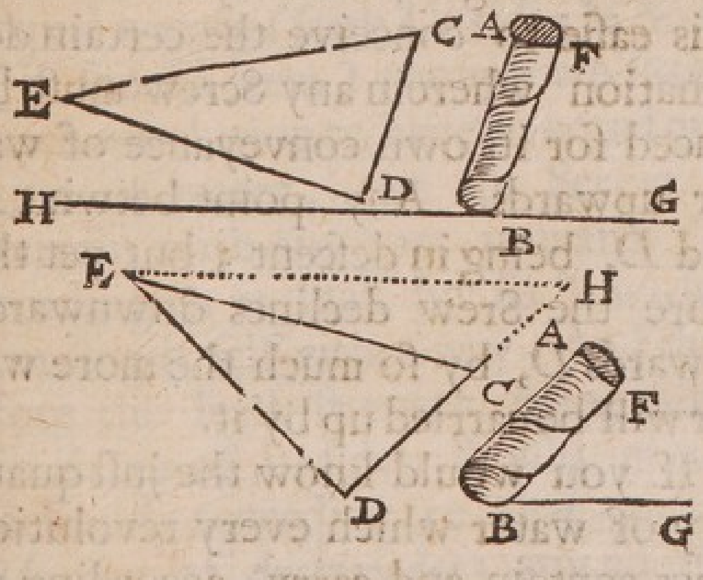
And becauſe the right underſtanding of this particular is one of the principal matters that concern the uſe of this engine, therefore I ſhall endeavour with brevity and perſpicuity to explain it. The firſt thing to be inquired after, is what kind of inclination these Helical revolutions of the Cylinder have unto the Horizon; which may be thus found out.



Let *A B* represent a Cylinder with two perfect revolutions in it; unto which Cylinder the perpendicular line *C D* is equal: the basis *D E* being supposed to be double unto the compass or circumference of the Cylinder. Now it is certain that the angle *C E D*, is the same with that by which the revolutions on the Cylinder are framed; and that the line *E C*, in comparison to the basis *E D*, does shew the inclination of these revolutions unto the Horizon. The grounds and demonstration of this, are more fully set down by *Guidus Ubaldus*, in his Mechanicks, and that other

other Treatiſe *De Cochlea*, which he writ purpoſely for the explication of this inſtrument, where the ſubtilties of it are largely and excellently handled.

Now if this Screw which was before perpendicular, be ſuppoſed to decline unto the Horizon by the angle *F B G*, as in this ſecond Figure;



then the inclination of the revolutions in it, will be increaſed by the angle *E D H*, though theſe revolutions will ſtill remain in a kind of aſcent, ſo that water cannot be turned through them.

But

But now if the Screw be placed ſo far declining, that the angle of its inclination *F B G*, be leſs than the angle *E C D*, in the triangle, as in this other Diagram under the former; then the revolutions of it will deſcend to the Horizon, as does the line *E C*, and in ſuch a poſture, if the Screw be turned round, water will aſcend through its cavity. Whence it is eaſie to conceive the certain declination wherein any Screw muſt be placed for its own conveyance of water upwards. Any point betwixt *H* and *D*, being in deſcent; but yet the more the Srew declines downwards towards *D*, by ſo much the more water will be carried up by it.

If you would know the juſt quantity of water which every revolution does contain and carry, according to any inclination of the Cylinder, this may be eaſily found by aſcribing on it an *Ellipſis*, parallel to the Horizon; which *Ellipſis* will ſhew how much of the revolution is empty, and how much full.

See a further explication of this in *Ubaldus de Cochler, l. 2. prop. 25.*

The

The true inclination of the Screw being found, together with the certain quantity of water which every *Helix* does contain; it is further considerable, that the water by this instrument does aſcend naturally of it ſelf without any violence or labour, and that the heavineſs of it doth lie chiefly upon the centers or axis of the Cylinder, both its ſides being of equal weight (ſaith *Ubaldus*); So that (it ſhould ſeem) though we ſuppoſe each revolution to have an equal quantity of water, yet the Screw will remain with any part upwards (according as it ſhall be ſet) without turning it ſelf either way. And therefore the leaſt ſtrength being added to either of its ſides, ſhould make it deſcend, according to that common Maxime of *Archimedes*; any addition will make that which equiponderates with another, to tend downwards.

Ibid. l. 3. *prop.* 4.

De Equipond. Suppoſ. 3.

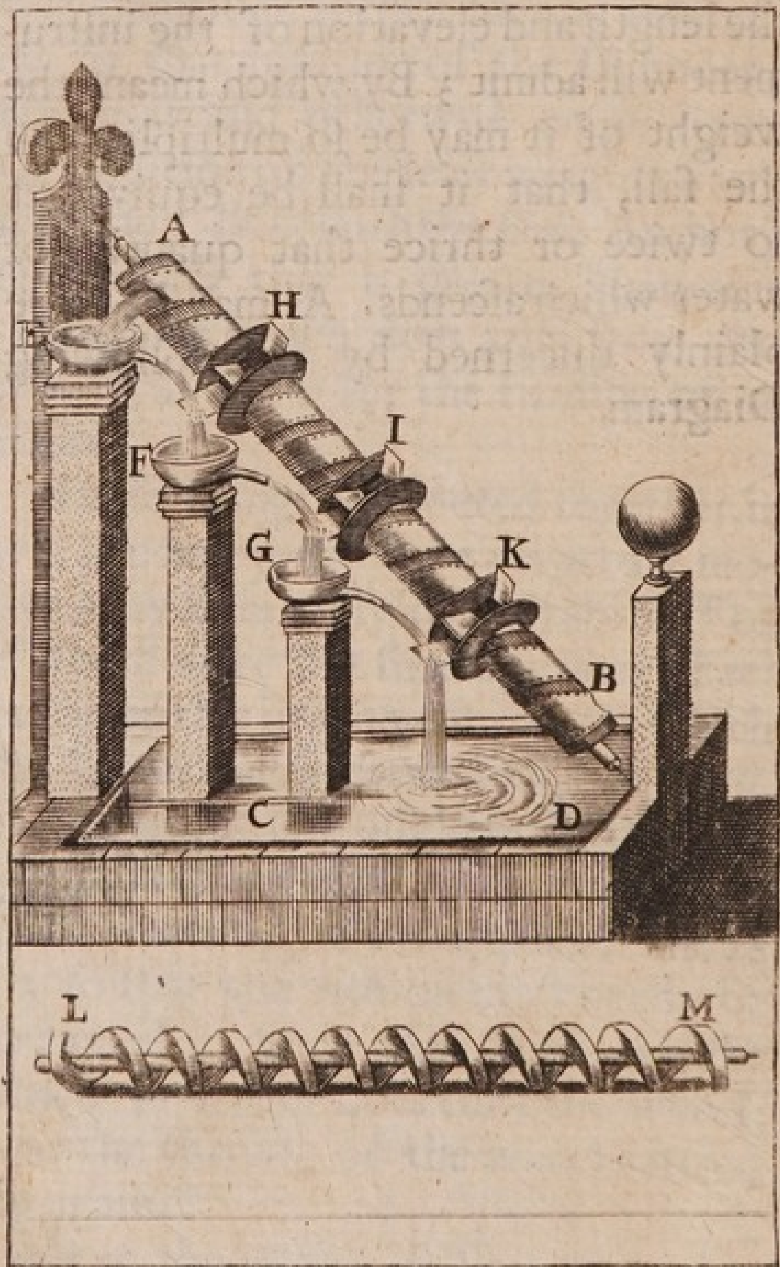
But now, becauſe the weight of this inſtrument, and the water in it, does lean wholly upon the axis, hence

hence is it (saith *Ubaldus*) that the grating and rubbing of these axes against the sockets wherein they are placed, will cause some ineptitude and resistency to that rotation of the Cylinder, which would otherwise ensue upon the addition of the least weight to any one side; But (saith the same Author) any power that is greater than this resistency which does arise from the axis, will serve for the turning of it round.

These things considered together, it will hence appear, how a perpetual motion may seem easily contrivable. For if there were but such a water-wheel made on this instrument, upon which the stream that is carried up, may fall, in its descent it would turn the screw round, and by that means convey as much water up, as is required to move it; so that the motion must needs be continual, since the same weight which in its fall does turn the wheel, is by the turning of the wheel carried up again.

Or if the water falling upon one

wheel would not be forcible enough for this effect, why then there might be two or three, or more, according as the length and elevation of the inſtrument will admit; By which means the weight of it may be ſo multiplied in the fall, that it ſhall be equivalent to twice or thrice that quantity of water which aſcends. As may be more plainly diſcerned by this following Diagram.


A
H
E
F
I
G
K
B
C
D
L
M

Where the figure *L M*, at the bottome does represent a wooden Cylinder with Helical cavities cut in it, which at *A B*, is supposed to be covered over with tin plates, and three water-wheels upon it, *H I K*. The lower cistern which contains the water being *C D*. Now this Cylinder being turned round, all the water which from the cistern ascends through it, will fall into the vessel at *E*, and from that vessel being conveyed upon the water-wheel *H*, shall consequently give a circular motion to the whole Screw: Or if this alone should be too weak for the turning of it, then the same water which falls from the wheel *H*, being received into the other vessel *F*, may from thence again descend on the wheel *I*; by which means the force of it will be doubled. And if this be yet insufficient, then may the water which falls on the second wheel *I*, be received into the other vessel G, and from thence again descend on the third wheel at *K*: and so for as many

There is another like contrivance to this purpose in *Pet. Bettin. Apiar. 4. Progym. 1. Prop. 10.* but with much less advantage than 'tis here proposed.

many other wheels, as the inſtrument is capable of. So that beſides the greater diſtance of theſe three ſtreams from the center or axis, by which they are made ſo much heavier ; and beſides, that the fall of this outward water is forcible and violent, whereas the aſcent of that within, is natural ; Beſides all this, there is thrice as much water to turn the Screw, as is carried up by it.

But on the other ſide, if all the water falling upon one wheel, would be able to turn it round, then half of it would ſerve with two wheels ; and the reſt may be ſo diſpoſed of in the fall, as to ſerve unto ſome other uſeful delightful ends.

When I firſt thought of this invention, I could ſcarce forbear with *Archimedes* to cry out εὕρηκα εὕρηκα ; It ſeeming ſo infallible a way for the effecting of a perpetual motion, that nothing could be ſo much as probably objected againſt it: But upon trial and experience I find it altogether inſufficient for any ſuch purpoſe

purpoſe, and that for theſe two reaſons:

1. The water that aſcends will not make any conſiderable ſtream in the fall.

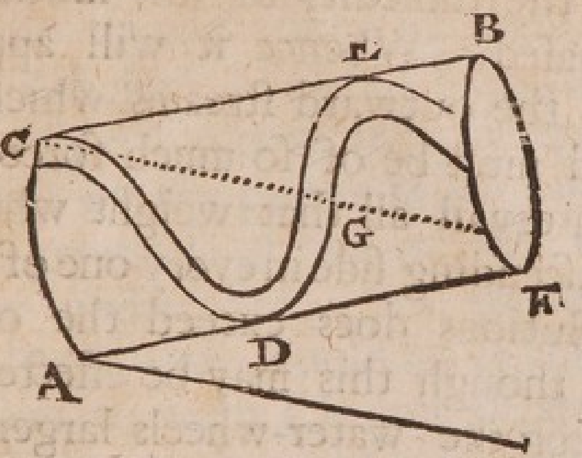
2. This ſtream (though multiplied) will not be of force enough to turn about the Screw.

1. The water aſcends gently and by intermiſſions, but it falls continuately and with force; each of the three veſſels being ſuppoſed full at the firſt, that ſo the weight of the water in them might add the greater ſtrength and ſwiftneſs to the ſtreams that deſcend from them. Now this ſwiftneſs of motion will cauſe ſo great a difference betwixt them, that one of theſe little ſtreams may ſpend more water in the fall, than a ſtream ſix times bigger in the aſcent, though we ſhould ſuppoſe both of them to be continuate; How much more then, when as the aſcending water is vented by fits and intermiſſions, every circumvolution voiding only ſo much as is con-

tained in one *Helix?* And in this particular, one that is not verſed in theſe kind of experiments, may be eaſily deceived.

But ſecondly, though there were ſo great a diſproportion, yet notwithſtanding the force of theſe outward ſtreams, might well enough ſerve for the turning of the Screw, if it were ſo that both its ſides would equiponderate, the water being in them (as *Ubaldus* hath affirmed). But now upon farther examination, we ſhall find this aſſertion of his, to be utterly againſt both reaſon and experience. And herein does conſiſt the chief miſtake of this contrivance. For the aſcending ſide of the Screw is made by the water contained in it, ſo much heavier than the deſcending ſide, that theſe outward ſtreams thus applyed, will not be of force enough to make them equiponderate, much leſs to move the whole. As may be more eaſily diſcerned by this figure.

Where



Where *A B*, repreſents a Screw covered over, *C D E* one *Helix* or revolution of it, *C D* the aſcending ſide, *E D* the deſcending ſide, the point *D* the middle. The Horizontal line *C F*, ſhewing how much of the *Helix* is filled with water, *viz.* of the aſcending ſide, from *C* the beginning of the *Helix* to *D* the middle of it; and on the deſcending ſide, from *D* the middle, to the point *G*, where the Horizontal does cut the *Helix*. Now it is evident that this latter part *D G*, is nothing near ſo much, and conſequently not ſo heavy as the other *D C*. And thus is it in all the other revolutions, which as they are either more, or larger, ſo will the difficulty of this motion be increaſed. Whence it will appear, that the outward ſtreams which deſcend muſt be of ſo much force as to countervail all that weight whereby the aſcending ſide in every one of theſe revolutions does exceed the other; And though this may be effected by making the water-wheels larger, yet then the motion will be ſo ſlow, that the Screw will not be able to ſupply the outward ſtreams.

There is another contrivance to this purpoſe mentioned by *Kircher de Magnete*, *l.* 2. *p.* 4. depending upon the heat of the Sun, and the force of winds, but it is liable to ſuch abundance of exceptions, that it is ſcarce worth the mentioning, and does by no means deſerve the confidence of any ingenious Artiſt.

Thus have I briefly explained the probabilities and defects of thoſe ſubtil contrivances, whereby the making of a perpetual motion hath been attempted. I would be loth to diſcourage the enquiry of any ingenious

Artificer,

Artificer, by denying the poſſibility of effecting it with any of theſe Mechanical helps; But yet (I conceive) if thoſe principles which concern the ſlowneſs of the power in compariſon to the greatneſs of the weight, were rightly underſtood, and throughly conſidered, they would make this experiment to ſeem (if not altogether impoſſible yet) much more difficult than otherwiſe perhaps it will appear. However, the inquiring after it, cannot but deſerve our endeavours, as being one of the moſt noble amongſt all theſe Mechanical ſubtilties. And (as it is in the fable of him who dug the Vineyard for a hid treaſure, though he did not find the money, yet he thereby made the ground more fruitful, ſo) though we do not attain to the effecting of this particular, yet our ſearching after it may diſcover ſo many other excellent ſubtilties, as ſhall abundantly recompence the labour of our enquiry.

Treated of before, l. 1.

And then beſides, it may be another encouragement to conſider the pleaſure

pleaſure of ſuch ſpeculations, which do raviſh and ſublime the thoughts with more clear angelical contentments. *Archimedes* was generally ſo taken up in the delight of theſe Mathematical ſtudies of this familiar *Siren*, (as *Plutarch* ſtiles them) that he forgot both his meat and drink, and other neceſſities of nature; nay, that he neglected the ſaving of his life, when that rude ſolder in the pride and haſt of victory, would not give him leiſure to finiſh his demonſtration. What a raviſhment was that, when having found out the way to meaſure *Hiero's* Crown, he leaped out of the Bath, and (as if he were ſuddenly poſſeſt) ran naked up and down crying εὕρηκα εὕρηκα! It is ſtoried of *Thales*, that in his joy and gratitude for one of theſe Mathematical inventions, he went preſently to the Temple, and there offered up a ſolemn ſacrifice. And *Pythagoras* upon the like occaſion is related to have ſacrificed a hundred oxen. The juſtice of providence ha-

οἰκείας καὶ συνοίκου σειρῆνος. *Plutarch. Marcell.*

Joan. Tzetzes, Chil. Hiſt. 35.

Valer. Maxim. l. 8. *c.* 7.

ving ſo contrived it, that the pleaſure which there is in the ſucceſs of ſuch inventions, ſhould be proportioned to the great difficulty and labour of their inquiry.

FINIS.