THE MOTION OF FLUIDS,

NATURAL and ARTIFICIAL;

In particular that of the

AIR and WATER:

IN A

Familiar Manner proposed and proved by evident and conclusive EXPERIMENTS, to which are added many useful REMARKS.

DONE WITH

Such PLAINNESS and PERSPICUITY, as that they may be understood by the UNLEARNED.

For whose Sake is annexed,

A Short EXPLANATION of such Uncommon Terms, which in Treating on this Subject could not, without Affectation, be avoided.

WITH

Plain DRAUGHTS of such EXPERIMENTS and MACHINES, which, by Description only, might not readily be comprehended.

Nata est Ars ab Experimento. QUINTIL.

By M. CLARE, *A. M. & F. R. S.*

The SECOND EDITION, Corrected and Improved.

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To the Right Honourable

RICHARD BOYLE,

Earl of *Burlington* and *Corke*,

One of the Lords of His Majesty's Most Honourable PRIVY-COUNCIL, *and Knight-Companion of the Most Noble Order of the* GARTER.

MY LORD,

I Esteem it no ordinary Happiness, that I have Leave, under Your Patronage and Protection, to offer to the Publick the *Second*

Edition of a Book, the principal Subject whereof has been thought worthy the Consideration of the Great and Learned Mr. BOYLE, Your LORDSHIP's Uncle, by whom it was cultivated with uncommon Diligence and Success.

ANIMATED by the same Zeal and Spirit, Sir, You also chuse to dedicate a considerable Part of your Time to the Culture of Fine and Useful Arts; of which the many elegant Edifices, as well Publick as Private, which have been conducted under Your LORDSHIP's Direction, and even plann'd with Your own Hands, will continue for Ages to come an incontestable Proof.

THE Benefit of Mankind is doubtless the best and most warrantable Inducement to the Pursuit of Fame; it is also the Standard of true and lasting Glory: By this the World will always very rightly distinguish its real Benefactors;

factors; hence will it rate their Labours, and in Proportion to this alone, make proper Acknowledgments.

THE Part Your Noble House, MY LORD, has long had in publick Beneficence and Utility, is too well known to need any farther Declaration. The Family of *BOYLE* has not been more conspicuous for its numerous and extensive Nobility, than for having produced Men famous in their Generation, and such as have been approved the FRIENDS OF MANKIND.

THAT Your LORDSHIP's Endowments and Abilities are such as eminently distinguish You, at a Time when Arts and Sciences may be said to flourish even to a great Degree of Perfection, is therefore the less surprising:

——————*Nec*——————
Progenerant aquilæ columbam. HOR.

THAT You may long continue thus an Ornament to your Country, a Pattern to your Contemporaries; happy in Yourſelf, your Relations, and every other Circumſtance of Life; is the ſincere Wiſh of

Your LORDSHIP'S

moſt Devoted,

Soho-Square,
March 25, 1737.

and moſt Obedient,

Humble Servant,

Martin Clare.

ADVERTISEMENT.

THE *following Sheets are the Substance of some Lectures, privately read to a Set of Gentlemen, who were so indulgent, both to the Matter and Form, as to encourage their Publication, for the Use and Advantage of Those who may have wanted Opportunities of inquiring into such Natural Causes as are the Subject-Matter of them*; viz.

I. HYDROSTATICKS, *whereby the* Nature *of the grosser Fluids is explained; their* Motions *on the Principle of Gravity ascertained; most of the Varieties of which Motions, whether in* Pipes, Pumps, Syphons, Fire-Engines, Jets-d'Eau, *or the chief* Water-Works *in Use, are both delineated to the Eye, and demonstrated to the Understanding,* *in ſo familiar a Way, that 'tis hoped even the* Unlearned *may, without great Difficulty, comprehend them. To which is added the conciſe Way of diſcovering the Specific Gravity of Bodies, by weighing them in Water.*

II. PNEUMATICKS, *wherein the chief Properties of the Air, its* Preſſure *and* Spring, *are made appear by Experiments and undeniable Proofs. Under which Head, ſhort but clear Sketches of* Muſcular Motion, *the* Circulation *of the* Blood, *the* Proceſs *of* Digeſtion *and* Nutrition, *with ſeveral other curious Subjects relating to the* Animal Oeconomy, *ſo far as they are at preſent underſtood, are occaſionally introduced. The* Meteorology, *or the* Cauſe *and* Origin *of the* Winds, Clouds *and* Storms, *generated in the Regions of the Air, with the* Cauſe *and* Progreſſion *of* Sounds *conveyed to the Ear by Means thereof, are alſo endeavoured to be illuſtrated from Reaſon, or are propoſed from the beſt Authorities. The Inſtru-*

ments

ments also for observing the Alterations *in the State of the Air, are herein particularly described, and the* Art *of* Diving *fully explained.*

IN doing whereof, Care has been taken to be as succinct as was consistent with Perspicuity, and to use as few hard Words *as possible: Such uncommon Terms however as could not be well avoided in treating on these Subjects, are by the short* Glossary *at the End of the Treatise, sufficiently explained.*

IF these Sheets do not contain any new or notable Discoveries in either of the Branches of Science proposed, 'tis hoped, that what has been found out relating to them, will appear to be so well connected, and disposed in so clear a Light, that the Reader may therein find at least Matter of Amusement; and, by perusing them, may not only become a tolerable Judge of what may be done in this Way, but be also made acquainted with the Manner of performing it.

The

The Artiſt will probably receive ſome Benefit from having the Reaſon and Principles of many Things he daily ſees and does, explained to him in an eaſy and familiar Manner. The young Philoſopher may certainly be aſſiſted hereby in his firſt Searches after Truth: Beſides which Advantage, his Mind will be better prepared for receiving Lectures in Natural *and* Experimental Philoſophy; *which might eaſily be introduced into moſt regular Societies, and ſo become of ſingular Uſe and Benefit to Mankind. That which by Experiment is made the Object of our Senſes, is generally found to leave deeper Impreſſions on the Mind, than Inſtruction in any other Way.*

THE Advantage Things of this ſort are already of to the World, appears in the frequent Improvements now made in all thoſe Things which either ſerve the Intereſts, ſupply the Neceſſities, or farther the Convenience of Mankind. By Experiments *performed with Accuracy and Judgment, 'tis cer-*

tain

tain Arts and Sciences have been more advanced within the laſt Century, than in ſeveral Ages before. The Hypotheſes, *or rather* Philoſophical Romances, *of Antiquity being now exploded, our Inquiries into Natural Cauſes are no longer biaſs'd by conjectural Schemes, and the Productions of warm and pregnant Imaginations; but our Principles are built on the ſureſt and moſt rational Baſis, that of* Experiment *and* Fact; *which cannot but be always acceptable to thoſe who admire* Demonſtration, *and delight in* Truth.

Nullius in Verba: ------ Experimentis ducor ad conſentiendum.

Symbol. Reg. Soc.

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ERRATA.

BESIDES a few literal Miſtakes, the Reader is deſired to amend the following. Page 94. Line 19. read 25. p. 109. l. 4. r. *ſenſible.* p. 157. l. 11. read *hydroſtatically.* p. 185. l. 19. r. *ſhewn often.* p. 197. l. 6. r. *voluntary.* p. 233. l. 23. r. *new Matter.* p. 235. l. 18. r. *Wainſcot.* p. 261. l. 23. r. *follow.* p. 259. l. 4. r. *Sotovento.* p. 274. l. 22. r. *if thoſe Vapours chance.* p. 309. l. 18. r. *Hills.* p. 311. l. 23. r. *when.* p. 348. l. 13. r. *F, Fig.* 17. *Plate* 9. *is an old Building.*

HYDROSTATICKS:

OR,

The Motion of FLUIDS,

NATURAL and ARTIFICIAL.

STATICKS in general ſhew the Equipoize of Bodies, and their Difference in point of Weight; and mere Staticks make up a Science only ſpeculative.

HYDROSTATICKS is that Part of Staticks, reſtrain'd to the Weight and Equilibria of Liquid Bodies. Under this Head, not only Accounts of the Nature and Properties of Fluids in general are introduced, and the Laws by which they act; but alſo the Art of weighing ſolid Bodies in Fluids, in order to diſcover their ſpecifick Gravities.

HYDROSTATICKS, as Mr. BOYLE obſerves, is a Branch of Natural Philoſophy inferior to none:

He terms it a Science reſulting from Reaſon, and affording Diſcoveries no leſs pleaſing than wonderful; ſince neither the moſt abſtruſe, or the moſt familiar Appearances of Nature can be well underſtood or accounted for, without hydroſtatical Principles. He recommends it as an Art, not only delightful in Speculation, but uſeful in Practice; of the higheſt Importance to the Improvements in Trade and Navigation; neceſſary to ſuch whoſe Buſineſs it is to compare the Magnitude and Gravities of certain Bodies, as Metals, Ores, *&c.* and with regard to the Raiſing of Water, for the Uſes of Life, its Importance is beyond Expreſſion.

On FLUIDITY.

Sir *Iſaac Newton*'s Definition of a Fluid is, *That it is a Body yielding to any Force impreſs'd, and which hath its Parts very eaſily mov'd one among another.*

IT muſt here be remark'd, That this Definition ſuppoſes the Motion ſpoken of, produced by a partial Preſſure; for in the Caſe of an an incompreſſible Fluid, it is demonſtrated by Dr. KEIL, that under a total or an equal Preſſure, 'twould be impoſſible the yielding Body ſhould move.

THE original and conſtituent Parts of Fluids are by the Moderns conceived to be, Particles ſmall, ſmooth, hard, and ſpherical: According to which Opinion, every Particle is of itſelf ſolid, or a fixed Body; and when conſider'd ſingly, is no Fluid, but becomes ſo only by being join'd with other Particles of the ſame kind.

'TIS probable that the Particles of Fluids are exceeding ſmall, becauſe their Texture has never yet been diſcover'd by the fineſt Microſcope; we judge them to be ſmooth, becauſe they are found eaſily to glide one over another; hard and impenetrable, becauſe no Fluid, the Air excepted, is capable of Compreſſion; and to be ſpherical, that they may only touch in ſome Points of their Surfaces; and ſo not only may be the more eaſily mov'd, but alſo form Interſtices or Vacancies between them, which may be proved.

WERE Fluids not compounded of primary Particles, form'd as above, but made up of one uniform homogeneous Subſtance, without Conſiſtence, equally denſe; there would be no Difference in their ſpecifick Gravity, and all Fluids would be of the ſame Weight, Bulk for Bulk; which is contrary to Experience.

THAT Fluids have Vacuities, will appear upon mixing Salt with Water, a certain Quantity whereof will be diſſolv'd, and thereby imbib'd, without enlarging the Dimenſions. A Fluid's becoming more buoyant, is a Proof that its ſpecifick Gravity is encreas'd, and of conſequence, that many of its Vacuities are thereby fill'd; after which it may ſtill receive a certain Quantity of other diſſoluble Bodies, the Particles whereof are adapted to the Vacancies remaining, without adding any thing to its Bulk, though the abſolute Weight of the whole Fluid be thereby encreas'd.

THIS may be demonſtrated, by filling a Cup of freſh Water to the Brim, out of which carefully refund a certain Quantity. To the Reſidue of the freſh, add the ſame Quantity of ſalt Water, noting firſt the Difference of the abſolute Weights of the ſalt Water and the freſh; and although a greater Quantity of Matter (always ſignified by the Weight) be really added, than was taken out, yet ſhall it not fill the Cup ſo high as the freſh Water did, by a notable Difference.

AND as Fluids have Vacuities, or are not perfectly denſe; 'tis alſo probable, that they are compounded of ſmall Spheres of different Diameters, whoſe Interſtices may be ſucceſſively fill'd with apt Materials for that Purpoſe: And the ſmaller theſe Interſtices are, the greater will the Gravity of the Fluid always be.

FOR inſtance: Suppoſe a Barrel be fill'd with Bullets, a great many Small-ſhot may afterwards be placed in the Interſtices of thoſe Balls; the Vacuities of the Shot may then be repleniſh'd with a certain Quantity of Sea-ſand; the Interſtices of the Grains of the Sand may again be fill'd with Water; and thus will the Weight of the Barrel be greatly augmented, without en-

creaſing

creaſing the Quantity: Now this being true with regard to Solids, is applicable alſo to Fluids. For inſtance: River-water will diſſolve a certain Quantity of Salt; after which it will receive a certain Quantity of Sugar; and after that, a certain Quantity of Allom, and perhaps other diſſoluble Bodies, and not increaſe its firſt Dimenſions.

WAS all Space, as the *Carteſians* affirm, abſolutely full of Matter, this Matter muſt either be fluid or fix'd. Was it fix'd, there could poſſibly be no Motion therein; it muſt therefore be fluid. But a Fluid without Vacuities will be denſer, conſequently heavier, than all Fluids; and if denſer, all Bodies will emerge, and ſwim therein, by hydroſtatical Laws, nor could there be ſuch a Thing as Gravity. But as Gravity cannot be denied, all Space therefore cannot be fill'd, even with a Fluid.

THESE Gentlemen have two Evaſions to avoid the Reſiſtance of their Vortices, or Whirlpools of *Subtle Matter*; by the Motion whereof, they endeavour to account for the Phænomena or Appearances in Nature. Their imagin'd *Materia Subtilis* they aſſert to be a *perfect* Fluid, not incumber'd with the leaſt Clammineſs, Coheſion or Tenacity, and therefore capable of no Reſiſtance. To this we reply, that the Reſiſtance of the common Fluids (as Sir ISAAC NEWTON'S Experiments aftermention'd, of Bodies falling in different Mediums, ſhew) ariſes from the Inactivity of Matter only, proportion'd always to its Denſity, and not at all from the Coheſion or Tenacity. Take theſe therefore from the *Carteſian* Fluid, the Inactivity, or *Vis Inertiæ*, by no means to be ſuſpended or diverted, will remain in Matter; it cannot therefore be without Reſiſtance. And as *Mercury*, near fourteen times denſer than Water, and Water about eight hundred and fifty times denſer than Air, are found to make proportionable Degrees of Reſiſtance; the Fluid juſt mention'd, being much denſer than theſe, will no doubt proportionably reſiſt.

THEIR ſecond Evaſion is, That their Fluid does not conſiſt of groſs Particles, as others do; and ſince, ſay they, the Diminution of the Particles of Matter leſſens the Reſiſtance proportionably, it follows, that their Fluid, conſiſting of Parts infinitely ſmall, can have no Reſiſtance at all. To this we anſwer; That though the Diminution of Parts does leſſen the Reſiſtance of any ſingle Part, yet is the Reſiſtance of the whole not alter'd: For if a Body be divided into twenty Parts, which, when combin'd, will make a certain Degree of Reſiſtance; if theſe be ſubdivided into twenty more, the Number of Parts will be doubled, each of which will make but a fortieth Part of the Reſiſtance of the whole; but taken collectively, they will have the ſame Reſiſtance, and be of the ſame Weight, as was the Body undivided. Nor is an Ounce of Gold the leſs ponderous, for being reduced into Duſt.

ANO-

ANOTHER Miſtake theſe Gentlemen make, is in their Definition of a Fluid, which they take to be a Body in continual Motion: Urging in Support thereof, that all Bodies have a Tendency to Conſiſtency; but that Fluids, by the Motion of their Parts, are kept ſeparate: And to this Motion they attribute their making leſs Reſiſtance than fix'd Bodies.

IN anſwer to which, it may be doubted whether all Fluids have a Tendency to be conſiſtent. Metals indeed, Wax, Butter, and Bodies of like Texture, artificial Fluids only, which are by Fire brought into a State of Fuſion, and are to be continued flux'd by a certain Degree of Heat, have a Tendency to be conſiſtent, from the particular Diſpoſition of their Parts: But there may be natural Fluids, ſuch as Mercury, for inſtance, or Air, which have no ſuch Property.

AND as to the Reſiſtance of Fluids being the leſs, on account of the continual Motion of their Parts, it ought to be conſider'd, that a Body in Motion will not reſiſt leſs than a Body at Reſt. For, ſuppoſe a Body moving in a Fluid: Thoſe Parts of the Fluid, which move the ſame way with the Body, will indeed give leſs Reſiſtance; but then thoſe moving in a contrary Direction, will reſiſt the more. And to imagine that an equal Number of Parts can conſtantly keep moving this way, and an equal Number that, is both ridiculous and abſurd. Beſides, ſhould it be granted, that the Particles of a Fluid may be once put in Motion, yet cannot they continue ſo: For 'tis certain, that if we take two Bodies, both moving the ſame Way, with different Celerities, if *A* overtakes and ſtrikes *B*, by the demonſtrable laws of Nature and of Motion, *A*, by ſuch a Congreſs, muſt loſe as much Motion as *B* acquires; and ſhould *A* meet *B*, in a contrary Direction, with equal Velocity, being alſo equal in Weight, they will both ſtop. Wherever Reſiſtance is, Motion is always loſt; there can therefore be no *continual* Motion in Fluids.

IT is moreover contrary to Obſervation: For Motion in Fluids of equal Denſity, whoſe Parts are every where therefore ſubject to equal Degrees of Preſſure, is generally owing to ſome Agency applied, which being withdrawn, the Effect alſo ceaſes; as, from Water boiling, take the Fire, the Motion is no more. Fermentations, which occaſion inteſtine Motions in Fluids, are only accidental; ſo that their Fluidity cannot be owing to any continued Motion of their Parts. Nor does Fluidity ſeem ſo much to conſiſt in a conſtant and actual Motion of Parts, as in a conſtant and actual Mobility, or a Diſpoſition to be eaſily mov'd.

THE more perfect a Fluid is, the more eaſily will it yield to all Impreſſions; and the more eaſily will the Parts unite and coaleſce, when ſeparated. A perfect Fluid is that, whoſe Parts are put into Motion by the *leaſt* Force imaginable: An imperfect one is that, whoſe Parts yield to a *ſmall* Force, not the *leaſt*. 'Tis probable,

that

that in Nature there is no perfect Fluid; since we see that the mutual Attraction of the Parts of all the Fluids, subject to our Experiments, renders them cohesive in some Degree; and the more they cling together, the less perfect their Fluidity is. If, for instance, a Glass be fill'd with Water above the Brim, it will visibly rise to a convex Surface, which, was it a perfect Fluid, free from either Tenacity or Cohesion, would be impossible.

MERCURY, the most perfect Fluid we know, is not exempt from this Attraction; for should the Bottom of a flat Glass, having a gentle rising toward the Middle, be covered thin with Quicksilver, a little Motion of the Machine will cause the Fluid soon to separate from the Middle, and lie round it like a Ring, having Edges of a considerable Thickness.

BUT if a like Quantity thereof be poured into a golden Cup, it will, on the contrary, appear higher considerably on the Sides than in the Middle. Which may proceed in part, perhaps, from the Gold's being of great Density, and therefore capable of exerting thereon a greater Degree of Attraction than other Metals. Probably too it may happen from its having Pores of an apter Disposition and Magnitude to receive the minute Mercurial Particles, than those of Iron, and some other Metals; and therefore the Attraction of Cohesion in this Experiment may obtain also: And every one knows how easily these two Bodies incorporate, and make a perfect *Amal-*

Amalgama. But the Reaſon commonly given for the two laſt Phænomena is, that Mercury, in the firſt Caſe, attracts itſelf more than it does Glaſs; and, in the laſt Caſe, Mercury attracts Gold more than it does itſelf.

OUR Sir ISAAC NEWTON was no doubt a *Prima-materialiſt*, and held all Matter to be originally homogeneous; and that, from the different Modifications and Texture of it alone, all Bodies receive their various Structure, Compoſition and Form. In his Definition of a Fluid, he ſeems to imply, that he thought Fluids to be compoſed of primary Solids; and, in the Beginning of his *Principia*, he ſpeaks of Sand and Powders as of imperfect Fluids.

BORELLI has demonſtrated, that the conſtituent Parts of Fluids are not fluid, but conſiſtent Bodies; and that the Elements of all Bodies are perfectly firm and hard. The Incompreſſibility of Water, proved by the *Florentine* Experiment, is a ſufficient Evidence alſo, that each primary Particle or Spherule thereof is a perfect and impenetrable Solid. Mr. LOCKE too, in his *Eſſay on Human Underſtanding*, admits this to be ſo.

THIS famous Experiment was firſt attempted by the great Lord VERULAM, who incloſed a Quantity of Water in Lead, and found that it inclin'd rather to make its way through the Pores of the Metal, than be reduced into leſs Compaſs by any Force that could be applied. The Academicks of *Florence* made this Experiment after-

afterwards more accurately with a Globe of Silver, as being a Metal leſs yielding and ductile than Gold. This being fill'd with Water, and well cloſed, they found, by hammering gently thereon, that the Sphericity of the Globe was altered to a leſs capacious Figure (as might geometrically be proved) but a Part of the Water always ſweat through its Sides, before this could be obtained. This has been attempted by Sir ISAAC NEWTON, and ſo many competent Judges, on Gold and ſeveral other Metals ſince, with equal ſucceſs, that we do not hold any Fluid in its Natural State, except the Air, to be either compreſſible or elaſtic.

The HYDROSTATICAL PRINCIPLES *demonſtrated.*

ALTHOUH the Original, the Conſtituent Parts of Fluids, may be very probably of the ſame Nature with thoſe which conſtitute other Bodies, and eſſentially have the ſame Properties as they; in external Forms and Circumſtance, we ſee they often differ: Since fluid Subſtances frequently become conſiſtent; as Water is changed into Ice; the Sap and Juice taken in by the Fibres of the Root, into the woody Parts of Trees, *&c.* and melted Metals, *&c.* afford Inſtances, that fixed Bodies may, in the like manner, be made fluid. In one Circumſtance however all material Subſtances, on which Experiments have been made, do certainly agree, *viz.* they conſiſt of Particles that have Weight; and

whatever

whatever be the Form, Texture or Diſpoſition of their Parts, their Gravity is always proportionable to the Quantity of Matter they ſeverally contain. This is an univerſal Property, of which Matter is not to be deprived; and if in ſome Fluids, that Gravity does not immediately appear to Senſe, 'tis becauſe the lower Parts, by ſuſtaining and buoying up the upper, hinder their Deſcent: Nor will it follow, that becauſe this Gravity is not immediately perceptible by us, that therefore the Parts of Fluids are without Weight.

NOTHING is leſs felt, perhaps, than the Weight of the Air; but yet, if we exhauſt the Air from a Veſſel, poiſe it at the Arm of a fine Balance, and let the Air into it again, we ſhall find that Air does gravitate, even in the Air; and that the Axiom of the Schools, *viz. That Elements do not gravitate in their proper Places, that is, in the ſame Elements,* is abſolutely a Miſtake.

IN like manner it may be ſhewn, that Water gravitates in Water. Take a Glaſs Bubble, and ſo poiſe it with Shot till the upper Part ſhall ſwim juſt level with the Surface of a Jar of Water; hook it on a Horſe-Hair, fixed to a Balance-Beam, on which it will then lay no Weight; fill it with Water, and a Difference of Weight will appear, *viz.* that between the Weight of the Air extruded, and that of the Water admitted: Which may ſerve to confirm our firſt Principle in HYDROSTATICKS, namely, *That all*

Parts

Parts of a groſs Fluid, as Water, *whatever be their Situation, Circumſtance or Poſition, gravitate, and are heavy.*

AND ſince all Fluids have Weight, there is no room to doubt, but that their upper Parts continually gravitate and preſs upon the lower; the Preſſure whereof is always in direct Proportion to the incumbent Matter, or to the Quantity of the Liquor above the Parts propos'd. *The higher therefore a Fluid is, the greater is its Preſſure*; *not only on the Bottom of the Veſſel, but alſo on the Parts of the intermediate Fluid:* Which is our ſecond hydroſtatick Principle, of itſelf ſufficiently evident.

NOW all Quantities of a Fluid may be conſider'd as divided into many other intermediate imaginary Surfaces, lying parallel to the upper and nether Surface thereof, and to the Horizon. For example; take a long Glaſs full of Water, as *Fig.* 1. *Plate* 1. which, for the Sake of Illuſtration, may be divided by Threads at equal Diſtances; call the firſt diviſion, *A*; the ſecond, *B*; the third, *C*; and ſo on. Suppoſe each Diviſion contains an Ounce of Water, the Surface then at *B*, will be preſs'd by one Ounce; that at *C*, will ſupport two; that at *D*, three Ounces; and the Bottom will lie under the Weight of four Ounces of Water.

NOW, whenever a Fluid is of the ſame kind, and incompreſſible, it will be of equal Denſity in all its Parts, which will all therefore continue at reſt, each being as low as of itſelf it can be: Since 'tis certain, that an Impulſe of one Ounce in *A*, cannot of itſelf deſcend and diſplace two in *B*; nor can two in *B*, overcome three in *C*; nor thoſe thruſt away four in *D*.

AND as a Quantity of Water, hydroſtatically conſider'd, is to be diſtinguiſh'd by imaginary Surfaces, parallel to the Horizon; it may be alſo conceiv'd, divided into imaginary Columns, perpendicular or vertical to it, in manner reſembling a Bundle of Reeds. Theſe being all of the ſame Height and Weight, will always preſs equally upon every part of each imaginary fluid Surface beforementioned, and cauſe them, no leſs than the upper Surface, to lie level with, and parallel to the Horizon. And conſequently, if a Body, of the ſame ſpecifick Weight with a Fluid, be therein immers'd, 'twill remain in any part thereof indifferently, and keep its Place, wherever 'tis put.

TO illuſtrate this, let us imagine a Cubick Inch of any Matter, of the ſame ſpecifick Gravity with Water, put, for example, nine Inches under the Surface; the imaginary Surface then beneath it, will be preſs'd with nine Inches of Water, and an Inch of a Body ſpecifically of the ſame Weight with Water: But every other part of that Surface, the ſame in Depth, ſuſtains the Preſſure of ten Inches of Water; therefore the ſaid Inch of ſolid Matter will there lie at reſt, and neither ſink or riſe.

To

To demonſtrate this by Experiment, we may charge a Glaſs Bubble, made of Matter ſpecifically heavier than Water, partly with Air, and partly with Water, that it may become equal in Weight to a like Bulk of Water with itſelf. If that be done, 'twill lie indifferently, either at Top, in the Middle, or at Bottom of a Jar of that Fluid, wherever it is put. And thus may our third hydroſtatical Principle be proved; namely, *That in homogeneous Fluids, all Parts are naturally in a State of Reſt.*

Our fourth Principle is, *That the lateral Preſſure of a Fluid is equal to the perpendicular.* For as the Preſſure of a Fluid againſt the Bottom of a Veſſel, is proportion'd to the Height of the Fluid in that Veſſel; ſo is the Preſſure of a Fluid, againſt every Side of a Veſſel, in a like Proportion to the Height of the Fluid, above the Part conſider'd.

Let a Veſſel be ſuppos'd fill'd with an incompreſſible Fluid, having no Gravity, and this be forced down with a proper Piſton, the Fluid would endeavour to ſpread; but being confin'd by the Sides, could not. The Bearing, in this Caſe, againſt all Parts of the Veſſel, muſt be juſtly equal to that Force wherewith the Piſton is driven. Suppoſe then Gravity reſtor'd to the Fluid, and the forementthe Preſſure continu'd, the nether Parts will then ſuſtain a greater additional Preſſure than the upper, from the Gravity reſtor'd; and that in Proportion to the Height

Height of the Fluid above the Part aſſign'd.

THIS Propoſition may be tolerably well demonſtrated by a Veſſel, having a Hole of a certain Bigneſs in the Bottom, and another of the ſame Dimenſions as near the Bottom as may be, fill'd with Water to any Height; let the Plugs be pull'd out and put in both at the ſame time, and if, upon Compariſon, equal Quantities of Water nearly ſhall have been yielded by them, 'twill ſhew the Force wherewith it iſſued to be equal, and ſufficiently confirm our fourth Principle in Hydroſtaticks, *viz. That, at all Depths, the lateral Preſſure of a Fluid is equal to the perpendicular.*

THE equal Preſſure of Fluids againſt all the Sides of a containing Veſſel, might alſo appear, by freely ſuſpending a deep Veſſel of Water, not over-heavy, by a String, hanging a Plumb-line, alſo at Liberty, parallel, near it: Upon making a Hole in the Side, the Veſſel, which, before ſuch Opening was made, had a perpendicular Direction, will then recede from it; the lateral Preſſure of the contained Fluid being, on the Side of the Opening, diminiſh'd.

THE Riſing of a Rocket in the Air is alſo occaſion'd by a like Inequality of Preſſure. The Gunpowder being ſet on Fire, turns to a very elaſtic Vapour, whoſe Parts endeavour to recede from each other equally every way. As the Caſe is cloſe ſhut above, and open where the Flame iſſues below, it is leſs preſs'd a great deal

by

by the Air about it, than by the Rapidity of the Flame, bearing againſt the Sides and Top of the Rocket within; which Difference of Preſſure has ſometimes carried a well-made Rocket, of no more than two Ounces in Weight, four hundred Yards high, with as much Thread veer'd out at the Tail as determin'd the Quantity of its Riſe. For the ſame Reaſon, in the Diſcharge of a Cannon the Force of the Powder acting againſt the Breech of the heavy Gun, and not being counterpois'd with an adequate Preſſure forwards, ſends out the Ball, with a precipitate Velocity: And if the Charge of Powder be overgreat, or the Piece not truly bored, it then commonly recoils, upon the ſame Account.

IN Fluids at reſt, each imaginary Surface is every where equally preſs'd; and whenever it happens otherwiſe, the imaginary Surfaces moſt preſs'd, will give way and retire, and thoſe leſs preſs'd will be forced upwards and riſe. The ſinking of a Stone in Water, is an Evidence of the one; and the ſwimming of a Cork, an Inſtance of the other.

BUT to demonſtrate this Matter plainer. Take a Tube of Glaſs, an Inch or more in Diameter; tie a pliant Bladder looſely over the End, and put it down any Depth in a Jar of Water. So long as the imaginary Surface of the Water, at the End of the Tube, is leſs preſs'd by the Atmoſphere within, than it is elſewhere by the Atmoſphere, and a Column of Water of equal Length with the immers'd Part of the

Tube, the yielding Bladder will be pushed upwards, and become convex within. Let Water then be poured into the Tube, to the same Height and Level with the upper Surface of the Water in the Jar, the imaginary Surface beforesaid being then equally press'd in every Part, the Bladder will appear level; but should the Fluid in the Tube be raised above the upper Surface of the Water in the Jar, the imaginary Surface beneath the Tube, being there harder press'd than in any other Part, the Bladder will bag down, and become convex without.

ONCE more: Take a Glass Tube, and suspend in it coloured Water, that the Effect may be more visible; which may be done, provided the Bore be not over-large, by stopping the upper End with the Finger. The Machine, so charged, immerse to any Depth in a Vessel of clear Water. The nether End of the Tube will then reach to, and rest on an imaginary Surface, by which 'twill be press'd upward with a Force just equal to the Weight of the small Pillar of Water thereby thrust away and displaced; but every other Part of the Surface will be press'd by collateral fluid Columns, all of equal Weight and Altitude. If then the Pipe be unstopped, the Air, which on Immersion repress'd and kept the Water out, will be expell'd; and the Water, being the weightier Fluid, will push into, and rise in the Tube till it is of a just Level with the rest of the Water in the Vessel. Again, if this Water be therein retain'd, stopping it as before, on bringing the

the lower Orifice of the Pipe near the upper Surface of the Water in the Jar, the Fluid will, when the Tube is unſtopped, immediately ſubſide, and become of the ſame Level with the Water in the Veſſel: Which will prove, Fifthly, *That if any Part of a Fluid be more preſs'd than another, the heavier will ſink till the Equipoiſe be reſtored.* As the former Experiment evinced, *That the lighteſt Parts of a Fluid, or thoſe leſs preſs'd, will riſe till an Equilibrium is obtained, if nothing obſtruct.*

IT may at the ſame time be farther demonſtrated, that the lateral Preſſure of Fluids, and the perpendicular both upwards and downwards, are alſo in a direct Proportion to their Heights, by Tubes bent to favour that Intention; as in *Fig.* 2. *Plate* I. *A, B, C, D:* And the Effect produced will on Experiment be the ſame in all, proceeding from a like Cauſe, *viz.* the equal Gravitation of homogeneous Fluids, which exerts itſelf every way, and every way equally.

THIS may be farther demonſtrated, by covering with a wet Leather a ſmooth Weight of Lead of any regular Thickneſs, as *B, Fig.* 3. *Plate* I. made to fit the Mouth of a large Tube, as *A*; to which, at its firſt Immerſion, let it be kept ſo cloſe as to admit no Water, by a String. By the time it is about twelve times its own Depth under Water, it may be let go, and the Puſh of the Water upwards will ſupport it. If it be put lower, it will adhere more ſtrongly;

and if ſhallower, it will, for want of a due Counterpoiſe, fall away.

AND as Bodies heavier than Fluids may be thus made to ſwim; ſo may Bodies lighter than Fluids be retained at any Depth in them, provided they cannot inſinuate, and get beneath, to force them up. For inſtance, a round Trencher will remain at Bottom of a Pail of Water, equal to itſelf in Diameter, if it be ſo fitted as that without ſticking no Water can get under it. And a flat Glaſs, with only a Drop of Oil or other Liquor between, will remain at the Bottom of a Jar of Mercury, if the Bottom be flat alſo, tho' the Glaſs be ſix times lighter than that Fluid, Bulk for Bulk. The Oil, *&c.* put between the Glaſs Planes, is only intended to fill Irregularities and Vacuities; for which, were they exact Planes, there would be no occaſion.

ONE general Conſequence of our Principles thus proved is, *That Fluids will always riſe to their own Level, or endeavour ſo to do.* This is what the Antients were ignorant of; and therefore they uſually built Aqueducts (vaſt Rows of Arches one above another, between two Hills, at a vaſt Expence of Money, Time and Labour) in order to convey Water over them, croſs the Valley, in a common Channel. This is now done to equal advantage, and at much leſs Expence, by a range of Pipes laid down one Hill and up the other.

AN Inſtance whereof may be given by a bent Tube,

Tube, a Crane or Syphon; into one of the equal Legs whereof if Water be poured, it will riſe to the ſame Level exactly in the other. The Reaſon is obvious: In the Leg *A*, *Fig.* 4. *Plate* 1. there are ſuppoſe two Ounces of Water endeavouring by the Power of Gravity to deſcend with the Force of 2; theſe will thruſt forward, buoy up, and ſupport an equal Quantity of a like Fluid in *B*; and the Bottom of the Machine *C*, againſt which both Sides equally bear, will of conſequence ſuſtain a double Preſſure, or that of four Ounces; and in the preſent Caſe will pretty well repreſent the Prop or fix'd Point of a Balance-beam; as the equal fluid Columns *A C*, and *B C*, may be admitted to denote equal Weights, ſuſpended on the Balance-arms, counterpoiſing each other. So that the Riſe of Fluids to their firſt Level, thus conſider'd, is a Caſe truly Statical; and all their other Motions proceed only from Weight added.

THE *Preſſure of Fluids is in Proportion to their perpendicular Heights only, and not according to their Quantity.* For inſtance: There can lie no greater a Preſſure againſt the Dikes that fence out the Sea in *Holland*, or againſt the Banks of the *Thames* or the *Danube*, in calm Weather, than there does againſt the Sides of any Veſſel fill'd to an equal Depth with the Water juſt mentioned; reſpect being only had to the Quantity of the Surface ſo preſſed.

To demonſtrate this; Take a Glaſs Veſſel *A*, of the ſame Bigneſs, or cylindrical from Top to Bottom, *Fig.* 5. *Plate* 1. toward the lower Part whereof let a Glaſs Pipe be fix'd, which, by help of the Joint *F*, will be capable of any Degree of Elevation. Suppoſing the Diameter of the Tube but the hundredth Part of the Diameter of the Jar (the Capacities of Circles being in Proportion to each other as the Squares of their Diameters) the Fluid in the Pipe will be but a ten thouſandth Part the Quantity of that in the Jar wherewith it communicates; and yet, if the Jar be filled to any Height, the Altitude of the Water in the Pipe, whether erect or inclined, perpendicularly taken, will be exactly in the ſame Level with that in the Jar, and always lie in the Line *C D*. Whence 'tis evident, that a ſmall Quantity of a Fluid, provided it be equal in Height, is able in certain Circumſtances to counter-balance any Quantity of the ſame Fluid; and the Reaſon is this:

THE Bore of the Pipe of Communication is of a certain Bigneſs, we will ſuppoſe the tenth of an Inch in diameter; by the Structure of the Machine there can at the ſame time preſs no more of the Jar-water againſt the Orifice thereof, than one Pillar equal in Height and Dimenſions to the Pipe; and it was before demonſtrated, that ſuch a Pillar will drive forward, and in the ſame Level ſuſtain a Pillar of Water equal in Weight and Size to itſelf: Which is the Caſe before us exactly. And did the tube communicate with the main Ocean, the Effect would be ſtill the ſame.

SHOULD we however fill a hundred Inches

of

of our Pipe with Water, and by a Cock or other Contrivance admit it ſingly into the Jar, 'twill raiſe the Fluid therein only one tenth of an Inch, and this ten times repeated will raiſe it only an Inch. But on the contrary, ſhould we, by thruſting a Piſton or a tight Cork into the Jar, depreſs the Body of the Fluid therein contain'd but the hundredth Part of an Inch, the Water would thereby be forced into the communicating Tube to the Height of ten Inches; and by a ſtill greater Preſſure, ſhould it be ſunk in the Jar a tenth of an Inch, 'twould riſe a hundred Inches in the Tube. Whence it appears, that this is alſo a Caſe nicely Statical, reſembling the Effect produced by the Steelyards; on which Machine if one Pound be hung at the diſtance of a hundred Inches from the Fulcrum or Prop, it will counter-balance and to a Level raiſe a hundred Pounds, at the diſtance of but one Inch; and juſt the contrary. For to make the larger Weight by its Riſe or Fall to move an Inch, the other muſt traverſe the Space of an hundred Inches; the Velocities of the Weights being always reciprocally proportional to the Quantities of Matter in them ſeverally contained. Whence it in general follows, that the Preſſure of Fluids is always truly eſtimated, when the Perpendicular Height of the Fluid is multiplied into the Area of the Surface it bears or preſſes upon, whether laterally or perpendicularly conſider'd.

The HYDROSTATICAL PARADOX.

A Due Conſideration of the laſt-mentioned Caſe gave Birth to the *Hydroſtatical Paradox*; whereby 'tis aſſerted, *That all Fluids, preſſing according to their perpendicular Altitudes, and not according to the Bulk or Quantity of their Matter, the Preſſure of a contained Fluid againſt the Bottom and Sides of the containing Veſſel will always be proportionable to the Height thereof, whatever Form it be of; and the ſame as if it was really of the ſame Bigneſs from Bottom to Top.* To explain which, take a Cylinder of a certain Baſe, that will hold perhaps a Pint; as *A*, *Fig.* 6. *Plate* I. This Veſſel being fill'd, the Bottom will be allow'd to ſuſtain the whole Weight of the Fluid therein contained; Gravity acting in a right Line, and perpendicularly. Again, take another Veſſel of equal Height and Baſe, partly cylindrical, and partly flanch'd out into a Portion of an inverted Cone, as *B*; this Veſſel ſuppoſe will hold a Quart. Then take a third Veſſel of equal Baſe, but cylindrical thereon only half way; to make it however of equal Height with the other two, let a ſmall Pipe be ſoder'd into the Lid, as *C*: let this Veſſel contain in the whole but half a Pint. If theſe be ſeverally filled with a Fluid of the ſame kind, we ſay that the Bottoms and Sides of each of theſe ſhall be preſſed thereby alike; and beginning with the ſecond, we prove it thus.

As all homogeneous Fluids, or thoſe of equal Denſity, are proved by our third Principle to be naturally every where at reſt, was the Tin-work of the cylindrical Part of our Veſſel *B* continued through the conical Part thereof to the Top, according to the prick'd Lines in the Draught, the Fluid thereby encloſed would be juſt in the ſame Circumſtances of that in the Veſſel *A*, and then the Side-water, contained in the conical Part, would bear againſt our Cylinder, ſuppoſed continued to the Top, as if the Water therein was frozen on the one Hand, and the Tin Sides of our conical Part on the other, according to the Height of the Fluid between them contained. Imagine then the Continuation of our Cylinder removed, or the Water frozen therein to thaw; the Preſſure of the Side-water would then lie againſt the fluid Cylinder itſelf, which being in all Parts of equal Weight and Moment with itſelf, will be thereby ſuſtained quiet and motionleſs in its proper Place. And 'twill be ſupported on the other Side, in like manner, by the ſloping Sides of the Veſſel, which being rigid, will eaſily ſuſtain the Quantity of the Preſſure made perpendicular thereon: Nor would the Weight on the Bottom, or againſt the fix'd cylindric Sides of this Veſſel, be at all encreaſed by the Alteration propoſed.

IT muſt however be admitted, that as there is double the Quantity of Matter, by Suppoſition, contained in a Veſſel of this Form, that was in the Veſſel *A*, the abſolute Weight of the

the whole together will be proportionable thereto. But then it muſt be conſidered, that this Increaſe of Weight and Preſſure affects only the ſhelving Sides of the Veſſel *B*; and as theſe by their Diſpoſition become an inclined Plane, they are doubtleſs made to bear the Difference of Weight propoſed, which muſt be thereby communicated to, and ſupported by the upright Sides of the cylindric Part of *B*, whereon they reſt: But on the Area of the internal Baſe of *B*, and againſt the Sides of the Cylinder within, no more Weight is laid than barely that of the Height of the Fluid above them.

LET us next conſider how a like Preſſure may be made on the Bottom and Sides of the Veſſel *C*, containing but half of the Fluid in *A*, and but a fourth Part of that in *B*. Suppoſing the Parts of a Fluid, as doubtleſs they are, globular, the Particles of the Water will be well repreſented by the Draught, *Fig*. 7. *Plate* I. wherein 'tis certain, that the central Column *A B* preſſes, according to our fourth Principle, not only perpendicularly upwards and downwards, but laterally alſo, and in every Direction alike; and conſequently all the Rows of Particles lying next the Bottom of the Veſſel, muſt be all impell'd thereby equally toward the Sides.

To prevent Confuſion, let us diſtinctly conſider the Effect of this Preſſure on one ſingle Rank of theſe Particles, which may be applied in like manner to the reſt. The lower Particles then of the Column *A B* gravitate on thoſe adja-

adjacent, and thruſt them, for example, from *B* towards *C*. At *C*, finding themſelves confin'd, their Effort will not there ceaſe, but be tranſferr'd, and made to preſs upward toward *D*, againſt which Part of the Lid a Puſh will be made, juſt equal to the Difference of the Preſſure of the two Columns conſider'd, *viz.* *A B* and *C D*; the firſt of which gravitates with the Force of 2, being ſuppoſed twice the Height of *C D*, which therefore preſſes but with the Weight of 1. The Impulſes being yet unequal, will not ſtop here; but the Particles will be thereby laterally puſhed from *D* towards *E*, where meeting with others in the ſame Level of equal Force and Moment with themſelves, will, being there equipoiſed, remain at reſt.

THE Gravity then of the Particles contained in the central fluid Column *A B*, acting againſt the Lid of the Cylinder in every Part, and the Lid reacting in like manner againſt the whole Body of the Fluid below, as great a Preſſure is thereon laid as if the Cylinder had been continued to the Top of the Pipe, and thereby fill'd.

ON pouring Water into one Leg of the Syphon, it will riſe, we know, to the ſame Level in the other. This may be applied here, by ſuppoſing a Pipe as high as the Neck fix'd in ſome Part of the Lid of our Cylinder, as at *D*. On opening the Plate in that Place, as much of the Fluid will be preſſed up immediately therein, as will bring it to a juſt Level with that remaining in the Neck; which being again re-

replenifhed, the other will alfo be filled. Whence 'twill be evident, that before the faid Opening was made, the Preffure beneath the Cover of the Cylinder in that particular Place, was equal to the general Preffure by the middle Column laid on every Part of the Surface of the Fluid in the fame Plane, that is, in the Level of the Lid. There is therefore Reafon to believe, that was the Lid fet entirely full of fuch Pipes, the Fluid in the Neck of the Machine would defcend in like manner, and fill each of them equally to a certain Degree: This, in effect, would be raifing the Lid. And fhould the Neck be feveral times thus fucceffively replenifhed, it would by degrees fill them all; which is much the fame thing as compleating the Cylinder, and filling it up.

A fingle Pint of Water may then be fo difpofed as to be of equal Force and Preffure with fome Gallons; and this the following Experiment will put paft all Doubt.

THE fmall Quantity of Water in the Tube *B*, *Fig.* 5. *Plate* I. is, we know, in that Situation, a Counterpoife to ten thoufand times the fame Quantity in the Jar. This may alfo be applied to the folving our Hydroftatical Paradox. Let us ftop up the Mouth of the Jar with a tight Cork, having a Glafs Pipe thruft therein, as *E*, by which with a Funnel let the Jar be gradually filled; as the Fluid rifes in *A*, 'twill advance proportionably in *B*, and preferve a juft Level in both. That done, proceed to replenifh the

the Tube *E* alſo, and the Water continuing then to riſe alſo equally in *B*, will demonſtrate that it is ſtill impelled by the ſame or an equal Force, and conſequently that the Preſſure on the Bottom and againſt the Sides of the Jar, is the ſame as if it were lengthen'd out to *E*, and filled. And the Experiment ſucceeding on a Veſſel of this Shape, leaves no doubt but 'twill always do ſo; ſince this Figure ſeems to be the leaſt advantageous to it that can be contrived.

AN Experiment to the like Purpoſe might alſo be made by perforating the Bottom of two Veſſels, a Cone ſuppoſe and a Cylinder, both equal in Baſe and Height, with Holes equal in Diameter. Let them be kept conſtantly filled; unſtop and ſtop them both at the ſame Inſtant, and they will be found both to have diſcharg'd equal Quantities of Water in the ſame Time. And if the Efflux of ſo even a Fluid as Water, from theſe Veſſels, be found equal; the impellent Force, by which it is puſhed forth, may with good reaſon be preſumed equal alſo.

HERE indeed it may be objected, that it being mathematically demonſtrable, that a Cylinder of equal Baſe, and of the ſame perpendicular Altitude with a Cone, is in Capacity or Content thereto as three to one. And ſhould ſuch a Cone, containing no more than two Pounds of Water, have its Bottom and Sides as much preſſed thereby, as will thoſe of the Cylinder by ſix Pounds of that Fluid; it ſhould ſeem, that, provided the Preſſure of the Fluid in the

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containing Veſſels, and the Weight of the containing Veſſels themſelves was alſo equal, their abſolute Weights, when full, ought to be equal alſo: To ſuppoſe which, in a Cone and Cylinder of equal Heights and Baſes, would be abſurd.

To this we reply: That the abſolute Weight of Bodies is not affected by their interior Diſpoſition or Circumſtance: For though the Preſſure on the Bottom and againſt the Sides of the tapering Veſſel, be three times as great as is the Weight of the Water therein contained; yet does it not follow, that it ſhould be three times as heavy. For a Whalebone, a Spring, or any other elaſtic Body, much bent and forced into ſuch a Veſſel, will not in the leaſt augment its abſolute Weight, by bearing againſt the Sides with any Force whatever.

In like manner it may be underſtood, that the Water included in a conical Veſſel, may preſs the Bottom and Sides, without increaſing the poſitive Weight of the whole. For ſuppoſing the Water in the conical Veſſel *A B C*, *Fig.* 7. *Plate* 2. divided into ſeveral Fruſtums of a Cone, *E*, *F*, *G*, parallel to the Baſe; from what has been ſaid, 'tis plain that the Bottom, *B C*, will be as much preſs'd by the Water in *G*, with that in *F*, aſſiſted by the Reaction of the inclined Sides *A B* and *A C*, as if it had been continued cylindrical to *H I*: And the ſame holding good with regard to the reſt, it follows, that againſt the Bottom and Sides of the Veſſel as great a Preſſure will be made, when full of a

Fluid,

Fluid, as if it had been a compleat Cylinder, and fill'd up to *K L*.

IT may perhaps alſo be objected, That if a Veſſel, having a Pipe inſerted in the Lid, and filled with Liquor, ſuffers the Preſſure ſpoken of; that a Pipe of the ſmalleſt Diameter, a capillary Tube, or one no bigger than a Hair, ought to produce the ſame Effect: Which is contrary to Experience.

TO this we anſwer: That the Preſſure in the Caſe thus propoſed, is indeed not the ſame; and the Reaſon is, becauſe all our Liquors are imperfect Fluids. They have all ſome Tenacity, Attraction, and Coheſion in their Parts, of which they cannot be diveſted, and which are by Experience found to prevail very much where the Tube is ſmall, that is, where moſt of the Parts of the liquid Column rais'd come into Contact with, or touch it; ſuch Tubes therefore ſuſpend and even raiſe Water: Whereas in thoſe of a larger Diameter, and ſuch wherein the Weight of the fluid Body over-powers the Attraction of the Coheſion, this will be ſcarcely ſenſible; and there the beforeſaid Experiment would have its full Effect. As it would doubtleſs alſo have, even in the Caſe of the capillary Tube, if Water were a perfect Fluid, and there was no Attraction from the Tube.

On

On the ATTRACTION *of Cohesion.*

IF the Bore of a Pipe be even an eighth of an Inch in Diameter, the Attraction ſpoken of will be very apparent: For on immerſing the End in ſome Fluid, and taking it out again, a great Part indeed will quit the Tube; but ſome will ſtill remain, and hang therein. And if we take ſeveral ſmall Glaſs Tubes different in Size, and immerſe them together in Liquors, thoſe of the ſmalleſt Bore will attract the Fluid moſt, and it will be found therefore always to ſtand the higheſt in them.

THE ſame Cauſe which inclines Fluids to riſe in ſmall Tubes above the Level of the reſt, which they very notably do, makes them aſcend alſo in the Filaments or Threads of Cloth, in the way of Filtration; which ſooner takes effect if the Pores of the Cloth be firſt filled with Liquor. The Cells of Bread, Sugar, and other porous Subſtances, for a like Reaſon imbibe Fluids plentifully; in which they riſe, againſt the Direction of Gravity, for the Reaſon juſt aſſigned.

THIS Attraction will be very notable in an Experiment upon a Crane or Syphon of a ſmall Bore. If one of the Legs of this Machine be immers'd in a Jar of Water, the Fluid, as in ſmall Tubes it does, will riſe therein, and ſenſibly ſtand ſomething above the common Level of the reſt: And if the Jar be filled quite to the Brim,

Brim, the Difference ſpoken of will take place in the Bend of the Syphon; which when it ſhall have paſt ever ſo little, (and if the Tube be firſt wetted within, this will ſoon happen) Gravity will then lay hold, and puſhing out the Air before it, bring it down; after which the Water will continue to riſe through the Bore of the Machine, like a continued Thread, till it ſhall have emptied the Veſſel to the Depth of the immers'd Leg; the Reaſon whereof comes next to be enquired into. But previous to this, the ſpecifick Gravity of Fluids ought a little to be conſider'd.

On SPECIFICK GRAVITY.

AS an equal Bulk of a heavier Fluid will ſink in a lighter with a Force proportionable to the Difference of their Weights; ſo will a lighter counterbalance, repreſs, and even raiſe a heavier, provided a proportionable Quantity thereof equal or ſuperior to it in Weight, be to that Purpoſe applied.

FOR inſtance; Water is heavier than Oil, in the Proportion of about 11 to 10, that is to ſay, eleven Inches of Oil equipoiſe ten of Water; Water therefore will ſink in Oil; and on the contrary, Oil in Water will ſwim. Now as ten Inches of Water are *in Equilibrio* with eleven Inches of Oil, if a Tube with Water in it, be put level with the upper Surface of a Jar of Oil, about a tenth of it will drop out and ſink;

the reſt will be buoyed up, and remain juſt ſupported therein. And ſhould the like Experiment be made on Water, having Oil in the Tube, the Oil will be buoyed and weighed up above the Surface of the Water about a tenth Part.

MERCURY, again, is near fourteen times heavier than Water; yet when we ſuſpend a little of it in a ſmall Tube (as by ſtopping out the Air's Preſſure at Top may with Care be done) on putting it about fourteen times it's own Depth in Water, 'twill not drop out of the Tube, when unſtopp'd above; but if it be put deeper, will be raiſed therein, and if brought ſhallower, will drop out, according as the imaginary Surface of the Fluid beneath the Tube ſhall be more or leſs preſs'd by the Weight of Mercury, than the other Parts of it are by the collateral Pillars of the Fluid, wherewith it is in theſe Experiments compared.

On the SYPHON.

IF a ſmall Syphon, whoſe Legs are of equal Length, be fill'd with Water, and turned downward, the Fluid will not run off, but remain ſuſpended therein, ſo long as it is held exactly level: But when an Inclination to either Leg is given, whereby one in effect becomes ſhorter than the other, the Water will ſhoot out by the longer Leg forthwith.

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THE Air is a Fluid whoſe Denſity near the Surface of the Earth is experimentally found to be to that of Water, at a Medium, as 1 to 850; ſo that eight hundred and fifty Gallons of Air, near the Earth, weigh as much as a Gallon of Water. This, according to the Nature of all other fluid Bodies, preſſes the Surface of all Things expos'd to it every way equally. When therefore the Legs of the Syphon, equal in Length, are turned down, (the Weight of the Atmoſphere above being kept off by the Machine) the under Air, bearing againſt and repreſſing the Water, endeavouring to fall out of either of them, with equal Force, keeps it in ſuſpence, and prevents its Motion. But when by inclining it to either Side, we in Effect ſhorten one of its Legs, and prolong the other, whereby an Advantage is given to the weightier Fluid to preponderate or over-weigh; then indeed the Water begins to deſcend, and by its Continuity brings away the whole: Juſt as pulling by one End of a Thread, will make the whole Clue follow.

AND to obſerve how ſmall an Inclination will ſerve this Purpoſe, one need only take a couple of Jars full of Water, and hang a ſmall Syphon, whoſe Legs are of equal Length, upon the Edge of one; the external Leg whereof will, from the ſloping of the Jar, naturally incline a little, and the Syphon will ſoon begin to act, by the Attraction of Coheſion before-mentioned; then taking it on the Edge of the other Jar, the like will immediately happen: And thus reciprocally may the Effect be produced, as often and as suddenly as you please.

AND hence the Reasons why in Practice the Legs of the Syphon are usually made of unequal Lengths; and why the shorter Leg is put into the Liquor, and the Fluid decanted by the other, will in part appear.

'TIS evident from what has been said, that the two Legs of the Syphon, *Fig*. 8. *Plate* I. being of equal Length in the Plane *A B*, are there equally repressed by the Atmosphere; and was the Crane fill'd with Liquor only to that Height, and held level, no Motion of the Fluid would follow, till an Advantage by inclining it should be given as beforesaid. Instead of which a Length of Pipe, of some Inches perhaps, as from *B* to *C* in the Figure, is commonly added to these Machines, which, previous to the Operation, is ordinarily fill'd as well as the rest with a gross Fluid, many Degrees heavier than a like Quantity of Air, wherewith it is then compared; by the Gravity whereof the opposite Side becomes greatly over-balanced: And therefore Liquors are by this Machine usually decanted apace, and with a good deal of Rapidity.

BUT as the Air's Pressure is a Thing in this Treatise as yet not fully proved, it may not be amiss in this Place to make an Experiment, which may shew the Action thereof on the Surface of the Fluid raised, by substituting a visible Substance, *viz.* Oil of Turpentine, in its room;

wherein

wherein *KL*, *Fig.* 3. *Plate* 3. is a large glaſs Jar, capable of receiving the following Apparatus, *viz.* *AB*, which is a ſmaller Jar of ting'd Water heavier than Oil, and *GI*, an empty Jar, into which the red Liquor between *A* and *C* may be decanted by means of a Syphon whoſe Legs are unequal, for Uſe, as aboveſaid; in the Bend whereof is an open Tube fix'd, as *EF*. The tinged Water will at firſt naturally riſe by its own Weight from *C* to *I*. Then let Oil of Turpentine be gently poured into *KL*, after *GH* has been fill'd therewith, and the tinged Water will at length be raiſed to the Bend at *E*, by the Preſſure of the Oil ſtill lying one tenth above it, as ſuppoſe in the Level of *NM*. The Air at firſt contain'd in the Syphon, will be gradually protruded from either Leg, through the Tube above at *F*. The Water then being a Fluid ſpecifically heavier than the Oil with which it then meets, will ſink down the Tube *ED*, and in Time the ting'd Liquor between *A* and *C*, will be decanted into *GH*, occupying the Space *DH*. And thus will the Principle on which the Syphon acts, be confirmed, by the Action of two viſible Fluids, different in Weight, upon each other.

THE Way of making this Experiment with beſt Succeſs, will be to ſtop the End of the Tube at *F*, before either of the two Liquors come up to the Bend, leſt the Oil, being the lighter Fluid, might by riſing faſter in *DE*, than will the Water in *EC*, and which by taking Place in the Bend, might there ſo gravitate thereon, as abſolutely to prevent the riſing of the Water thither at all. But, by the Way now propoſed, on removing the Finger ſuddenly, the Air compreſſed in *F* will partly eſcape, and the two Liquors thereupon meeting fairly, with a kind of Shock, the more ponderous will ſink through the other, and produce the Effect deſired.

On the SYPHON *diſguiſed.*

BEFORE we proceed farther on this Subject, let us attend to ſome of the Varieties in which the Syphon may appear. It may, for example, be diſguiſed in a Cup, from which no Liquor will flow till the Fluid is raiſed therein to a certain Height; but when the Efflux is once begun, 'twill continue till the Veſſel is emptied. For inſtance; *Fig.* 9. *Plate* I. is a Cup, in the Center whereof is fixed a glaſs Pipe *A*, continued through the Bottom at *B*, over which is put another glaſs Tube, made Air-tight at Top by means of the Cork at *C*; but left ſo open at Foot, by Holes made at *D*, that the Water may freely riſe between the Tubes as the Cup is fill'd. Till the Fluid in the Cup ſhall have gained the Top of the inmoſt Pipe at *A*, no Motion will appear: The Air however from between the two Pipes, being in the mean time extruded, by the Riſe of the denſer Fluid, and paſſing down the inner Tube, will get away at Bottom, and the Water, as ſoon as the Top of the incloſed Tube ſhall be covered thereby, will very ſoon follow, and continue to riſe in this Machine, as in the Syphon, till the whole is run off.

THIS

THIS is called by ſome, a *Tantalus' Cup*; and to humour the Thought, a hollow Figure is ſometimes put over the inner Tube, of ſuch Length, that when the Fluid is got nearly up to the Lips of the Man, the Syphon may begin to act and empty the Cup.

THIS is in effect no other than if the two Legs of the Syphon were both within the Veſſel, *Plate* 1. *Fig.* 10. in which the Water poured in will riſe in the ſhorter Leg of the Machine, by its natural Preſſure upwards, as high as its own Level; and when it ſhall have gain'd the Bend of the Syphon, it will come away by the longer Leg, as already deſcribed. An Apple, an Orange, or any other Solid, may be put into the Veſſel to raiſe the Water, when it is near the Bend, to ſet it a running, by way of Amuſement.

THERE are other artful Ways of diverſifying and concealing the Syphon, to make its Effects appear the more ſtrange and amuſing; but as they all depend on the ſame principle, 'twill be ſufficient only to deſcribe one of the beſt. Let the Handle of the Cup, *Fig.* 11. *Plate* 1. be hollow; let the Tube *C D*, ſcrewed therein, communicate freely with the Water poured into the Cup, that it may riſe equally in both. Being once above the Level *E D*, 'twill overflow, and deſcending through the Cavity *DB*, will empty the Cup of its Liquor.

On NATURAL SYPHONS.

SOME uncommon Phænomena in Nature may be accounted for upon the ſame Principle. There is a Pond near *Graveſend* in *Kent*, out of which the Water actually ebbs all the Time the Tide is coming into the adjacent River, and into which the Water flows during the Time that the Tide is going out of the *Thames*.

THIS Appearance is occaſioned, no doubt, from there being ſomewhere in the Bank a ſubterranean Reſervoir, equal in Capacity to the whole Riſe and Fall of the Water in the Pond. This Reſervoir, when empty, may not improbably be fill'd from the River, pretty near the Top of the Tide, through ſome proper Channel in the Bank.

BETWEEN this Reſervoir and the Pond, from the accidental Diſpoſition of the Parts of Matter in that particular Place, there may very probably be ſome natural Syphon, whoſe Bend lying ſomething lower than the Surface of the Water in the Reſervoir, when full, may by the Riſe of the Water therein, have the Air protruded from the ſhorter Leg; and when the Water is once above the Bend, 'twill ſoon ſhoot down and diſpoſſeſs the longer of it. The Syphon will thereupon begin to act, and may continue thereby to repleniſh the Pond during the whole

whole Tide of Ebb, by which Time the Reservoir being exhausted, the Syphon will gather Air, and cease to act.

THE Pond being thus fill'd to a certain Height, 'tis not unlikely but that a second natural Syphon, concealed in the Earth somewhere near the Pond, whose Bend also lying something lower than the Surface of the Water in the Pond, being thus replenished, may in like manner begin to act, about the Turn of the Tide in the River; and continuing so to do all the Tide of Flood, may easily produce the odd Phænomenon now describ'd.

THERE is also a Spring in *Derbyshire*, called *Wedding-Well*, or *Tydes-Well*, of which Mr. COTTON, in his *Description of the Wonders of the Peak*, gives the following Account.

IT is, says he, a small and to Appearance an inconsiderable Spring constantly rising at the Foot of an Hill, which on occasions, after a rumbling kind of Noise heard as under Ground, flows so briskly as to make a pretty smart Torrent. It usually flows in this manner for about three Minutes, and issues with a singing kind of Noise resembling the playing of a *Jet-d'Eau*.

HE takes Occasion to inform us, that Mr. HOBBS was of Opinion, that this temporary Flux could not proceed from the Sea, because the Water was intirely fresh; and such was its Irregularity, that it could not be under the Influence

of

of the Tides. But ſays he conjectures, that in the Paſſage of the Spring, there might probably be ſome narrow Vent, which in wet Weather might not be able to receive all the Water that came down; he therefore imagines, that the Air there pent up, might alſo by endeavouring to oppoſe its Paſſage, cauſe it to heave as if convulſed, to lie as it were gargling there, and ſo occaſion the Noiſe abovementioned under Ground.

BUT to this Account Mr. COTTON himſelf objects, That was this the Cauſe of the Appearance before-cited, it would never happen but in wet Seaſons, and the Water would alſo be ſometimes thick and muddy; both which are obſerved to be contrary to Fact and Experience.

THIS remarkable Phænomenon happens, it muſt be obſerved, at a great diſtance from the Sea, and much above it, in a very mountainous Country. Now the Hills generally intercept the humid Particles, or the Vapours floating in the Air, and driven by the Winds, whether it rains or not. In this Country there are ſeveral vaſt Caverns in the Belly of the Hills, found to have Water continually trickling down the Rocks, as well within the Earth as without. In the Caſe before us, it is then very probable, that a natural Reſervoir, not over large, may be concealed ſomewhere within the adjacent Hill, and ſo conveniently placed as to receive the deſcending Waters. This being fill'd by the Drippings beforeſaid to a fit Height, ſome natural Syphon may begin

to

to run, and the Water deſcending through the ſubterraneous Vents, iſſues at the Place as there deſcrib'd. The Syphon perchance happens to be large, and therefore cauſes it to come down briskly as in a Torrent. Thus upon rational Principles, and with great Probability may be explain'd, what ſeem'd ſo great a Difficulty to Mr. COTTON and Mr. HOBBS.

AT *Lambourn* in *Worceſterſhire*, again, there is a Brook, which in Summer-time is ſaid to receive a Flow of Water ſufficient to turn a Mill; but during the Winter, it runs with a very inconſiderable Stream. 'Tis probable that this proceeds likewiſe from ſome very large ſubterraneous Reſervoir, which the winter Snows and Rain, in a Length of Time, may fill to a certain Height; and then ſome large natural Syphon may take Effect, and bring away its Water in a Stream equal to the Dimenſions of the Bore. And when the Reſervoir is thus exhauſted, what runs afterwards may be no more than the Weeping of the adjacent Springs.

The Uſe of the AIR'S PRESSURE *in raiſing* FLUIDS.

BEFORE we leave this Subject, we ought to be ſatisfied, That 'tis the Air's Preſſure on the Surface of Fluids which principally makes them riſe in the Syphon. This Machine we are to obſerve is always to be Air-tight; otherwiſe the Air admitted, though never ſo ſmall in Quantity,

tity, being of the ſame Denſity with that adjacent, will counter-balance the Weight of the Atmoſphere acting upon the Surface of the Fluid to be decanted, and immediately cauſe the Motion to ceaſe. To demonſtrate this, we need only take out the Cork *C*, ſtopping the exterior Tube, when the Syphon of our *Tantalus' Cup*, *Fig.* 9. *Plate.* 1. is in Action, and the Flux will thereupon immediately ceaſe.

THIS may be farther evinced, by running off a Phial of Mercury through a Syphon fix'd into the Cork, into which a ſhort Quill is alſo put, by way of Ventage, to let in the Air, and continue the Preſſure of the Atmoſphere ſucceſſively on the Surface of the decanted Fluid. So long as the Quill remains open, the Mercury will run off with great Freedom; it can no ſooner be ſtopp'd, but the Flux of the Fluid will be ſo too.

IT will not be unacceptable to the Curious nevertheleſs to intimate, That however the Air's Preſſure be the true and general Cauſe of the Riſe of Liquors in the Syphon, yet will they alſo riſe, under certain Circumſtances, and to certain Limits, *in Vacuo*, when that Preſſure is withdrawn. This has been already hinted to be owing to their being imperfect and tenacious Fluids, ſubject to the Attraction of Coheſion, which between ſome Bodies is more prevalent, between others leſs. And this may be eaſily try'd on a Jar of Water, by a ſmall Syphon *in Vacuo*, and from the Diſcharge then made, a

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Judgment may be formed how great the Tenacity of Water, and what the Attraction of the Glaſs thereon is: For was it a perfect Fluid, and the Attraction away, it could not, *in Vacuo*, be ſuppoſed to riſe or run at all.

THE Way of making this Experiment with Succeſs is, not abſolutely to fill the Veſſel brimful of Water at firſt; but, by help of a Wire paſſing through a Collar of Leathers, when the Air is pretty well exhauſted, let down ſomething ſolid into the Water, which may raiſe it to the Brim, and ſet the Syphon a running. By this the Liquor may be decanted nearly perhaps to the Depth of the Leg immers'd, provided the Syphon be very ſmall: If it is any thing large, this will never happen in any Degree.

THE like may be try'd upon Mercury, by help of an Apparatus that will keep the Syphon from ſwimming. This may be effected by fixing a piece of a ſtrong wooden Tube, exactly fitting the upper Part of your glaſs Jar thereto. On one Side of which let there be a ſmall Groove, juſt wide enough to receive the glaſs Syphon, which may afterwards be cloſed with a convenient Slider, and a little Cement if occaſion be, both to confine your Mercury and keep your Syphon fix'd. Then filling up your Jar with Mercury to a convenient Height, and exhauſting the Air, let down your ſolid Body abovementioned into the Jar, to raiſe the Fluid ſomething above the Bend of the Syphon, and it will begin to run, as before. By obſerving

then

then how much of the Mercury will run off thereby, and comparing it with the Quantity of Water before diſcharg'd, the Difference of the Tenacity of theſe two Fluids, and their Attraction to Glaſs, as was ſaid, will in part appear, if the ſame Syphon be uſed in both Experiments, and the Thing accurately done.

NOW as the Air's Preſſure near the Earth, by ſeveral undeniable Experiments may be proved at leaſt to be equal to the abſolute Weight of thirty three Foot of Water, it will at all times counterbalance, and therefore raiſe and ſuſtain that Quantity for Service. It will actually do ſo in the Pump, and in the Syphon would very probably do ſo, was it neceſſary to apply it in that manner: So that a Fiſh-pond, or any other Head of Water, might be run off thereby, over a Dyke, much above the Surface, if a Sough or Drein, to carry it off otherwiſe, could not be made.

WATER will riſe in the common Air in a Jet, when over-balanced by the Spring of Air compreſs'd. Air of the common Degree of Denſity, will produce a like Effect in Air attenuated or more rarify'd, as by proper Experiments hereafter will be ſhewn. As an Inſtance of the latter kind, at preſent, however take the Machine, *Fig.* 12. *Plate* 1. in Form not unlike and in reality differing but little from the Syphon; except that where the Legs communicate, there is a tranſparent Veſſel fixed, through which a Jet of Water may be ſeen. Into this Part of the Machine,

chine, thro' either of the Legs, firſt pour a ſmall Quantity of Water, which when the whole ſhall be revers'd, will miſs the Hole of the jetting Pipe *A*, communicating with the Veſſel *C*, and make its Way down the longer Leg *E*, through an adequate Opening made at *B*. The ſhorter Leg is at the ſame Inſtant to be put into the Jar of Water *C*. Upon this the Veſſel *D*, before fill'd part with Water, and part with Air, by the falling away of the Water, which it was before charg'd with, will be fill'd with Air only, a ſmall Matter thus rarify'd and expanded. The Atmoſphere then preſſing the Surface of the Water in the Jar with its whole Weight, and the inward Air, thus attenuated, reſiſting with but a diminiſhed Force, will cauſe the Water to riſe from the Jar into the glaſs Head; whence continuing ſtill to deſcend by the longer Leg *E*, the Machine will agreeably play a Jet of Water, ſo long as there is any Liquor left in *C* for a Supply.

On SUCTION *by* MACHINES.

THE Quantity of the Air's Preſſure may be demonſtrated either by Experience on the Pump itſelf, or by its equipoiſing and at a Medium ſuſtaining twenty nine Inches and a half of Mercury, a Fluid near fourteen Times heavier than Water, in the common Barometer. And the way we know that 'tis the Air's Preſſure on the Surface of the Fluid, whereby the Water is raiſed, by this Kind of Pump; and become certain that

that it proceeds from no Property, Power or Efficacy in Suction is, that in the Air, Water, and even a Fluid ſo denſe as Mercury, may be raiſed by proper Machines: But if the Air's Preſſure be removed, it cannot be raiſed at all; as may be ſhewn by an Exhauſting Syringe, (to diſtinguiſh it from the Forcing or Injecting) commonly called a Sucking Syringe, or if you pleaſe a common Pump. Let this be fix'd to a tranſparent Tube, and the nether End thereof put into a Jar of Mercury, incloſed within a tall Receiver; before the Air is exhauſted, if the Piſton be raiſed, the Mercury will immediately follow; after 'tis exhauſted, no ſuch Effect will appear.

THIS being determined and certain, all then we are to underſtand by Suction is, That whenever by any mechanical Diſpoſition or Contrivance, the Preſſure of our ſurrounding Fluid, the Air, is in any Place abated, the adjacent Matter, urged on by the Weight of the Atmoſphere, will tend thither; and if that Matter be fluid, 'twill ſo far riſe above its common Level, as till, by it's abſolute Weight, a juſt counter-balance is made, in order to preſerve the Equilibrium, which ought every where to exiſt, by the eſtabliſhed Laws of Nature and Providence.

BEFORE GALILEO's Time, Philoſophers fancied this Riſe of Water and other Fluids, to be the Reſult of *Nature's abhorring a Vacuum.* Not to cavil at the Term *abhor*, which can only properly be apply'd to animal Affection; but to take it

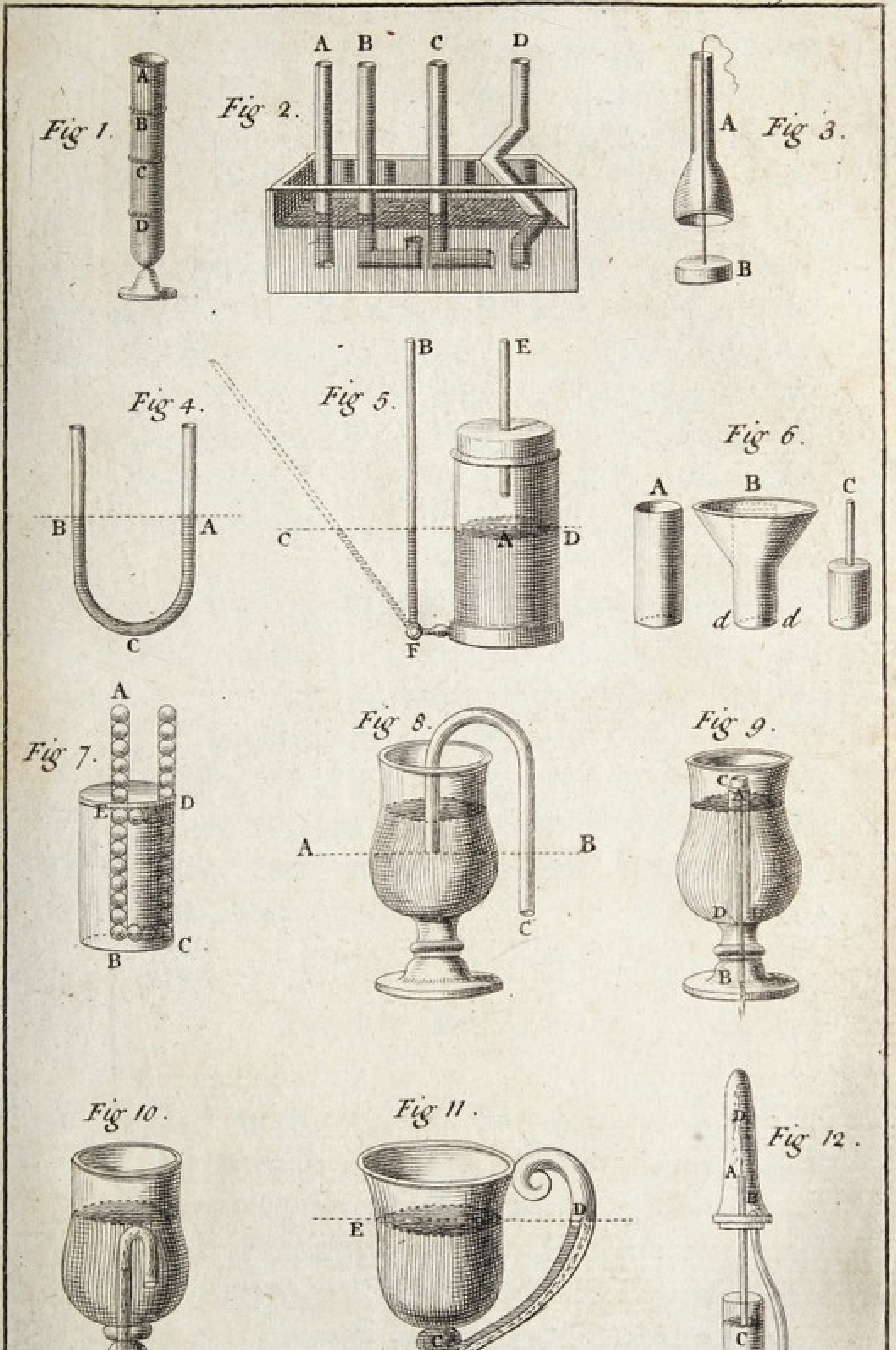


Fig 1.
A
B
C
D
Fig 2.
A B C D
Fig 3.
A
B
Fig 4.
B A
C
Fig 5.
B E
C A D
F
Fig 6.
A B C
d d
Fig 7.
A
E D
B C
Fig 8.
A B
C
Fig 9.
C
D
B
Fig 10.
Fig 11.
E D
C
B
Fig 12.
D
A
B
C
E

J. Cole Sculp.

as it was probably intended, in a metaphorical Senſe: We may reaſonably enquire, How Nature came to abhor a *Vacuum*, in the Caſe before us, to the Height of between thirty and forty Foot, from the Surface of the Earth, and no farther? Had ſhe abſolutely abhorred a *Vacuum*, this Abhorrence would have been indefinite; and Water, upon this Principle, might have been raiſed three thouſand, as well as thirty Foot high. But this is otherwiſe in Fact. And by Experience we find that Nature has no Antipathy to a *Vacuum*; but that in general, *One heavy Body only riſes, when another ſuperior in Weight deſcends.*

THE Riſe of Water in the Sucking-Pump, by the general Preſſure of the Atmoſphere incumbent on the Surface of the Water in the Well, a Preſſure not to be excluded from the Bowels of a Body ſo porous as the Earth, being thus ſettled, the Parts of this Machine, with the Manner in which they act, will next come under Conſideration.

On the PUMP.

THIS uſeful Piece of Mechaniſm was firſt invented by CTESEBES, a Mathematician of *Alexandria*, about a hundred and twenty Years before Chriſt. When the Air's Preſſure came afterwards to be known, 'twas much improved; and 'tis now brought to a great Degree of Perfection.

OF this Machine there are ſimply three Kinds, *viz.* the Sucking, the Forcing, and the Lifting Pump. By the two laſt, Water may be raiſed to any Height, with an adequate Apparatus and ſufficient Power: By the former it may, by the general Preſſure of the Atmoſphere on the Surface of the Well-water, be raiſed no more than thirty three Foot, as was before hinted, tho' in Practice it is ſeldom apply'd to the raiſing it much above twenty eight; becauſe from the Variations obſerv'd on the Barometer, 'tis apprehended that the Air may be on certain Occaſions ſomething lighter than thirty three Foot of Water; and whenever that ſhall happen, for want of the due Counterpoiſe, this Pump may fail in its performance.

On the SUCKING-PUMP.

THE common and moſt uſual Pump, conſiſts of a Pipe open at both Ends, in which there is a ſliding Piſton as big as the Bore, which by means of the Hand, or ſome other Contrivance, may be moved up and down without ſuffering any Air to come between it and the Sides of the Pipe; which is otherwiſe call'd the Barrel, as *AB* in *Fig.* 2. *Plate.* 2.

IF the lower End of this Pipe and Piſton be put into Water, and the Piſton raiſed, by Lifting away the Column of upper Air, a *Vacuum* will be made in the Pipe, upon which the Atmoſphere preſſing on the Well-water, will

will force it to follow the Piston, even to the Height of thirty three Feet, could the Stroke be of that continued Length; and if there be a Valve or Clack, something like a Trap-door, to shut downward, as *Fig.* 1. *Plate* 2. placed in some convenient part of the Pipe below the Water so raised, as at *C*, *Fig.* 2. *Plate* 2. 'twill certainly be retained therein. But if this Contrivance be wanting, upon shoving down the Piston again, the Water will recede along with it towards the Spring: So that by the Motion of the Piston up and down, the Water indeed might rise and sink in the Barrel at every Stroke; but without an under Valve to confine and keep it there, none can be drawn for Service.

THE Frame *A* of these Valves, *Fig.* 1. *Plate* 2. is usually made of Wood, exactly fitted to the Bore of the Pipe, and not over-thick, that it may not stop too much of the Water-way. To this the Hinge of the leather Flap *B*, which is usually lined with Lead, not only to make it fall readily, but to give it Strength sufficient to bear the Weight of the Water raised without warping, is commonly nail'd.

IN this kind of Pump there is, besides this fix'd Valve, a moveable one for Conveniency's sake placed in the Piston, as at *D*, *Fig.* 2. *Plate* 2. also opening upwards, or the Way the Water is to rise. Such a Piston is commonly call'd the Bucket.

WHEN the Bucket of this Machine deſcends, if the Bore of the Pipe be already full of Water, the Reſiſtance thereof will puſh open the moving Valve, and part of the Water will get above; and whenever the Piſton is drawn upwards, this Valve will cloſe under the Weight, and the Water will be raiſed by the Force applied: So that whenever the moveable Valve by being raiſed, is made to lift the Weight of the Column, as well of Air as Water lying thereon, the fix'd Valve is diſcharged of all Preſſure; and then a Quantity of Water, preciſely equal to that by the Bucket lifted and drawn off, will by the ordinary Preſſure of the Atmoſphere, as was ſaid, on the Water in the Well, be forced or weighed up through it, to repleniſh the Pipe or Barrel. This alternate Action of the two Valves is viſible thro' the glaſs Pumps.

BUT if the Bore of this Machine be full of Air only, before Water can be drawn that Air muſt be exhauſted; which may be done, if the Piſton Valve be tight, by the ordinary Motion thereof: But for the greater Certainty and Expedition, Water is commonly poured thereon down the Pipe, vulgarly call'd *Fetching the Water*; which is of no other Uſe than to wet the Valves and ſupple the Collar of Leather fixed to the Bucket or Piſton, that it may lie cloſe to the Sides of the Barrel, and ſuffer neither the upper Air or Water to eſcape by it, when 'tis moved up and down.

THE firſt Stroke of the Pump-handle, if ſufficiently long, makes a total *Vacuum* in the Pipe; if otherwiſe, an Approach is only made towards it, and but a Part of the contained Air lifted away; upon which the Air remaining in the Cavity of the Bore, from it's natural Spring, will be conſiderably dilated. To reſtore the natural Denſity whereof, the Atmoſphere then preſſing harder on the Well-water than can the dilated Air on that in the Pipe, will cauſe the Water to riſe therein ſo far, as that, together with the included Air (yet a little rarify'd by the depending Weight of Water) it ſhall juſt counterpoiſe the Weight of the outward Air. The very ſame Thing will again happen on a Repetition of the Stroke, till by Degrees the Water ſhall have reached the moving Valve; and then the Proceſs will go on ſteadily as before. And Water, by means of this Contrivance, may be raiſed to any Height whatever, if the Power applied be ſufficient to lift the Weight, and the Pipes ſtrong enough to bear the Fluid's lateral Preſſure.

THE Preſſure on the Pipes in Pump-work, has already been proved to be in Proportion to the ſtanding Height of the Fluid above the part conſidered: But the Weight incumbent on the Bucket or moving Valve of a Pump, in Action, is nearly proportionable to that of the Column of Water raiſed. For tho' the Puſh of the Atmoſphere on the Surface of the Spring, when the Bucket riſes, be really equal to the Weight of thirty three Foot of Water; yet is this Aſſiſtance counter-balanced exactly by the Weight of the Atmoſphere incumbent on the Surface of the Water thereby raiſed: So that all the Advantage to be obtained by or expected from Hydraulick Machines, or Engines to raiſe Water, as well indeed as from all other Pieces of Mechaniſm whatever, is only the putting Things into a convenient Method of being executed, and the Performance depends on the moving Power entirely, under the Diſadvantage of Friction always againſt it.

On the Diſpoſition of PUMP-WORK.

A Pump therefore intended to raiſe Water to any Height whatever, will always work as eaſy, and require no greater a Power to give Motion to the Bucket, if both the Valves be placed towards the Bottom of the Pipe, than if they were fixed thirty three Foot above the Surface of the Water.

THE playing of the Piſton thus low in the Pipe, will beſides prevent an Inconvenience which might happen was it placed above, *viz.* in Caſe of a Leak beneath the Bucket, which, in a great Length of Pipe may very eaſily happen, the outward Air getting thro', would hinder the neceſſary Rarefraction of the Air in the Barrel, on moving the Piſton; and conſequently the Pump might fail in its Operation. This can only effectually be prevented by placing the Pump-work in or near the Water. In which

Caſe,

Caſe, ſhould any Leak happen upward, 'twill only occaſion the Loſs of ſome of the Water, without any other Inconvenience. And the leather Valves being thus kept under Water, will always be found ſupple, pliant, and in a fit Condition to perform their Office.

IT may be objected; That the ſpecifick Weight of the iron Rod, to which the Bucket is fixed, may be an Incumbrance to the working of the Pump: But if it be made of Oak, when well ſoak'd, 'twill be nearly of the ſame ſpecifick Weight with Water, and ſo no Burden on the moving Power, when the Stroke is fetch'd.

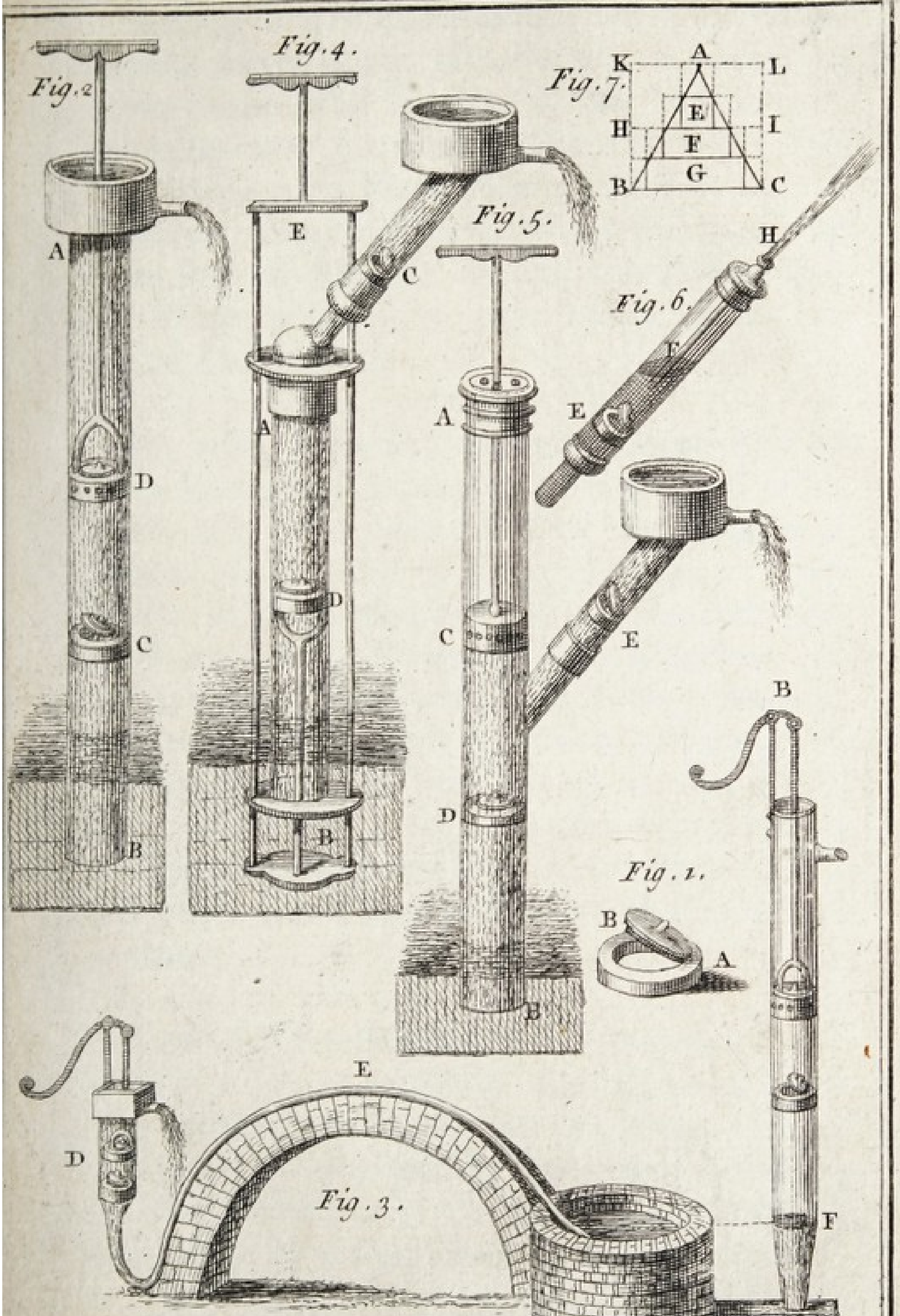
PLACING the Pump-work, that is the Valve and Piſton, pretty low and near together, will alſo prevent the Inconvenience of our not being able in all Caſes to fetch up Water from the Spring, by the ordinary Pump, when of an equal Bore; by Reaſon of the Shortneſs of the Stroke, which therefore cannot rarify the Air ſufficiently to bring the Water up to the Piſton from the nether Valve. For Inſtance: Take a ſmooth barrell'd Pump, twenty one Foot long, having its Piſton fetching ſuppoſe a Foot Stroke, plac'd above, and the Clack at the other End below. By the playing of the Piſton, admit it poſſible for Water to riſe eleven Foot, or if you will, let Water be poured on the Clack, to the Height of eleven Foot; and refit the Piſton. There will remain ſtill nine Foot of Air between it and the Water, which cannot be ſufficiently rarify'd by a Foot-ſtroke, to open the Clack, or fetch up any more Water: For in this Caſe, the Air can only be rarify'd in the Proportion of 9 to 10; whereas to make a bare Equilibrium with the Atmoſphere, it ought to be as 9 to $13\frac{1}{2}$: Since, as 22, or the Complement of 11, to 33 Foot of Water, the Weight of the whole Atmoſphere, is to 33 Foot, or the Atmoſphere; ſo is the Interval ſpoken of, 9, to $13\frac{1}{2}$; to compleat which, the Stroke ought to be at leaſt $4\frac{1}{2}$ Foot long.

HOWEVER by filling the whole Void between the Piſton and Clack at firſt with Water, this laſt Objection might be removed.

On the DISPOSITION *of* PIPES *of* CONDUCT.

IN ſome Places the Pump cannot be placed conveniently perpendicular to the Well: For Example, being to raiſe Water out of the Well at *A*, *Fig.* 3. *Plate* 2. by Means of a Pump at *B*; the beſt Way will be to carry the Barrel as low as is the Spring, communicating therewith by means of the Pipe at *C*. The Bucket then playing in the Barrel at *B C*, will have the ſame Effect, as if the Well was made perpendicular to the Pump: Becauſe the Water, by its proper Weight, will always repleniſh *BC*, thro' *A*, to the Level of the Well-water at *F*.

AND



Fletcher Sculp.

AND if it ſhould happen, from ſome conſiderable Impediment, that the Barrel cannot go down to the Well directly, it may be led about any other way for ſake of Convenience. And then making the Pipe of Conveyance *E*, leſs in Diameter than the Barrel, it will the ſooner be exhauſted of Air, by moving the Piſton, and the Water will follow very briskly, as by the leaden Pump at *D*.

IT will, however, always be more eaſy to draw Water with Pipes that are large, and of an equal Bore throughout; becauſe the Water will have a leſs Velocity in them, and the Friction will be in Proportion leſs. Upon this Account, the Pumps ordinarily made by the Plumbers, go not ſo eaſy as thoſe bor'd out of Trees: Becauſe, by making their Pipe ſo much leſs than the Bucket, they as it were wire-draw the Water rais'd. If the Barrel, for Inſtance, be three Inches in Diameter, and the Pipe of Conduct one, it will move nine Times as faſt thro' this, as it will in that.

FOR the like Reaſon, it will be alſo a Fault to bore a Pump conically upward, becauſe the Water cannot with Freedom get away ſo faſt as a *Vacuum* by the moving Piſton may be made; and the Reflection of the Water from the Sides, will always be a Hindrance to the Operation.

On

On LEATHERING *the* PISTONS.

ANother Miſtake the unskilful Workman is very apt to make, is leathering the Piſton ſo ſtiff, as to bear ſo very hard againſt the Sides of the Barrel, and to wear it much away, commonly called *Chambering the Pump.* However, ſuch a Machine may be very tight, it will, on Account of the great Friction, require more Labour to work it than is neceſſary.

THE upper Leather of a Shoe, if good, is ſtrong enough to reſiſt any reaſonable Preſſure from above, as in the Caſe of the Sucking and Lifting-Pump Piſtons; or to overcome any Thruſt made below, as in the Caſe of the Piſton of the Forcing Pump, and will laſt a long Time.

THE way of leathering the Piſtons of theſe Machines, is always ſo as to face their Work; that when the Strain comes, the Leather, being a ſtrong, tough, and yielding Subſtance, may ſpread, and ſuffer neither Air nor Water to paſs between them and the Sides of their Barrels, when they are moved. If the Pump be to work hot Liquors, coarſe Cloth is commonly uſed inſtead of Leather for this Purpoſe.

On the LIFTING-PUMP.

THE Structure of the Lifting-Pump, *Fig*, 4. *Plate* 2. differs from that of the Sucking-Pump in nothing but the Diſpoſition. As that has its fix'd Valve below, and the moveable one above, in the Barrel *AB*, *Fig*. 2. *Plate* 2. this is juſt the contrary, as *C* and *D*. As the Bucket or Piſton of that is moved by a Rod within the Bore of the Pipe, this is ſo by means of a ſtrong Frame fixed to a Rod without at *E*. As in that, 'tis of Advantage, for fear of a Leak, to have the Pump-work, if poſſible, in or near the Source of Water; this in Practice is commonly made to do ſo, and for that Reaſon is very ſeldom ſubject to any Failure in its Performance. An Elbow in this kind of Pump, to lead the lifted Water clear of the playing of the Rod, which of Neceſſity muſt move perpendicularly, is unavoidable. The Friction occaſioned hereby will however always be leſs the nearer this Bend comes to a ſtraight Line.

FROM the Name and Structure of this Machine, it may be imagined, perhaps, that the Air's Preſſure is not of equal Service to this kind of Pump, as to the former; but it is quite otherwiſe. For if both Valves be not perfectly Air-tight, Water cannot be well raiſed thereby: But in Caſe neither of them is defective, Water will be raiſed to very good Purpoſe, by much the ſame kind of Proceſs as that of the Sucking-Pump,

Pump, before explained. Nor is there any doubt, but that if two Machines, a Sucking and a Lifting-Pump, were made of equal Bores, wrought with equal Force, and were in every Circumſtance alike, they would be found of equal Service in raiſing Water.

N. B. *The Repreſentations of the ſeveral Piſtons, and their Valves, in the common Pump-work, are expreſs'd in the Draughts ſufficiently plain, and all diſpoſed in their proper Actions, when the Machines work.*

On the FORCING-PUMP.

AND as the Weight of the Atmoſphere is of very great Uſe in the two Pumps already deſcribed, it is of no leſs Advantage to the Forcing-Pump; which conſiſts, as in *Fig.* 5. *Plate* 2. of a Barrel *AB*, a Piſton or Forcer *C*, leather'd upwards, that it may withſtand the Preſſure of the Atmoſphere from above, that ſo by ſucking, when raiſed, it may bring up the Water to ſupply the Barrel; and 'tis alſo leather'd downwards, that, when depreſſed, it may reſiſt the Weight of the Water to be forced up, or raiſed for Uſe. There are always two fix'd Valves in this kind of Pump; one in ſome convenient part of the Streight, otherwiſe called the Sucking-Pipe, as at *D*, the other in the Branching or Forcing-Pipe, as *E*. Theſe ought in like manner to be Air-tight, and ſo diſpoſed as to let the

the Water freely riſe, but are abſolutely to hinder its Return.

WHEN the Forcer is firſt moved upwards in the Barrel, the Air between that and the Water below, having Room to dilate, by its natural Spring, will of courſe be rarify'd therein; the Preſſure of the Atmoſphere then being intercepted by the Forcer in the Barrel *AB* on this Hand, and by the upper Valve at *E* in the Branching-Pipe on that; the Water will riſe from the Spring into *AB*, for the Reaſon already given: And repeated Strokes of the Piſton will fetch up the Fluid to the Forcer, and at length fill the Cavity of the Pipes between the fixed Valves *D* and *E*. This done, the Water, in this manner ſucceſſively raiſed, being ſtopp'd from going down again by the nether Valve, will be preſſed by the Forcer every Time it deſcends, and be thereby obliged to make its Way where the leaſt Reſiſtance is, *viz.* thro' the upper Valve at *E*. And whenever on the riſing of the Forcer, this Preſſure intermits, the Valve at *E* will immediately cloſe under the Weight of the upper Water, and prevent its Return that Way, while the Piſton is riſing with a freſh Supply; and this is repeated at every Stroke of the Forcer.

On FIRE-ENGINES.

ENGINES for extinguiſhing Fire, are either Forcing or Lifting-Pumps, and, being made to raiſe Water with great Velocity, their

their Execution in great Meaſure depends upon the Length of their Leavers, and the Force wherewith they are wrought.

FOR Example, *AB*, *Fig.* 1. *Plate* 3. is the common ſquirting Fire-Engine. *DC* is the Frame of a Lifting-Pump, wrought by the Leavers *E* and *F*, acting always together. During the Stroke, the Quantity of Water raiſed by the Piſton *N*, ſpouts with Force thro' the Pipe *G*, made capable of any Degree of Elevation by means of the yielding leather Pipe *H*, or by a Ball and Socket, turning every Way, ſcrew'd on the Top of the Pump. Between the Strokes on this Machine the Stream is diſcontinued. The Engine is ſupply'd by Water poured in with Buckets above; the Dirt and Filth whereof is kept from choaking the Pump-work, by help of the Strainer *IK*.

A conſiderable Improvement has of late been made to theſe Machines, in order to keep them diſcharging a continual Stream. In doing whereof, it is not to be underſtood that they really throw out more Water than do the ſquirting ones of the ſame Size and Dimenſions with themſelves; but that the Velocity of the Water, and of Courſe the Friction of all the Parts, being leſs violent, the Stream is more even and manageable, and may be directed hither or thither with greater Eaſe and Certainty, than if it came forth only by Fits and Starts: The Machine thus improved, is therefore generally better adapted to the Purpoſe intended than the former, eſpecially in the Beginning of theſe calamitous Accidents.

THIS

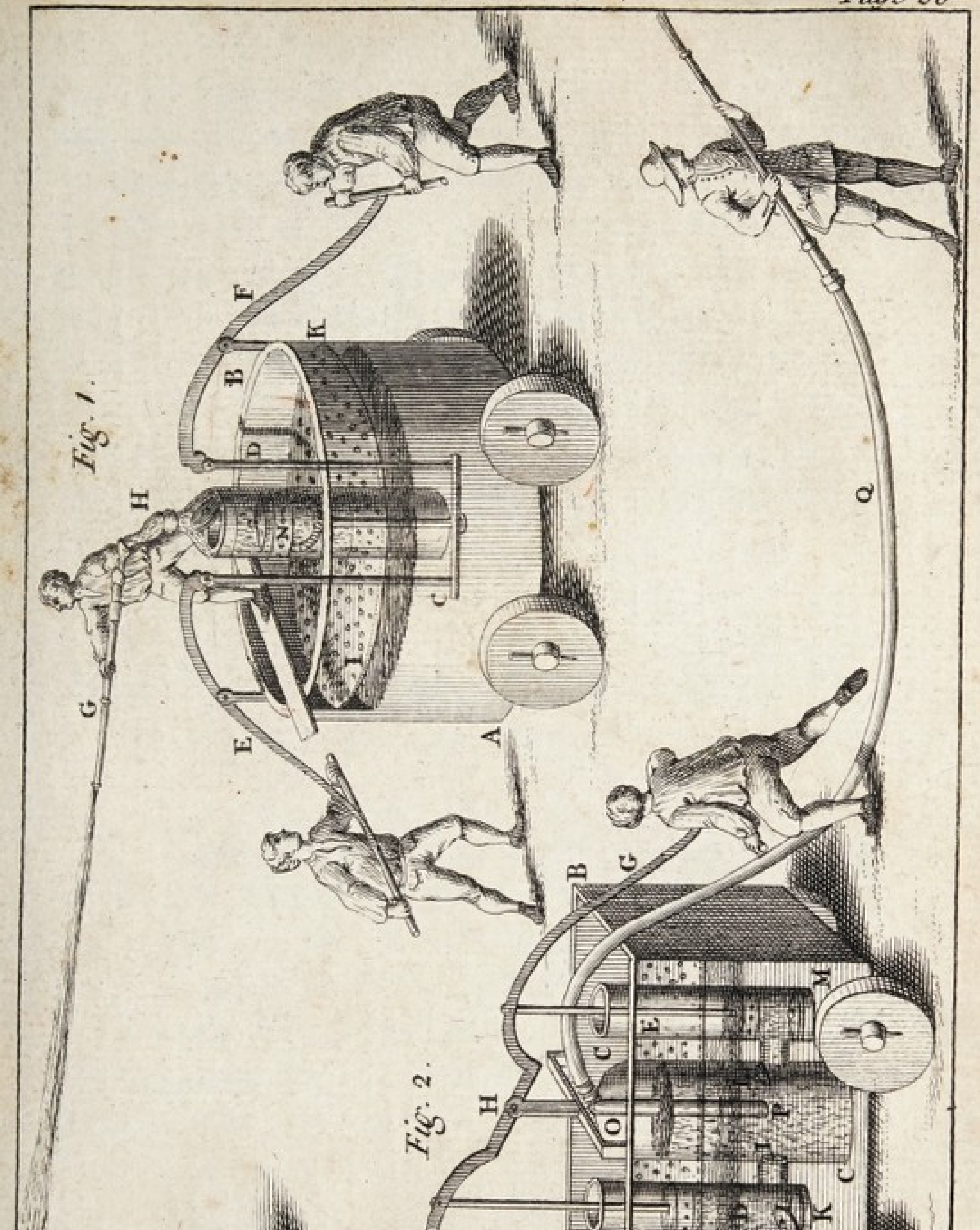
THIS is performed by the Spring of Air confined in a ſtrong Metal Veſſel *CC*, in the Fire-Engine *AB*, *Plate* 3. *Fig.* 2. fixed between the two Forcing-Pumps *D* and *E*, wrought with a common double Leaver *FG*, moving on the Center *H*. The Piſtons in *D* and *E* both ſuck and force alternately, and are here repreſented in their different Actions; as are alſo the reſpective Valves at *IK* and *LM*.

THE Water to ſupply this Engine is alſo poured into the Veſſel *AB*; and being ſtrained thro' the wire Grate *N*, is by the Preſſure of the Atmoſphere raiſed thro' the Valves *K* and *M* into the Barrels of *D* or *E*, when either of their Forcers aſcend; whence again it will be forcibly puſhed, when they deſcend into the Air-veſſel *CC*, thro' the Valves *I* and *L* by turns. By the Force whereof, the common Air between the Water and the Top of the Air-veſſel *O*, will from time to time be forcibly crowded into leſs Room, and much compreſſed; and the Air being a Body naturally endowed with a ſtrong and lively Spring, and always endeavouring to dilate itſelf every Way alike, in ſuch a Circumſtance, bears powerfully both againſt the Sides of the Veſſel wherein it is confined, and the Surface of the Water thus injected, and ſo makes a conſtant regular Stream to riſe, thro' the metal Pipe *P*, into the leather one *Q*, ſcrewed thereon, which being flexible, may be led about into Rooms and Entries, as the Caſe may require.

SHOULD

SHOULD the Air contained in this Veſſel, be compreſſed into half the Space it took up in its natural State, the Spring thereof will be much about doubled; and as before it equall'd, and was able to ſuſtain the Preſſure of a ſingle Atmoſphere, it will have now a double Force, and by the Power of that Spring alone, will throw Water into Air, of the common Degree of Denſity, about thirty Foot high. And ſhould this Compreſſure be ſtill augmented, and the Quantity of Air which at firſt filled the whole Veſſel, be reduced into one third of that Space, it's Spring will be then able to reſiſt, and conſequently raiſe, the Weight of a treble Atmoſphere; in which Caſe 'twill throw up a Jet of Water ſixty Foot high. And ſhould ſo much Water again be forced into the Veſſel, as to fill three Quarters of the Capacity, it will be able to throw it up about ninety Foot high; and wherever the Service requires a ſtill greater Riſe of Water, more Water muſt be thruſt into this Veſſel, and the Air therein being thus driven by main Force into a ſtill narrower Compaſs, at each Exploſion of the Machine, the gradual Reſtitution thereof to its firſt Dimenſions, is what regularly carries on the Stream between the Strokes, and renders it continual during the Operation of the Machine.

THIS Experiment, in little, may be either made on the Lifting or Forcing-Pump, the Noſels of which may be left large, on Purpoſe for the Reception of the ſmall Pipe *F*, *Fig.* 6. *Plate* 2. reaching nearly to the Valve at *E*, and occaſionally



J. Cole Sculp.

casionally to be ſcrew'd in. Between this Pipe and the Sides and Top of the Noſel *H*, a Quantity of Air will be lodged, which when the Forcer acts, will be compreſſed at every Stroke by the Riſe of the Water, more whereof will be puſhed thro' *E* than can immediately get away thro' the Pipe *F*, which is to be always leſs in Diameter than the Opening of the Valve at *E*. The Degree of which Condenſation, and that of the Reſtitution to its natural State of Denſity, may be obſerved through the glaſs Machines to Satisfaction.

The Deſcription of the ENGINE *for raiſing* WATER *by* FIRE.

A SHORT Account and Explanation of the Engine of great Uſe in Coal-works, and other Mines, for the raiſing of Water by Fire, cannot be unacceptable to the Curious. They are uſually Forcing-Pumps, with an Air-veſſel applied, and are wrought by the Weight of the Atmoſphere preſſing on a Piſton, under which a *Vacuum* is to be made by the help of the Steam of boiling Water.

Now tho' the Water itſelf cannot be condens'd by any external Force, as is evident from the *Florentine* Experiment related above, *Pag.* 11. that is, it cannot be reduced into a ſmaller Bulk or Space than it ordinarily has with us in very cold Weather, yet may it be very much rarify'd or dilated by Heat; as may appear on putting ſeveral ſmall Bubbles of Glaſs, Metal, *&c.* that are of a Weight juſt fit to ſwim, into cold Water. Theſe when the Water is ſet near a Fire, or over a Lamp, will ſink one by one, according to their ſeveral Weights, as the Fluid warms and grows more rare.

BY accurate Experiments 'tis prov'd, that Water may be rarify'd near fourteen thouſand Times by being reduced into Steam, the Particles whereof muſt be endowed with a very powerful repellent Force; ſince they are able, when confin'd, to drive before them Air, and lift even a great Weight of Water to very conſiderable Heights.

IN order to ſupply a large Quantity of Steam for this Purpoſe ſucceſſively, the Machine ſpoken of has a large globular Veſſel of Water, which, when the Engine is at work, is kept boiling over a briſk Fire, in which the Steam is cloſe confin'd, and in *Plate* 4. mark'd *A.*

WHEN the Steam herein is ſufficiently denſe, or ſtrong enough for the Purpoſe, Part of it is let go, by turning a Cock into the hollow Cylinder *B*; by means whereof, the Air therein contained is expell'd thro' a proper Clack, and the whole Cavity of conſequence fill'd with Steam only; which being a Body that may be condens'd again to Water, by a Jet of cold Water diſperſed among it, that which in the Circumſtance of Steam took up the Space of fourteen

thouſand

thouſand Pints, will this Way be reduced into that of one. By which Artifice, a *Vacuum* in the hollow Cylinder is nearly to be obtained. The Piſton then, *C*, preſſed by the Atmoſphere above, will be weighed down, and deſcend with a Force equal to the Inches of the Diameter ſquar'd, and multiplied by twelve Pounds, the ordinary Weight of Air incumbent on every circular Inch near the Earth. And a Pull thus made at the End of a Leaver, equally divided at *D*, will always raiſe an equal Weight at the other: So that all the while the Steam is entring *B*, the Piſton *E* ſinks and forces, and when that Steam comes to be condenſed, it ſucks and riſes; and thus alternately (ſix or eight Times perhaps in a Minute) according to the Size of the Boiler, and the Intenſeneſs of the Fire that is to ſupply the Steam.

ACCORDING to the Length of the Stroke, and the Diameter of the metal Forcer *E*, a Body of Water of like Dimenſions will be raiſed at every Pull, from the Spring at *Z* into the Sucking-pipe *N*, and being brought up thro' the fix'd Valve at *O*, whenever the Piſton ſinks by the Weight of the counterpoiſing Lifts of Lead at *H* (occaſionally to be laid on, according as the Atmoſphere happens to be more or leſs heavy) will be puſhed thro' the fix'd Valve in the Branching-pipe *Q*: At which time the whole Column of Water in *F* being lifted thereby, an equal Quantity will be diſcharged and run off at *Y*. To this Machine, an Air-veſſel, as *G*, may alſo be added, if it be thought pro-

 per,

per, to leſſen the Velocity of the Water in *F*; but in Draining of Mines, this can hardly be neceſſary.

THE Forcer of this Engine *E*, is beſt made cylindrical, and as long as the Stroke intended from *I* to *N*. In which Caſe the Collar *I*, in which it works, is leather'd both upwards and downwards, which is found to be more convenient, and yet to have the ſame Effect, as if the Piſton was ſo leather'd, and made to move within a hollow Cylinder; as in the common Forcing-pump they do.

THIS Machine, according to late Improvements, begins of itſelf to work, as ſoon as the Water boils; and by little Contrivances the Motion of the grand Machine is made ſubſervient to the Operation, either in turning the Steam out of the Boiler into the hollow Cylinder from time to time, or ſhutting it off; and alſo by letting in the Jet of cold Water, ſupplied when wanted, from the Ciſtern *K*; and by a third Device the whole may eaſily be ſtopp'd.

IF at any Time the Fire and the Steam grow too intenſe, to prevent Miſchief from blowing up the Copper, and the like, there is a ſnifting Valve of a certain Weight, a little conical, put into that Machine at *L*; which when the Steam becomes too elaſtic or over-ſtrong, will be thrown out, or at leaſt raiſed, to give it vent.

THE

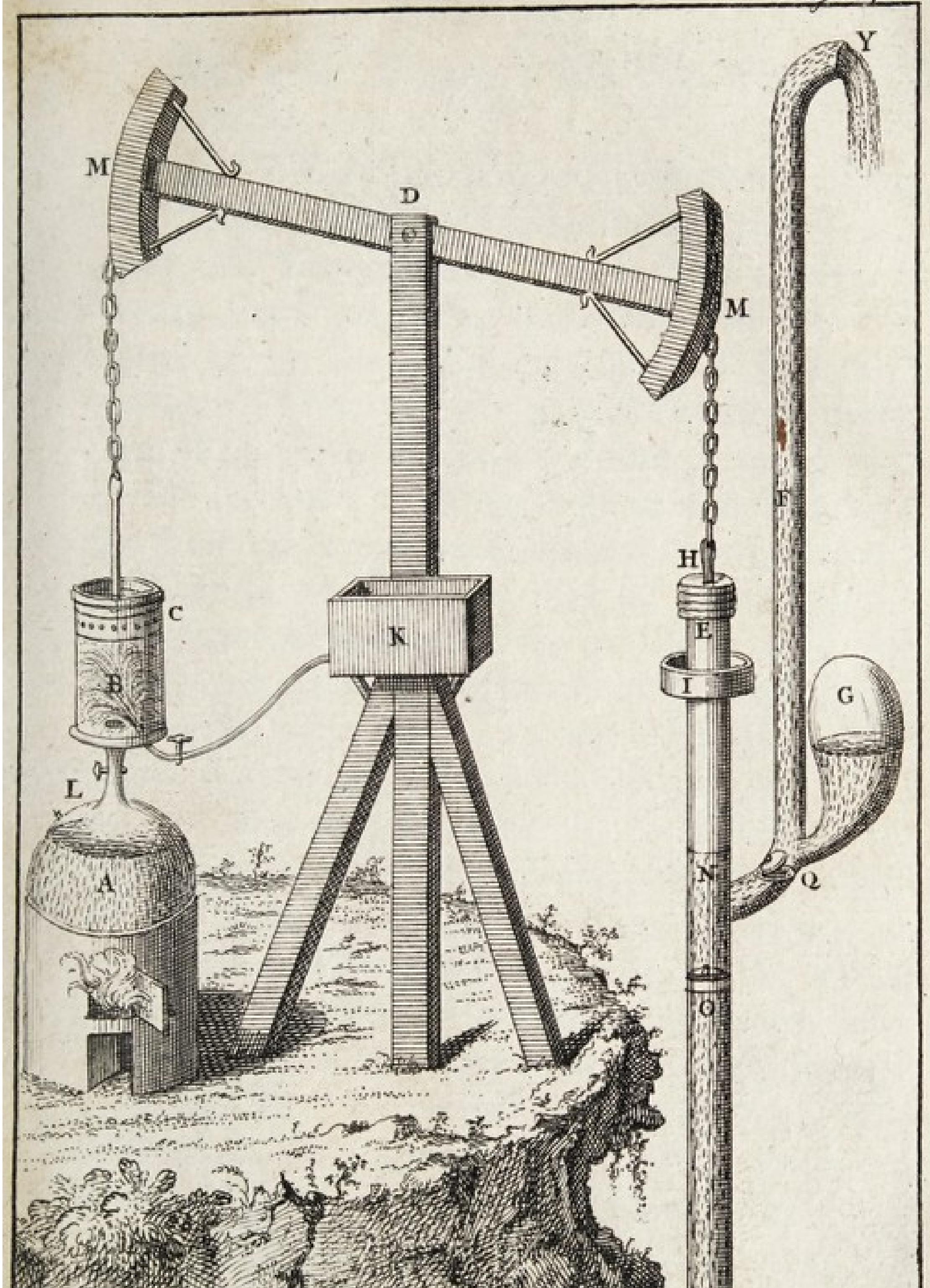
THE Segments of Circles *MM*, fixed at either End of the great Leaver, are to give the Chain to which the Piston and Forcer hang, a perpendicular Direction in all Parts of the Stroke.

THERE is indeed a Vein of Mechanism and good Contrivance runs thro' this whole Machine; and it is very well worth considering as a Hydraulick-Engine; however, in point of Profit, it may not answer the Expectations of such as use it, where Fewel is not very cheap: For the saving whereof, a Fire-box having the boiling Water nearly round it, in the Nature of the copper Machines for boiling Tea-water, has been used with good Success.

THE original Engine for raising Water by Fire, as described in HARRIS's *Lexicon Technicum*, did not work a Forcing-Pump like this; but the Vessel put here in Place of the hollow Cylinder, was first cleared of Air by a Quantity of Steam turned in thro' a Valve, which being next condensed by a Dash of cold Water thrown thereon, was then filled by Water from the Spring, which by the repellent Force of the Steam, a second Time admitted from the Boiler, was gradually lifted through Pipes annexed, to the Height intended. And this in Mines, where Room for working the great Leaver is wanting, is still in Use.

HAVING here mentioned the Strength of the Steam of boiling Water, in working the foregoing Machine, it may not be amiſs juſt to mention the Uſe it might be of in ſeveral other Caſes; thoſe eſpecially in which the Uſe of Fire itſelf is dangerous: Such as is the boiling of all inflammable Bodies; the Diſtillation of ſpirituous Liquors; boiling of Turpentine, Tallow, Oils and Varniſhes; the Drying of Gunpowder, and the like: All which Things may with Safety be done, by having the Boiler and Furnace at a Diſtance, or in another Room; whence by Pipes the Steam might be conveyed, and by the turning of a Cock, admitted into the Cavities of double Pans, Stills, or other Veſſels fit for the Purpoſe intended: It may be likewiſe ſhut off, increaſed or abated at Pleaſure by ſuch a Contrivance, according to the Exigencies of the Caſe. And tho' Water itſelf, having once got a boiling Heat, is capable of receiving but a ſmall Degree of Heat more than what made it boil at firſt; yet will the Steam ariſing from it be more or leſs heated in Proportion to the Denſity of it: So that it has ſometimes melted ſoft Solder, which is a Mixture of Lead and Tin; but has never yet been able to fire Gunpowder.

MALT and other Things of the like kind, might alſo be dry'd this Way, and the ſmoaky Taſte often attending theſe Manufactures would thus doubtleſs be prevented, as well as the fiery Taſte very uſual in diſtilled Liquors.



J. Cole Sculp.

On the CHAIN-PUMP.

THERE is ſtill another Machine for raiſing Water, called the Chain-Pump, *AB*, *Fig.* 1. *Plate* 6. 'Tis ordinarily made from twelve to twenty four Foot long, and conſiſts of two collateral ſquare Barrels, and a Chain of Piſtons of the ſame Form, fixed at proper Diſtances thereon. The Chain is moved round a coarſe kind of Wheel-work at either End of the Machine, the Teeth whereof are ſo made as to receive one half of the flat Piſtons, and let them fold in; and they take hold of the Links as they riſe. The Machine is wrought either by the turning of one Handle or two, according to the Labour required, depending on the Height to which the Water is to be raiſed. A whole Row of the Piſtons (which go free of the Sides of the Barrel, by perhaps a Quarter of an Inch) are always lifting when the Pump is at Work; yet do they by the general Puſh in the ordinary Way of working, as 'tis pretty briſk, commonly bring up a full Bore of Water in the Pump. This Machine is ſo contrived, that by the continual folding in of the Piſtons, Stones, Dirt, and whatever happens to come in the Way, may alſo be cleared; and therefore it is generally made Uſe of to drain Ponds, to empty Sewers, and remove foul Waters, in which no other Pump could work.

On the ENGINE *for raising* WATER *by a* MULTIPLYING-WHEEL.

IT would be endlefs to confider and defcribe the Mechanifm and all the Contrivances of Engines for drawing of Water. The general Principles whereof being well underftood, the Ufe and Application of all Machinery for that Purpofe, will eafily be difcerned. The Defcription however, and Sketch of an Hydraulick Machine, that has no fort of Dependance on the Action of the Atmofphere; but which, by the Weight of Water only, and without Pump-work of any kind, raifes Water fufficient to ferve a Gentleman's Seat in *Buckinghamfhire*, with an Overplus for Fountains, Fifh-ponds, *&c.* (executed by the late Mr. GERVES) it is to be hoped the Curious will eafily excufe.

A and *B* in *Plate* 5, are two copper Pans or Buckets of unequal Weight and Size, fufpended to Chains, which alternately wind off and on the Multiplying-wheel *YZ*; whereof the Wheel *Y* is fmaller in Diameter, and *Z* larger, in Proportion to the different Lifts each is defigned to perform.

WHEN the Buckets are empty, they are ftopp'd level with the Spring at *X*, whence they are both fill'd with Water in the fame Time.

THE

THE greater of the two, *A*, being the heavier, when full, preponderates and deſcends ten Foot perhaps from *C* to *D*; and the leſſer, *B*, depending on the ſame Axis, is thereby weighed up or raiſed from *E* to *F*; ſuppoſe thirty Foot.

HERE, by particular little Contrivances, opening the Valves placed at Bottom of each of theſe Buckets, they both diſcharge their Water in the ſame Time thro' Apertures proportionable to their Capacities; the ſmaller into the Ciſtern *W*, whence 'tis conveyed for Service by the Pipe *T*, and the larger at *D*, to run waſte by the Drain below at *H*. The Bucket *B* being empty, is ſo adjuſted as then to overweigh, and deſcending ſteadily, as it roſe betwixt the guiding Rods *VV*, brings or weighs up *A* to its former Level at *X*, where both being again repleniſhed from the Spring, they thence proceed as before. And thus will they continue conſtantly moving (merely by their circumſtantial Difference of Water-weight, and without any other Aſſiſtance than that of ſometimes giving the Iron-work a little Oil) ſo long as the Materials ſhall laſt, or the Spring ſupply Water.

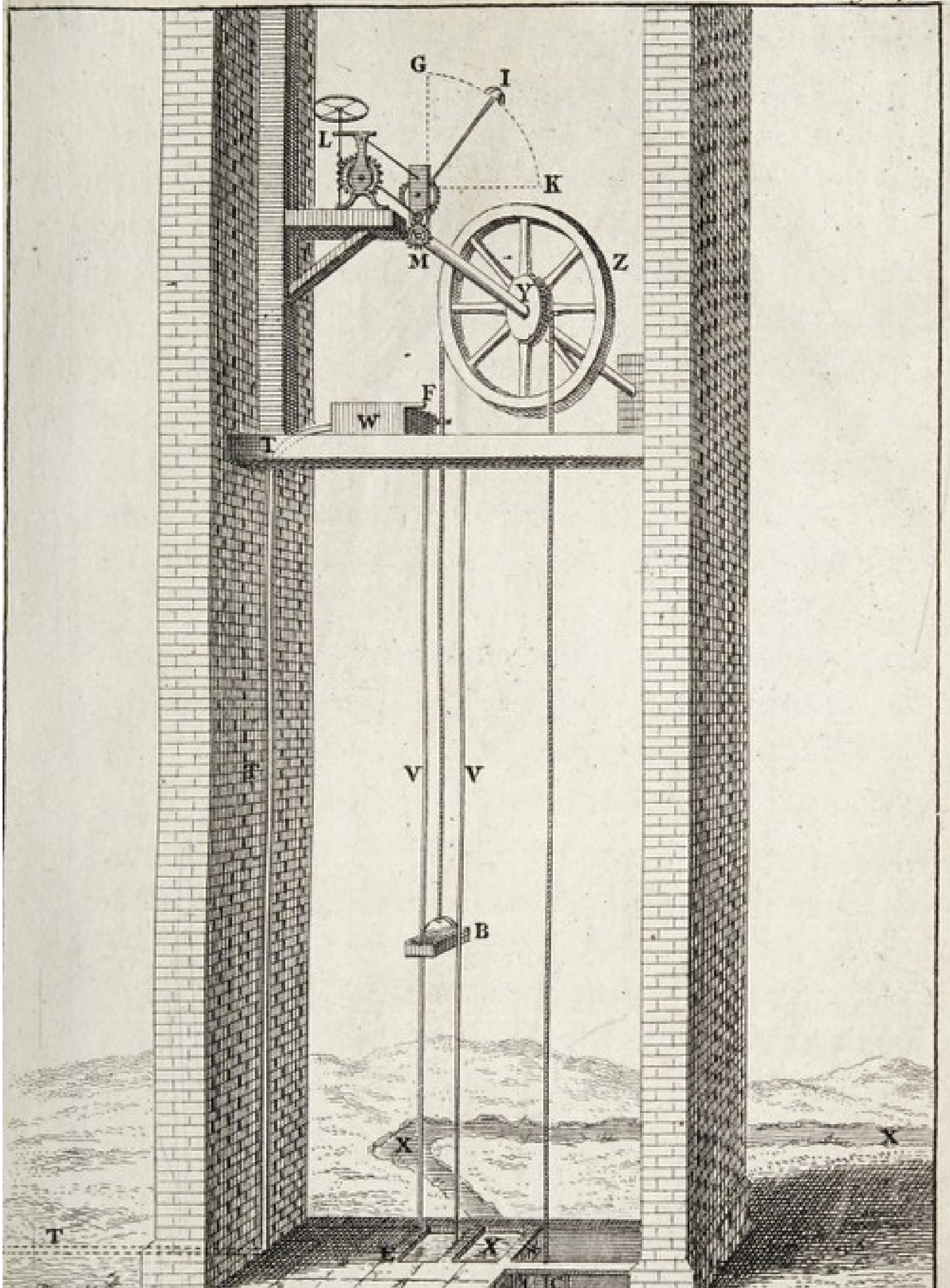
THE Steadineſs of the Motion is in Part regulated by a Worm turning a Jack-fly, and a little ſimple Wheel-work at *LM*, which communicating with the Multiplying-wheel Axle at *M*, is thereby moved forward or backward, as the Buckets either riſe or deſcend. But what principally

principally keeps the whole Movement ſteady, is the Equilibrium preſerved in the whole Operation by a certain Weight of Lead, at the End of a Leaver of fit Length, and fixed on one of the Spindles of the Wheel-work, the Numbers whereof are ſo calculated as during the whole Performance up and down, to let it move no more than one fourth of a Circle, from *G* to *K*; by which Contrivance, as more or leſs of the Chains ſuſpending the Buckets come to be wound off their reſpective Wheels *Y* and *Z*, this Weight gradually falls in as a Counter-balance, and ſo continues the Motion equable and eaſy in all its Parts.

THE Water waſted by this Machine, is not above the hundredth Part of what a Water-wheel will expend, to raiſe an equal Quantity. But where a Fall, proportionable to the intended Riſe of Water, cannot be had, with a convenient Sewer to carry off the Waſte-water over and above, this Device cannot be well put in Practice.

N. B. *The Iron Wheel-work or the Jack in this Draught, is repreſented ſomething larger than its proper Proportion, for the ſake of being diſtinct.*

PLATE V.



J. Cole sculp.

FLUIDS *are ſuſtained in the* AIR, *without a* COUNTER-PRESSURE *from above.*

THE Service of the Atmoſphere in the raiſing of Water being aſcertain'd, it may not be amiſs in the next Place to ſhew, that a Quantity of a Fluid ſo heavy as Water, will not ſink therein, unleſs the Air have Liberty to preſs on the upper Surface thereof, as well as the nether; which may be prov'd by filling, ſuppoſe a Pint Mug, or a large Drinking-glaſs, to the Brim with Water, then covering it with a ſmooth flat Piece of Paper, and inverting it, the whole Body of the Fluid will remain therein ſupported; as in *Fig.* 2. *Plate* 6.

IT will be granted, that if the Paper was put dry on ſuch a Veſſel empty, it would ſink in the Air, and fall away even by its own Gravity; and if put on wet, 'twere to be doubted whether a very ſmall Weight added thereto, would not ſeparate it from the Glaſs, ſo inconſiderable would the Tenacity of the Water be in this Caſe. The Paper therefore cannot be ſuppoſed to ſupport the incumbent Weight of Water; and the true Cauſe thereof muſt be this. The Bottom and Sides of the inverted glaſs Veſſel being rigid, keep off the Preſſure of the Air from the Fluid above, whereas it hath Liberty of Acceſs, and freely acts thereon below: And that it does ſo, will in Part appear to an Obſerver by the Concavity

vity of the Paper underneath. Could the Air's Preſſure in this Caſe be any how admitted thro' the Foot of the Veſſel inverted, without doubt the whole Column would deſcend together. And the like would happen ſhould the Paper be removed; but for a different Reaſon, *viz.* the large Column of Water in the Mug, being compoſed of many collateral ones, which being diſpoſed as in a Bundle, reſt on the Paper wherewith the Veſſel is covered, as on a common Baſe; and theſe being all equally denſe, and equally fluid, are all retained, and kept of the ſame Length by the general and uniform Preſſure of the Air againſt the Paper below; and ſo long as this continues, none of them getting the leaſt Advantage over the reſt, they are all ſuſtained in a Body compact together. But when the Paper is removed, it being ſcarce poſſible to hold the Veſſel ſo exactly level, but that ſome one or other of theſe ſmaller fluid Columns will become longer, ſo heavier than thoſe adjacent, and overbalancing the reſt will deſcend, and give the lighter Fluid, the Air, leave to riſe into its Place, even to the Top of the Glaſs; the general Preſſure whereof being there admitted, will ſoon cauſe the reſt of them to move, and the whole Quantity will then deſcend, ſeemingly together.

AGAIN, ſhould a Veſſel be but Part filled with Water, the ſame Effect will follow to a certain Degree: For Inſtance, ſuppoſe we fill a long Glaſs one half with Water; cover it with Paper, and turn it down as before. Six Inches ſuppoſe of Water, endeavouring to deſcend, will by its

Weight

Weight rarify the Air in the Glaſs above it, perhaps a ſixtieth Part or more. The denſer Air without will then overpoiſe the Air rarify'd within; and therefore a certain Quantity of Water, equal to the Difference of the two Preſſures, will in this Caſe be thereby buoyed up and ſupported. But the Air within the Glaſs being dilated as aforeſaid, the Water ſuſpended muſt be expected to hang ſomething below the Mouth of it, though not enough perhaps to overcome the Tenacity of the Water, and make it all deſcend.

On the FOUNTAIN *at* COMMAND.

UPON this Principle acts the *Fountain at Command, Fig.* 3. *Plate* 6. The upper Part whereof, *A*, is hollow, having a Pipe ſoder'd therein, as *C*, continued nearly to the Top, on which, being thruſt into a Wire-Socket, it reſts; and by which it may be charged with Water, when turned down, to any Height. In the under Part of *A*, at *a a*, are ſeveral ſmall Tubes, thro' which this Water will, on the Admiſſion of freſh Air thro' *C*, on Occaſions iſſue. The Bottom Part *B*, is hollow to receive the Water which theſe ſhall diſcharge thro' an Opening of a certain Bigneſs, placed immediately under the Orifice of the middle Pipe *C*, the Area of which Aperture is ſomething leſs in Content than that of all the ſmall Holes at *a a* taken together. When therefore theſe all run, they will yield more Water than can by the other be received

in

in any given Time. This will cauſe the Water to riſe in the Baſon, ſo as frequently to cover the End of *C*, and interrupt the ſucceſſive Entrance of the Air, and conſequently take off its Preſſure from the Surface of the Water incloſed in *A:* Whereupon the Deſcent of the Fluid thro' *a a* will be diſcontinued, till ſuch Time as the Water collected at Foot is run off, and the Paſſage for the Admiſſion of freſh Air cleared: 'Twill then be repeated, ſtopping and running by Turns, as at the Word of Command, which may be eaſily given, by obſerving the Motion of the Fluid about the Foot of *C.*

On the DOUBLE FUNNEL.

IT is for the ſame Reaſon that the Juggler's Funnel *AB*, *Fig.* 4. *Plate* 6. is uſed to run or ſtop by Permiſſion.

THIS Machine is made of Tin doubled, and as it is to be firſt filled to the Brim with Water, ſtopping the End of the Pipe with the Finger, the Fluid will riſe into the Vacancy or Hollow between the Plates, as in the greater Cavity of the Funnel equally. The Air in ſuch Vacancy incloſed, being puſhed by the riſing Water thro' the Hole, ordinarily concealed under the Handle, which muſt be ſtopp'd when the Machine is full, and continued ſo till the Artiſt thinks fit to diſſolve the Charm, and ſet the Waters confin'd at Liberty, which he can do by a ſingle Touch of his Finger.

On

On the AIR-PIPE, *commonly called the* ANTIGUGLER.

THIS Subject may not be dismissed, without considering the Use of the Antigugler, in the quiet decanting of Liquors liable to a Sediment. Having seen the Necessity of the Air's upper Pressure, to promote the easy and uniform Flux of Fluids from close Vessels, commonly called *Giving them Vent*; 'tis no Wonder that in decanting of Liquors, where this is wanting, there should happen a kind of Struggle between the grosser Fluids, endeavouring by their greater Gravity to issue forth, and the Air, by its Repressure endeavouring to prevent it; whence such convulsive Motions in the Body of Liquors are produced, as often raise their Bottom, and make them foul. To prevent this Inconvenience (which, was it proper to make a Hole in the Bottle, might soon be removed) the Antigugler was invented. This Machine is no more than a crooked Tube of Metal, so bent as easily to be introduced in the Neck of most Bottles. Its general Form is represented *Plate 6. Fig. 5.*

IN order to use this Instrument with Success, the Bottle containing the Liquor to be decanted is to be inclined a little to one Side. Let then a small Quantity of the Liquor, half a Spoonful perhaps, gently run off, to answer which, an adequate Quantity of Air will enter

ter thro' the Neck with a kind of Glub, and take Place in the upper Part of the Bole. With your Fore-finger then, in the Ring *C*, and your Thumb held close on the End of the Pipe *A*, introduce the Machine into the Neck of the Bottle, thrusting it quite thro' the Body of the Liquor, till the End *B* reaches, or is pretty near to the Bubble of Air before admitted. In doing whereof, the Liquor cannot enter, to obstruct the Passage of the Tube, being kept out by the Air inclosed, and by the Thumb confined therein. This done, on taking off your Thumb, an immediate Vent will be given to your Bottle, and the Liquor will continue to flow out steadily and unconvulsed, with much less trouble than by the Syphon, and to equal Advantage: For a Current of Air, equal both in Weight, Force, and Quantity, to the Liquor decanted from the Bottle, will then successively enter the Pipe, to maintain a just and peaceful Equilibrium between them.

On the FLUX *of* FLUIDS *in a* STREAM, *both confined and not.*

WHEN Water is at Liberty to flow from the Surface of a Pool, or any other Head, thro' a Hole an Inch Square, kept just full, Monsieur MARRIOTE, who has been very exact in this kind of Experiment, informs us, that thirty cubick *Paris* Feet and a half, will be thereby discharged in an Hour's Time. That thro' a Hole two Inches below the Surface, and one Inch broad, eighty one cubick Feet

Feet will paſs unforced. By one of like Breadth, four Inches deep, two hundred and twenty two cubick Feet and above half will run off. By another of eight Inches deep, that five hundred and eighty three cubick Feet and near a half will be diſcharged, *&c.* Quantities by no means, in any regular Proportion. And from the ſame Author we learn, that a Channel eighteen Inches deep, and one broad, will yield near one thouſand nine hundred and ſixty ſix cubick Feet, almoſt three Times as much as does one but nine Inches deep, and ſixty four Times the Quantity given by a Hole one Inch ſquare in the ſame Time, next the Surface.

WHENCE it appears, that the Weight and Preſſure of the incumbent Fluid above, augments the Efflux of Water below, and continues progreſſively to do ſo the deeper we go. And ſince this is the Caſe, where every Part of the confluent Pillar hath Liberty and free Scope to follow the Laws of Gravitation, it may well be expected, that when a Head of Water is kept up and confined, all the collateral Columns whereof are known to preſs equally according to their common Height, ſhould it then be opened in divers Places below the Surface, the Expence of Water at each would be very different, thro' Apertures or Holes of the ſame Diameter. And this Expence is always found to be in a ſubduplicate Proportion to their Diſtances from the Surface: That is to ſay, the Hole that is four Foot below the Surface, ſhall yield twice the Water in the ſame Time as will the ſame Opening at one

 Foot.

Foot. One at nine Foot, ſhall give three Times the Water of the firſt; and at ſixteen Feet deep, the ſame ſhall ſupply four; and at twenty five Feet, five Times the Water in any given Time that may be had from a Hole made but one Foot beneath the Surface of the Head; and the contrary, inverting the Propoſition. For Inſtance: I find in one Part of the Service, that *B* receives three Times the Water that *A* does in another, thro' Pipes of equal Bore in equal Times; it follows then, that he lies nine Times lower with reſpect to the Reſervoir, than *A*; and ſo of any other Proportion.

Now the Quantity of Water each may expect to receive, may be eſtimated ſufficiently near, from the ſaid Monſieur MARRIOTE'S Experiments; who found, that the Expence of Water, iſſuing horizontally thro' a Quarter of an Inch Bore, thirteen Foot beneath the Head (*Paris* Meaſure) yielded juſt fourteen *Paris* Pints in a Minute. On this Principle the following Table is calculated, which may ſerve to give an Idea of the Expence of Water made thro' vertical Apertures in any Service, not more than fifty two Foot beneath the Reſervoir, where extraordinary Friction and Hindrances are removed: Remembring only, that the Proportion of the *Paris* is to the *Engliſh* Foot, as 16 to 15 nearly; and that the *French* Pint is a very ſmall Matter bigger than our Quart, for which proper Allowances are to be made in all Calculations of this Kind.

The TABLE.

PARIS FEET.	PARIS PINTS.
1	3,8829
5	8,6824
10	12,2770
13	14,0000
15	15,0383
20	17,3648
25	19,4144
30	21,2675
35	22,9715
40	24,5540
45	26,0472
50	27,4560
52	28,0000

AND from the ſame Principle, the juſt Expence of Water, for a greater or leſs Depth, at any Time, might be found according to Theory, by ſaying,

As 13 Paris *Feet; the Height of the Reſervoir on which the Experiment was made,*

Is to 14 Paris *Pints; the Quantity in a Minute yielded thro' a Quarter of an Inch Bore:*

So is the geometric Mean between the ſaid 13 *Foot and the Depth propoſed; or the Square Root of their Product,* *To the Expence of Water in like Time issuing thro' an equal Bore, at the Depth required.*

IT may by the Way be here remarked, that on the Trial, the Quantity of effluent Water very often falls short of what might thus be expected from Theory; the Reason of which will be consider'd hereafter.

THE Proportion of Water that may be supply'd, in like Circumstances, at any Depth below the Head, being however thus far determined, the Quantity to be received there for Service, will next be found to depend on the Bigness of the Bore, or the Section of the Pipe leading from the Main.

On the SIZE *of* PIPES *of* CONDUCT.

T*HE Capacities of Circles are always in Proportion to the Squares of their Diameters:* So that if a certain Quantity of Water be supplied by a Bore a Quarter of an Inch in Diameter, in any Place, thro' one of half an Inch, four Times, and by one of an Inch, sixteen Times, the Water will in the same Time be admitted.

AND to find in general what the Size of cylindric Pipes to supply Water on the same Level, in any given Proportion, ought to be, this Analogy may be used.

As

As the known Quantity of Water ſupply'd by a Pipe of any certain Bore, in a given Time,

Is to the Square of the Diameter thereof:

So is the Quantity of Water in an equal Time required,

To the Square of the Diameter of the Bore of the Pipe ſought; in a direct Proportion.

AGAIN: Suppoſe I have a Water-pipe two Inches in the Bore, which on Experiment ſupplies my Ciſtern in an Hour and a half; but wanting this to be done in half the Time, I would know what the Bore of the Pipe for this Purpoſe ought to be. I then ſay,

As 90 *Minutes, the Time in which 'tis now done,*

Is to 4, *the Square of* 2:

So is 45 *Minutes, or half the Time,*

To the Square Root of 8, *or* 2,828 *Inches, the Diameter of the Pipe required*; in a reciprocal Proportion.

And by the ſame Rule, a Pipe 3,464 Inches in Diameter, will be found to do the ſame Service in a third of the Time, or thirty Minutes.

BOTH the Rules foregoing may be ſufficiently confirm'd by Experiment. The firſt by making Holes of the ſame Diameter in any perpendicular Pipe, kept always full of Water, at Diſtances in the Proportion propos'd, *Pag.* 81. The firſt ſuppoſe at three Inches beneath the Surface, the ſecond at twelve, the third at twenty

 ſeven,

ſeven, the fourth at forty eight Inches, *&c.* and 'twill be found, that double the Water will be yielded by the ſecond as will iſſue by the firſt in equal Times; thrice the Water by the third; and by the fourth, double the Water of the ſecond, *&c.*

AND to prove the ſecond Rule given, *viz.* that by an Opening of twice the Diameter, four Times the Diſcharge will be made at the ſame Level; in any Part of the Tree make ſuch Openings, or for greater Exactneſs, have Slip-pipes, bor'd well in that or any other Proportion, to thruſt into the Holes. Let theſe be ſtopp'd and unſtopp'd at the ſame Inſtant; and the Meaſure of the Water iſſuing will clearly demonſtrate them to be in Proportion as are the Squares of their Diameters, if nothing obſtruct.

On FRICTION *in* WATER-WORKS.

THE Obſtructions in Water-Works commonly proceed from the Friction of the Fluid with the Pipes of Conveyance, and other Parts of the Apparatus, either from an undue Confinement in ſome Part or other, or from Flexure, that is, by a Change of the Line of its natural Direction to another, by a too acute or an improper Angle.

SINCE the Circumferences of Circles are in a direct Proportion to their Diameters, the larger the Pipe of Conduct is, the leſs will the Fric-

tion

tion always be. For Inſtance; the Circumference of a Circle whoſe Diameter is 2, is no more than twice as great as that whoſe Diameter is but 1; and its Surface being only double, there can be no more than twice the Friction of Parts from this, as from that; provided the Fluid move in both with equal Degrees of Velocity: Whereas the Area's or Sections of circular Pipes, are in a duplicate Proportion, or directly as the Squares of their Diameters. The Pipe then, which has 2 for its Diameter, has 4 for its Area; and conſequently, with only double the Friction of the Pipe whoſe Diameter is 1, diſcharges four Times the Water in equal Times.

THAT there is a Diſadvantage attending the Change of the Direction of a Fluid, appears from Experiment; ſince it has been found on Trial, that if fifteen Pints run from a Hole made in the Bottom of a Veſſel kept conſtantly full of Water, in a given Time, there will iſſue but fourteen thro' an Opening of the ſame Size, and in the ſame Level, ſpouting perpendicularly upwards, tho' each Hole had the ſame Height of Water conſtantly above it, and when the Work was done with the greateſt Judgment, and the leaſt Friction that could be. This Check proceeded no doubt from changing the Direction from the perpendicular Line of Gravitation, to another contrary to it, thereby occaſioning probably ſeveral Reflections of the Fluid from Side to Side of the Bend, which muſt needs prove a conſiderable Hindrance to the iſſuing Stream:

Whereas had a Length of Pipe been affixed and added to the Bottom Hole, the Efflux of the Water thereby would be ſtill greatly augmented; becauſe the longer a heavy Body continues to fall, the greater is its Acceleration downward.

Mr. MARRIOTTE found, upon repeated Trials, that a cubick Foot of Water would run off thro' a Pipe of an Inch Bore ſix Foot long, in thirty ſeven Seconds; thro' a Pipe of equal Bore, and but three Foot long, it was diſcharged in forty five Seconds; and by the Hole only, without any Pipe at all, in ninety five Seconds: Whence it appears, that a Length of Pipe added, does greatly promote the Acceleration of a falling Fluid.

SINCE the Efflux of Water thro' any Hole muſt be with the Celerity a Body wou'd acquire in falling from the Weight of the ſuper-incumbent Water, it is not difficult to determine *à priori* what the Velocity and Quantity of effluent Liquors ought to be: Yet in reality, as was hinted, there generally comes out leſs than the Theory requires; the Odds being ſometimes greater and ſometimes ſmaller, depending doubtleſs on the Form of the Hole or of the Cock thro' which the Water ſpouts; that is, as theſe happen to be more or leſs properly adapted to the Figure or Shape of the effluent Vein of Water, naturally contracting itſelf into a much narrower Area than that of the emitting Perforation. But if that Paſſage or the Cock were ſo well fitted to the converging Motions of the ſtreaming Fluid, as adequately

to

to embrace the contracting Vein in all its Parts, then the Quantity of Water and its Velocity passing thro' the narrowest Part of the Aperture, will answer pretty near to the Theory, as Sir ISAAC NEWTON has observed.

AN Experiment was accurately made by Dr. DESAGULIERS, of the running of Water horizontally thro' a Hole five eighths of an Inch in Diameter, the Centre whereof was just four Foot below the Surface of the Water of a Vessel kept always full. This Vein of Water so contracted itself, that at half an Inch Distance from the Hole, that is, where it seem'd thinnest, it all ran thro' a Hole of half an Inch Diameter made in a tin Plate. By afterwards weighing the whole Body of Water produced, and reducing it to a Cylinder of half an Inch Diameter, or something under, it appear'd, that the Velocity of the Water issuing, was the same as a Drop of Water wou'd have acquir'd in falling the Height of four Foot *in Vacuo*. In this Case therefore we are not to call the Hole, or Aperture, five, but four eighths of an Inch in Diameter; and that we may always consider as a Hole without Friction, with which the Theory will sufficiently correspond.

IT must at the same Time however be confessed, that considering the great Difficulty there is in making Experiments of this kind with tolerable Accuracy, the Want of Excellency in a proper Apparatus for the Purpose, and the Nicety and Skill required in measuring the Breadth of the running

ning Vein, to which may be alſo added, the Length and Diſpoſition of the Sides of the emitting Pipe, and all other Impediments to be conſider'd, that it will not be improper to have an Eye at the ſame Time upon Experiment and Meaſure in Caſes of this Kind, and not wholly to depend on any Tables or Calculations whatever; according to the Advice of the Marquis DE POLINI, that ingenious and truly accurate Author, in his Treatiſe *de Caſtellis*, Sect. 64.

On the ACCELERATION *of* FALLING BODIES, *by* GRAVITY.

THE Acceleration of Bodies falling *in Vacuo*, may be rightly repreſented by the odd Numbers, as they progreſſively riſe. If in the firſt Second of Time, a heavy Body, free'd from any Reſiſtance of the Medium thro' which it ought to paſs, will deſcend with the Velocity of ſixteen Foot, and one tenth; for ſake of Brevity, ſay, about one Rod; during the Space of the ſecond Second, 'twill fall with the Velocity of three: So that at the End of the ſecond Space of Time, it will be got downwards in all four Rods. By help of this Acceleration, continually promoted by the Power of Gravity, or Attraction toward the Earth, during the third Second, 'twill fall with the Velocity of five Rods; during the fourth with ſeven; the fifth with nine; and ſo on progreſſively till it reach the Center of Gravity, which with us is the Center of the Earth.

THE

THE Action of Gravity on falling Bodies, is easier to be conceived by Reflection than illustrated by Words; because we want Images wherewith the progressive Action of it can be well compared. Let us, however, suppose a Body like a Tennis-ball, without Weight, and therefore not subject to the Law of Gravitation: Such a Body put in Motion, and meeting with no Impediment, will move, as all Matter inclines to do, in a straight Line, according to the Direction given it. Let us then suppose a Number of Men standing a Rod asunder, in a Row, with Rackets in their Hands. Let the first strike this Ball, giving it one Degree of Motion; 'twill therewith proceed on to the second. Let him also give it a Stroke; 'twill then go on with two Degrees of Motion to the third; who striking it also, will send it forward with three Degrees of Motion to the fourth; who communicates another Degree of Motion to it, and so forward. Or, which is the same thing in Effect, let one Man give it a Blow, then follow and strike it successively at the End of every Rod. 'Tis certain, the more Impulses are thus given by the Strokes of the Rackets, the greater will the Acceleration be; and a Body having no Weight will, in this Circumstance, thus proceed.

Now it cannot be supposed that Gravity acts, as the Case is here put, by Fits and Starts; but incessantly, and at every Instant, from the very Beginning to the End of the Fall. Let us then suppose Gravity, or Weight, given to our Ball,

and

and that it is either Iron or Lead, and dropp'd from ſome Eminence. If at the End of the firſt Second of Time, when it has acquir'd the Velocity of one Rod, it ſhould loſe its Gravity, and ceaſe to be heavy; it would thence-forward, meeting with no Impediment, proceed with the Velocity of one Rod in a Second continually. But as that cannot happen, and as the Impulſe of Gravity is conſtantly acting thereon, it not only will, in the ſecond Second, gather Power to go one Rod forward, as at firſt; but alſo acquire an additional Force, precipitating it ſtill onwards a Rod: As if the Racket ſhould not only ſtrike it, at the Beginning of the ſecond Space of Time, but ſhould make thereon a kind of a ſhoving Stroke; ſo as to ſend it on thenceforward with the Force of three. At Beginning of the third Second, let us imagine it to receive a new Impulſe and Gravity, in the Interval, ſtill acting, brings it to the fourth Second with the Velocity of five. In this Manner, an additional Impulſe being obtained by the Weight ſtill drawing, 'twill during every ſucceeding Second be accelerated by the Force of two progreſſively; which makes the Velocity by falling Bodies acquired, always to increaſe in the Ratio of the odd Numbers, *viz.* 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, *&c.*

HOWEVER difficult it may be to deſcribe the Action of Gravity on falling Bodies, in Words; 'tis certain, that in Practice, and on Experiment, the aboveſaid Rule is found to be true: The Space paſſed thro' by falling Bodies, where no no Obſtruction is, being always in Proportion to the Squares of the Times paſſed over during their Deſcent. For Example; one Rod paſſed by a heavy Body, in the firſt Second of Time, with three Rods paſſed in the ſecond Second, make four Rods, equal to the Square of the Time, or two Seconds. Again, this four added to the five Rods, paſſed thro' in the third Second, make nine, equal to the Square of three. And nine added to ſeven Rods, paſſed in the fourth Second of Time, make ſixteen, equal to the Square of four. To this add nine Rods, gone thro' in the fifth Second, and 'twill make twenty five, equal to the Square of five; and ſo forward.

To meaſure therefore any Depth, 'twill be a very good Way to count the Seconds a heavy Body, or one not ſenſibly affected by the Reſiſtance of the Air, is falling; and the Square of thoſe Seconds, multiplied by the known Space that a heavy Body falls thro' in one, will give the Anſwer in Feet, ſufficiently near. For

As 1, the Square of one Second,
Is to 16 Foot, the Deſcent in that Second:
So is the Square of any other Number of Seconds,
To the Space by a Body fallen thro' in the Time required.

FOR Inſtance; I find by all Circumſtances, that a Stone falls plumb into Water, 7 Seconds after 'twas delivered from the Hand: 'Twill then be 49 Times 16, or 784 Foot down to the Water.

Water. We ought indeed to allow about eleven hundred and fifty Foot, or three hundred and eighty three Yards, in a Second, for the Return of Sound to the Ear, if it cannot be ſeen to plunge: But if that be done, ſuch Allowance is not neceſſary; ſince the Progreſſion of the Rays of Light is incomparably ſwifter than that of Sounds.

AND on the contrary; if the Height be known, by the ſame Rule may likewiſe be determined in what Time a heavy Body, let fall from the Top, will reach the Bottom. Let us, for Example, take *Salisbury* Steeple, ſaid to be four hundred Foot high.

As 16 *Foot, the Space paſſed in one Second of Time,*
Is to the Square thereof, or 1:
So are 400 *Foot, the given Space or Fall,*
To 22, *the Square of five Seconds, or the Time in which this Experiment might be made.*

AND in order to diſcover what Space a falling Body may have paſſed thro' in any one particular Second of Time during its Fall, for Example, in the twelfth after the Delivery; the Difference between one hundred and forty four, the Square of the twelfth, and one hundred and twenty one, the Square of the eleventh Second, the Time under Conſideration, will determine it to be about twenty three Rods.

AN Idea of this Matter may alſo be pretty well

well had from GALILEO's Method, delineated *Fig.* 6. *Plate* 6. wherein the Intervals or Times of the Body's Fall, repreſented by the equal Parts *A B C D E* in the Line *A E*, the Velocities wherewith they fall, are denoted by the equal Lines *B F*, *C G*, *D H* and *E I*, at right Angles therewith; and the Area of the triangular Spaces, all ſimilar and equal, point out directly the Quantity of the Fall, or the Acceleration of the Body, in any particular Space of Time. For Inſtance; in the firſt Second, *A B* repreſenting the Time, *F B* the Velocity ariſing from Gravity; the Triangle *A B F* compleated, will denote the Space gone thro' in that Time, or one Rod. If the Time be doubled, as *A C*, the Velocity will alſo be doubled, and then repreſented by *C G*. Compleat the Triangle *A C G*, and the firſt Space *A B F*, will be found four Times contained therein. If the Time be tripled, the Velocity will ſtill bear the ſame Proportion, and then the Space paſſed thro' will be repreſented by the whole Triangle *A D H*, containing nine Spaces or Rods; and ſo on to the fourth Second, and forward.

SINCE falling Bodies are in this Manner accelerated, it may ſeem difficult perhaps to conceive how a perpendicular Pipe, fix'd at Bottom of a Veſſel of Water, ſhould continue, during the Efflux, always full; which, ſtrictly ſpeaking, ought not to be ſo, on Account of this Acceleration, which ought to cauſe the Water to run out of the Pipe faſter than it really could come in: Whence it might be apprehended,

hended, that in Time the Pipe might be empty before the Water was all out of the Veſſel. To which we reply, that tho' all Bodies are by Gravity accelerated in their Fall, in the Proportion of the odd Numbers already mentioned; and muſt allow, that if two heavy Bodies, *A* and *B*, be let fall one Second after another, the firſt would get a Head of the other, nor would they keep at an equal Diſtance during their Deſcent. For if at the End of one Second, after *A* is let go, *B* ſhould be delivered, the firſt will be proceeding at the Rate of 3, while the other is getting on but at the Rate of 1. During the third Second, *A* will be by Gravity urged on with the Force of 5, while *B* can have obtained the Celerity but of 3. So that if at the End of the firſt Second, they were but a Rod aſunder, at the End of the ſecond they would be three Rods apart; five at the End of the third, ſeven at the End of the fourth, and ſo forward progreſſively. Yet it ought here to be conſider'd, that the Water in our perpendicular Pipe, does not run into, and out of it, ſucceſſively and by Starts, but evenly and continually. And tho' by the Acceleration of falling Bodies, their Velocity does increaſe, on which Account the Water in its Progreſs thro' the Pipe, if the Reſiſtance of the Air and every other Impediment was away, might be allow'd to be a ſmall Matter rarify'd; yet as the Particles of Water contain'd in the deſcending Pillar, ſet forward one after another in Spaces of Time infinitely ſhort, and being tenacious, adhere pretty well together, they appear as to Senſe to make an even Stream, and full in every Part. 'Tis therefore impoſſible, that ſo long as there is Water in the Veſſel for a Supply, ſuch Pipe ſhould become void of Water; nor is the Objection any more than a Nicety.

IT may however here be remarked; that when the Preſſure of the Fluid above the Hole of the Pipe, is ſo far abated as not wholly to fill it, the Evacuation will then be continued in a ſpiral Figure. The like happens on pulling up the Plug of a Ciſtern; when the Water is almoſt run off, being reſiſted by the Air beneath, it falls of itſelf into a ſcrew-like Motion, leaving a Hollow in the Middle, round which it ſeems to twiſt itſelf forward. Nor is it unlikely, but that the whole Column of Water in its Progreſs thro' the Pipe, even when fulleſt, may naturally incline always to move in this Manner, the better to overcome the Friction of the Fluid againſt the Sides. A very great Diſpoſition to this kind of Motion may be obſerved by the Stream, as often as Liquors are poured leiſurely from one Veſſel to another: And indeed in all ſmall Effluencies or Veins of running Water whatever, this Spinning in the Fluid is very remarkable.

The MOTION *of* PROJECTILES, *nearly in the* PARABOLIC CURVE, *demonstrated.*

TO the Power of Gravity attracting heavy Bodies downward, in Combination with the impellent Force, by which they are obliged to follow a different Direction, it is owing, that Fluids, in the Way of *Jets-d'Eau*, and indeed all other Projectiles, move nearly in the parabolic Curve; which a Spout of Water, or rather Mercury, will at any Time describe, if the Jet have any Degree of Elevation: And if it be made horizontally, only a semi-parabolic Figure. The Draught of the one is exhibited *Fig.* 7. and that of the other *Fig.* 8. *Plate* 6. The Reason why projected Bodies endeavour to move always in that Manner, will come next under Consideration.

'TIS a famous Proposition in Mechanicks, That when a Body is impelled by two different Forces, not directly in the same Line, that it will not proceed strictly in either of their Directions; but somewhere between both, *viz.* in the Diagonal of a Parallelogram compounded of both. For Instance: Let a heavy spherical Body at *A*, *Fig.* 9. *Plate* 6. be struck with a Spring, or receive some other impulsive Force, in the Direction *AB*, it would thereupon incline to move from *A* to *B*; or let a like Im-

pulse

pulſe be given it along the Line *AC*, the ſame will happen: But let both Springs ſtrike it together, and give it different Directions as before, it will then roll abſolutely in neither, but along the Diagonal Line *AD*, thereby intimating to us the certain Direction of that Force which is thus compounded of the other two.

To prove this by Experiment: Take a Ball, faſten to it two Threads; in a Table bore two Holes, as in the Diagram at *C* and *B*, thro' which put the Ends of the Threads, to which let equal Weights be hung; bring the Ball to the Point *A*. In this Caſe ſhould either of the Weights, *&c.* be ſuffered to draw ſingly, no doubt our Ball will follow in the Line of either Direction indifferently from *A*: But let them both act thereon together, it will then move in the Diagonal, and incline to paſs from *A* towards *D*, tho' from the Nature of the Experiment it can only reach half Way.

AFTER this, let the impulſive Forces be put unequal, the like will happen, and the Diagonal of a Parallelogram, whoſe contiguous and oppoſite Sides are proportionable to the different Weights at Bottom apply'd, will truly point out the Path or Line of Direction, in which the Body thus impelled will incline to move. For Inſtance: Let the Force intimated by the Line *AB* continue the ſame as before, but diminiſh that repreſented by *AC* one half; the Line denoting the new Force muſt be dimiminiſhed in the ſame Proportion, and the Parallelogram will then be conſtructed on the Lines *AB* and *AE*, the half of *AC*; the Diagonal whereof will be the Line *AF*. In this Caſe alſo bring the Ball again to *A*, and quitting it, ſuffer theſe two Forces to act thereon together, you'll find the Ball will move along the Diagonal of this new Parallelogram, as before it did along that of the other, ſo long as the impulſive Forces continue to act in Conjunction; which will be, as before, to about half Way of the Line *AF*.

THIS holds univerſally true, and may therefore properly enough be applied, in accounting for the Movement of Spouts of Water, and all other projected Bodies nearly in the Direction of the Parabola; which is generated between that Force by which the Body is impelled forward continually decreaſing, and the Power of Gravitation continually increaſing.

FOR Inſtance: Let us ſuppoſe a Cannon planted at the Top of the Pike of *Teneriff*, or any other ſharp Hill, was, with a ſmall Charge of Powder, to diſcharge a Bullet horizontally, which, had it no Gravitation towards the Earth, that is, was it without Weight, would fly off, as all Matter inclines to do, having a horizontal Direction given it, or one different from that of Gravity in a Tangent Line to the Earth; juſt as does a Stone from the Circle wherein 'tis whirl'd round by the Sling. And was the Reſiſtance of the Air and all other Mediums removed, it would always maintain the ſame Ve-

locity

locity with which it left the Muzzle of the Piece. But as neither of theſe can happen, in the preſent State of Things, let us conſider what will follow. Firſt, the Reſiſtance of the Medium thro' which the Ball paſſes, will every Moment obſtruct, and at length become equal to the Impulſe by the Powder given; which will in time reduce it to a State of perfect Reſt. Secondly, the Power of Gravity continually acting thereon, will at the ſame time conſpire to bring it out of the Line of the Fire, and cauſe it to tend downward, in the Proportion of the Acceleration of falling Bodies, already mentioned.

LET us ſuppoſe, that in the firſt Second, when the Impulſe is ſtrongeſt, the Bullet will paſs forward, at the Rate of ten Rod. Gravity, as ſoon as the Exploſion is made, puts in its Claim, and tho' it be then but weak, and the other ſtrong, yet will be able to bring it down toward the Earth by the Space of one Rod; or in *Fig*. 7. *Plate* 6. from *A* to *B*. During the next Second, ſuppoſe it retarded ſomewhat, by beating thro' that Quantity of Air, ſo that it can get forward in this Second but at the rate of nine Rod. Gravity, never ſilent, but always acting, will bring it downward that while with the Velocity of three: Of conſequence therefore, 'twill move along the Diagonal of the two acting Forces, as in the Draught from *B* to *C*. The third Second, 'twill, being ſtill retarded as before, proceed but with the Velocity of eight Rod. Gravity by that Time will demand a Deſcent of five Rods; ſo that the Place of the Projectile will then be found at *D*. The following Second, for the ſame Reaſon, it gets on at the Rate of ſeven Rods perhaps; Gravity in the mean Time cauſing a Deſcent of ſeven Rods, the Ball's Place will then be at *E*. The fifth Second, 'twill keep on at the rate ſuppoſe of ſix Rods; Gravity that while making it deſcend nine, and the Ball moving along the Diagonal of a Parallelogram whoſe Sides are proportionable to the Strength of the two Forces, by that Time will bring it as far as *F*. And thus one of them gaining, and the other loſing Power continually, it will reach perhaps the Earth, having deſcrib'd a Curve pretty near a Semiparabola.

THE Repreſentation of the Parabola in all its Varieties, may by a Jet of Quick-ſilver, receiving all the different Degrees of Inclination, contained in a Quadrant or Quarter-circle, be at any Time obſerved. And here it may be remarked, that the utmoſt Range, or the greateſt Projection that can be made of a Ball, is always obtained when the Elevation of the Tube or Piece is about forty five Degrees, or the half of a Right-angle, above the Horizon, as in *Fig*. 8. *Plate* 6. Wherein the greateſt Diſtance a Bomb can be thrown to from the Mortar at *C*, is ſuppoſed to be repreſented in that Degree of Elevation. Whereas ſhould it be raiſed above that Angle, for Inſtance, to fifty Degrees, it will not throw it near ſo far; and ſhould it be lower'd as much, or down to forty Degrees, the Conſequence will

will be the ſame. And thus, by two different Inclinations of the projecting Tube, a Projectile may be made to fall on the ſame ſpot of Ground; traverſing however very different Tracks of Air to get thither.

IT ought here however to be remarked, that were Bodies near our Earth to be projected in an unreſiſting Medium, according to the Doctrine of GALILEO; their Motion wou'd be perform'd in the Parabola exactly. But as all our Obſervations muſt be made on Bodies moving in the Air, the Curve they really move in falls conſiderably ſhort of that Line, which they wou'd otherwiſe have deſcribed; and eſpecially toward the End of their Motion, when the projectile Force by Reaſon of the Reſiſtance of the Air is much impaired. Nor is this Deviation inconſiderable, even tho' the projected Body be of Lead or Iron, eſpecially if they be thrown far: But the Odds is ſtill greater, if the projected Body be ſo light as Water.

Sir ISAAC NEWTON demonſtrates, that the Motion of Projectiles in Air is rather perform'd in a Curve of the hyperbolic Kind; and he accordingly found that a horizontal *Jet-d'Eau*, which ſhould have gone to the Diſtance of forty Inches in a Parabola, upon Trial reach'd only to thirty ſeven; the Reſiſtance of the Air taking off a thirteenth Part of its projectile Force. In Dr. GRAVESAND's Experiments, inſtead of thirty one Inches and a half, it only reach'd twenty nine and a half; not much different in

Proportion from the former. And even in the Experiments which Mr. ROEMER made with a Body ſo denſe as Quickſilver, the Heights and Diſtances, eſpecially in great Elevations, were ſomething leſs than the Theory of Parabolas required, merely from the Reſiſtance of the Air; the Quantity of which Reſiſtance is now to be conſidered.

On the RESISTANCE *of* FLUIDS *to* BODIES *moving therein.*

THERE are two Kinds of Reſiſtance in Fluids: The one is from the Viſcidity, Tenacity, or Coheſion of their Parts; the other from the Inactivity, or what Sir ISAAC NEWTON calls the *Vis Inertiæ* of Matter.

THE Reſiſtance of the latter is that Force by which every Body endeavours to continue in the State 'tis in, whether of Reſt or Motion. That of the former is a Reſiſtance, produced over and above that of the *Vis Inertiæ*, by the Spiſſitude or Viſcidity of ſome Fluids. For Example; was a Body dropp'd into melted Honey, ſuppoſing the Honey in that Circumſtance to be a perfect Fluid, the Reſiſtance it meets with, when moved therein, will be according to the *Vis Inertiæ* only: But when the Parts of the Honey, by cooling become ſtiff, the Difference of the two Reſiſtances will then be that of the Tenacity.

THE

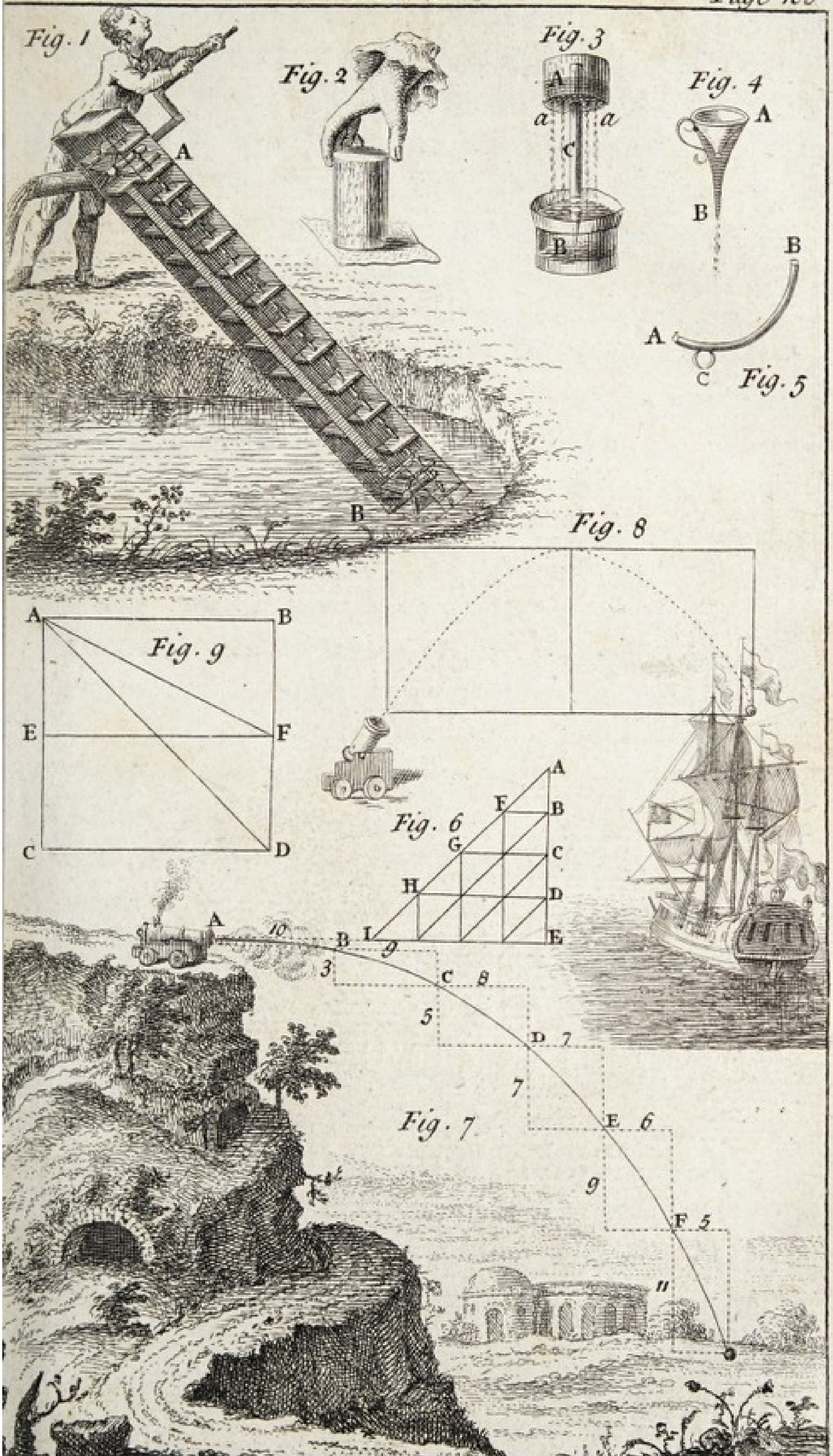


Fig. 1
A
B
Fig. 2
Fig. 3
A
a
a
C
B
Fig. 4
A
B
B
A
C
Fig. 5
Fig. 8
A
B
Fig. 9
E
F
C
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Fig. 6
G
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A
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D
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Fig. 7
E
6
9
F
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11

J. Cole sculp.

THE *Vis Inertiæ* of Matter is no where more conſpicuous, than in the ſudden Motion of a Veſſel full of Water along a Plane, upon which the Liquor at firſt ſeems to move with a Direction contrary to that of the Veſſel; for riſing againſt the hinder Side, it will commonly flaſh over. Not that there is really any ſuch Motion impreſſed on the Liquor; but that by the *Vis Inertiæ* of Matter, the Water endeavouring ſtill to continue in a State of Reſt, the Veſſel cannot in an Inſtant communicate its Motion to it; it not being a conſiſtent or a fixed Body like itſelf, but a Fluid: The Liquor therefore perſeveres for a ſmall Time in its firſt State of Reſt, while the Veſſel makes forward, and therefore ſeems to move a contrary Way. But when the Liquor has the Motion of the Veſſel fully communicated to it, and begins to move with a Velocity equal to that of the Veſſel, they then proceed very quietly together. Yet even then ſhould the Veſſel be ſuddenly ſtopp'd, the Liquor endeavouring to continue its Motion, will daſh again over the other Side of the Veſſel.

THIS paſſive Principle or Inactivity, is eſſential to Matter; becauſe it can no how be depriv'd of it. It can neither be ſuſpended in it, nor abated; but is always proportionable to the Denſity of Bodies, or the Quantity of Matter they reſpectively contain.

THE Refiftance from Tenacity in Fluids, if it be not always uniform, is directly according to the Degree of Velocity in the moving Body only; becaufe the Vifcidity of the Matter will be barely feparated to make Way for its Motion. And this yielding of the Parts is always the fame, whether the Motion be fwifter or flower: whereas the Refiftance of the *Vis Inertiæ* is always as the Squares of the Velocity of the moving Body; that is to fay, fuppofe one Body moves with three Degrees of Velocity, and another but with two; the different Refiftances they will meet with in that Cafe, will not be as 3 to 2, as is that of the Tenacity, but as 9 to 4. Or again; fuppofe a Body to move firft with one, and then with two Degrees of Motion, the Difference will there be as 1 to 4; becaufe the Body having twice as much Motion, it muft ftrike twice as many Parts, and doing it with double the Velocity, muft ftrike them twice as hard, and confequently pufh them twice as far. Juft as if I fhould give ten Shillings to-day to ten Men, and to-morrow fhould give twice the Number of Shillings a-piece to double the Number of Men; 'tis plain, my Diftribution to-morrow will be four times what it was to-day.

THIS again may be demonftrated by Experiment, thus: Take four or more fmooth flat Bodies, fuppofe boxen Draught-men; let thefe reprefent as many Particles of any fluid Matter. Lay them on a fmooth Surface, two and two abreaft, pretty clofe together; pafs any Thing that

that is ſmooth and hard gently through them, they will be juſt ſeparated thereby, and puſhed ſideways barely to once the Breadth of the moving Body. Join them again, and let the Body paſs thro' them with twice the former Velocity, they will not only be parted as before, but will be ſtruck off laterally alſo, to twice the Breadth of the moving Body. Increaſe the Velocity ſtill, and the Parts moved thereby and diſplaced, will evidently appear to be according to the Square of the Degrees of the Celerity wherewith this is done.

UPON this Account, 'tis plain the Reſiſtance of Fluids to moving Bodies may on ſome Occaſions be very conſiderable; and when the Velocity of the Projectile is very great, it may equal even the Reſiſtance of a ſolid or fixed Body. For Inſtance; let a Cloth be ſpread ſuppoſe a Yard under Water, with a moderate Charge of Powder fire a Bullet at it, 'twill pierce it probably; whereas ſhould you double the Charge, and repeat the Experiment, 'twill be beaten flat, and not reach it before the Force of the Powder is ſpent.

In Vacuo all Bodies fall equally faſt; a Cork for Inſtance and a Bullet, a Feather and a Piece of Gold, all lodge themſelves exactly together. The true Quantity of this Fall, in the firſt Second after Delivery, is experimentally found as was ſaid to be 16,1 Foot *Engliſh*; tho' in our former Calculations, the Word Rod was uſed to prevent Multiplicity of Words, and Confuſion from

broken

broken Numbers. Was there a Medium for these Bodies to paſs thro', they would none of them fall ſo far in the ſame Time; and the leſs ponderous Bodies would be affected by its Reſiſtance moſt: So that the Cork might ſoon ceaſe to move with an accelerate, and afterwards continue to fall with an equable Motion in the Air; which the Feather would likewiſe do, but ſooner ſtill.

THE Reſiſtance of the ordinary Fluids, ſuch as the Air, Water and Mercury, is obſerved to be chiefly owing to that of their *Vis Inertiæ*, and very little to their Tenacity: So that the Denſity of Fluids being known, their Reſiſtance is eaſily calculated. Thus Water reſiſts about eight hundred and fifty, and Mercury about eleven thouſand nine hundred Times more than Air. And it has been found by cauſing Pendulums to oſcillate or ſwing in thoſe Fluids, that the Motion loſt by their Reſiſtance, was juſtly proportionable to their Denſities, or the Quantities of Matter in them ſeverally contained.

FOR the Confirmation hereof, we muſt refer to Sir ISAAC NEWTON's Experiments: Who filling a Veſſel of a conſiderable Length with Water, let fall in it ſpherical Bodies, of different ſpecifick Gravities, and then calculating how far they would fall in that Medium, regarding its Denſity only, and rejecting the Tenacity, he found the Experiment anſwer'd to it. And in Company of Dr. DESAGULIERS, he let fall Bodies of like Form, from the upper Gallery of

St. *Paul's* Cupola, two hundred and ſeventy two Feet from the Ground, and found the ſame Thing to happen alſo in the Air. Whence it ſufficiently appears, that the Air has no ſenſibly Tenacity; much leſs then can it have either Attraction or Coheſion of Parts.

Of JETS-D'EAU.

WE have ſeen that Fluids led in Pipes, will always riſe to the Level of the Reſervoir whence they are ſupplied; the riſing Column being puſhed forward, and raiſed by another equally heavy, at the ſame Time endeavouring to deſcend. And a like Effect might be expected from Jets of Water, thus impell'd, did not Friction againſt the Sides of the Machines, and the Reſiſtance of the Air, both lateral and perpendicular, generally prove an Abatement, and prevent its riſing ſo high as the Head.

WHERE Jets are executed in the beſt Manner, and the Friction ſpoken of is as much as poſſibly removed, the Impediment of the Air only, thro' which they needs muſt beat in their Riſe, will cauſe them, according to Experiment, to fall ſhort of the Height of the Reſervoirs, in the following Proportions, *viz.*

RESERVOIR.	JETT.
FEET.	FEET. INCH.
5	5 : 1
10	10 : 4
15	15 : 9
20	21 : 4
25	27 : 1
30	33 : 0
35	39 : 1
40	45 : 4
45	51 : 9
50	58 : 4
55	65 : 1
60	72 : 0
65	79 : 1
70	86 : 4
75	93 : 9
80	101 : 4
85	109 : 1
90	117 : 0
95	125 : 1
100	133 : 4

WHENCE in general it may be obſerved;

That ſo often as a five Foot Jet (to be taken in theſe Matters as a Standard)

Shall be contained in the Height of any Jet propoſed:

By ſo many Inches multiplied into themſelves, or ſquared,

The Surface of the Water in the Reſervatory which ſupplies it, ought to exceed that Jet in Height.

THUS

THUS to obtain a Jet of thirty Foot, which contains five Foot ſix Times, the Reſervoir ought to be thirty ſix Inches or a Yard higher; and a Jet of ſixty Foot may be had from a Head higher by four Times that Difference, or four Yards. So that *Jets fall ſhort of the Heights of their Reſervatories, in a kind of ſubduplicate Ratio of the Heights to which they riſe.*

THIS great Diſproportion in the Riſe of Jets muſt in general be owing to the Reſiſtance of the Air they are made to move thro'; which has been ſhewn to be in Proportion to the Squares of their Celerities reſpectively: Nor can the Acceleration of the falling Water in the Pipe, or the Retardment of the riſing Stream by the Action of Gravity, be concerned at all in it; ſince theſe are adequate, and counterbalance each other every where in the ſame Level.

THE Air's Reſiſtance being thus conſiderable, 'twill always be found neceſſary to increaſe the Bore of the Adjutage or Spouting-pipe, with the Height of the Reſervatory: For if it be too ſmall, the riſing Stream will want ſufficient Weight and Power to cleave the Air; which being denſeſt near the Earth, a ſmall Stream of Water, endeavouring to mount to a great Height, will be daſhed againſt it with ſo great Violence, as to fall away in a Miſt and be wholly loſt. And it may be obſerved, that the weightier any Body is, the greater Force it will have when in Motion: Since an Ounce Ball fir'd fir'd from a Muſquet, will go much farther, and do greater Execution, than will an equal Weight of Shot; and theſe again will be projected farther than ſo much Lead raſp'd into Powder and fir'd off. A Charge of Water wou'd ſcarce wet a Paper at the Diſtance of ſix Foot. And accordingly, ſhould a Caſk of Water be any where pierc'd with Holes, two, four, ſix, eight and twelve Lines over, all in the ſame Level, the larger Bore will always be found to throw the Water fartheſt.

IT may be of Uſe here to add Mr. MARRIOTE's Proportions of the Bores of the Adjutages and Pipes of Conduct, who was very converſant in theſe Things, and hath written very well on this Subject.

N. B. *The* French *divide their Inch into twelve equal Parts, which they call Lines.*

Heights of Reſervoirs.	*Diameters of fit Adjutages.*	*Diameter of the Pipes of Conduct.*
FEET.	LINES.	LINES.
5	3, 4, 5, or 6	22
10	4, 5, or 6 - -	25 INCHES.
15	5, or 6 - -	27, or $2\frac{1}{4}$
20	6, or half an Inch	30, or $2\frac{1}{2}$
25	Ditto - - -	33, or $2\frac{3}{4}$
30	Ditto - - -	36, or 3
40	7, or 8 - - -	51, or $4\frac{1}{4}$
50	8, or 10 - -	65, or $5\frac{1}{2}$
60	10, or 12 -	72, or 6
80	12, or 14 -	84, or 7
100	12, 14, or 15	96, or 8

HENCE

HENCE it may be remarked, that there is a certain and fit Proportion to be obſerved between the Adjutage whereby the Jet is delivered, and the Pipe conducting it from the Head. In general, *About five times the Diameter of the Adjutage for Jets under half an Inch, and ſix or ſeven Times for all above, will ſize the Pipes of Conduct pretty well:* Not but 'twill always be an Error on the right Side, to have them rather larger than in ſtrictneſs they ought to be, that the Jet may always be freely ſupplied with Water, and in due Time.

FOR a like Reaſon, if there be Occaſion for a Cock to be placed in any Part of the Pipe of Conduct, Care ſhould be taken that it ſhould be there bigger in Proportion, that the Water-way may not be pinched; but that the Cavity be left at leaſt equal to the reſt of the Bore of the Pipe.

THE Expence of Water made by Jets to any Altitude, may be pretty well collected from what was ſaid under the Article of the Flux of ſtreaming Fluids from Openings beneath their Head, *Page* 83, and the following, *viz.* That from equal Bores, it would always be in a ſubduplicate Proportion of their Heights. All neceſſary to be added thereto is, That if thro' any Hindrance or Deficiency in the Conduct-work, a Jet ſhould happen not to riſe ſo high as might be expected from the Regulation in this Section laid down *Page* 110, the Expence of Water on that Occaſion ought not to be computed from the Height of the Reſervatory, but from the Rise of the Jet. For Instance: Suppose a Reservoir of thirty three Foot, which ought to play a Jet of thirty Foot, plays but one of twenty, which a Reservoir of twenty one Foot four Inches, done in a good Manner, would also do, in this Case regard being had to the Size of the Adjutage, the Expence of Water can possibly be no greater than what a twenty Foot Jet might be expected to make.

THE Bore of an Adjutage cannot be too smooth or true. Those that are cylindrical are best; those that are bored conical worse, because of the Reflections of the Water from the inclined Sides of the Machine, which in the Hurry of the issuing Stream will in them unavoidably be made.

To conclude this Subject, let us attend to the Construction of a very pretty portable Fountain, that being once charged with Water, and inverted, will play a Jet nearly as high as the Reservoir, till the Fluid is exhausted; and then turned up on the other End, the same Thing will happen, and a real Clepsydra, or Water-Clock, be thereby formed.

THIS Device represented *Plate* 7. *Fig.* 1. consists of two hollow Vessels, *A* and *B*, communicating with each other only by the recurv'd Tubes *C* and *D*; at the Ends of which, *E* and *F*, are plac'd small Adjutages to direct the Jet. *G* and *H* are two open Tubes, soder'd into the Bottom of the Basons belonging to *A* and *B*, thro'

thro' which the Water flows in, and fills those Veſſels to a certain Height, that is, according to their Length. They by their Diſpoſition alſo prevent the Return of Water the ſame Way, when the Machine is turned upſide down.

On the SPECIFICK GRAVITY *of* BODIES.

ARISTOTLE's Notion of the Elements was, That the Earth and Water were poſitively heavy; Fire poſitively light; and Air indifferent as to either. His Followers therefore affirm, That the Aſcent of Bodies is owing to their poſitive Levity, as that of Flame and Smoke, for Inſtance. But in this they are miſtaken: For Bodies are only relatively light or heavy, according as they are compared with others of a different Kind. So that Flame or Smoke aſcend not becauſe they are really light; but becauſe they are buoyed up by the Air, which is denſer, and therefore in its Nature heavier than they: For Flame *in Vacuo* will ſoon ſubſide; and Smoke, when the fuliginous Parts thereof become heavier than the Medium round them, will viſibly deſcend. Thus, Oil or Wine do not ſwim on Water becauſe of their own Levity; but becauſe Water is the heavier Fluid, and ſinks in them. In Air moſt Bodies ſink, becauſe it is very light; in Water not ſo many, it being far more denſe; in Mercury ſcarce any may be totally immers'd, from the like Cauſe. Nor is there any greater Reaſon that Cork ſhould be termed light, becauſe 'twill ſwim in Water; than that Iron ſhould be eſteemed ſo, becauſe 'twill ſwim in Mercury.

IN general therefore, *One Body is ſaid to be ſpecifically heavier or denſer than another, when it contains more Matter, or a greater Degree of Weight, under the ſame or an equal Bulk; or an equal Degree of Weight, in leſs Space or Compaſs.* For Inſtance; a cubick Inch of Gold weighs ten Ounces Troy, an equal Quantity of Lead hardly ſix, of common Water ſomething better than half an Ounce; ſo that Gold is about nineteen, and Lead about eleven times denſer and therefore ſpecifically heavier than Water: And thus of the reſt.

SPECIFICK Gravity then is appropriate or the Gravity peculiar to any Body, whereby it may be diſtinguiſhed from Bodies of a different Kind. 'Tis ſometimes, and not improperly, called *relative* or *comparative* Gravity, to diſtinguiſh it from *abſolute* or *poſitive* Gravity; which laſt always increaſes in Proportion to the Bulk of the Body weigh'd, directly, the other not. Abſolutely conſider'd, a Pound of one Thing is as heavy as a Pound of another, without regard to what their ſpecifick Gravities are: Thus a Pound of Feathers, Cork, or Spunge, weighs as much as does a Pound of Lead; but with regard to their relative Gravities, or Bulk for Bulk, they are very different.

A BODY ſpecifically heavier than a Fluid, will ſink therein, becauſe it weighs more than the

Fluid

Fluid by it diſplaced, and whoſe Room it takes up: So that the imaginary Surface immediately under the Body, being there more preſs'd than by the Water in any other Part, it therefore yields, and lets it thro'. But a Body ſpecifically lighter than a Fluid, will always riſe therein; becauſe it preſſes leſs on the imaginary Surface beneath it, than the Fluid in whoſe Place it is ſubſtituted would have done.

WAS there any Neceſſity of proving this by Experiment, it might thus be done: Take a ſmall glaſs Bolt-head, which, was it ſolid and of a Lump, wou'd be near three times heavier than Water; but being hollow, and full of Air only, 'twill emerge and ſwim. This may be ſo nicely filled with Water, by the Stem, that at Top of a Jar it may be made to ſwim; in the Middle it may remain at a poiſe; and put beyond that, or lower, it may ſink.

THIS will be brought about by the Spring of the Air included therein; which being compreſſible, will either contract or dilate itſelf according to the Degree of Preſſure 'tis under. Toward the upper Part of the Jar 'twill be preſs'd by little more than the Atmoſphere; toward the Middle, by the Atmoſphere and ſome Inches perhaps of Water; and at the Bottom, by more Water ſtill. In the firſt Caſe, the Air in the Machine cannot be ſo much preſs'd as in the ſecond; in the ſecond, not ſo much as the laſt: Whence, as the Preſſure comes to be increaſed, more Water will be gradually thruſt into it, as the Mouth of the Machine is unſtopp'd, making the whole ſpecifically more heavy, and ſo will produce the forementioned Effect very viſibly, when tried on a Machine that is ſmall.

UPON the ſame Principle it is, that glaſs Images are made to riſe or ſink in a long Jar of Water at the Word of Command. Theſe have commonly a Hole left in their lower Parts, thro' which, by only ſucking out the Air, having a little Water at the ſame time in one's Mouth, they may be ſo far charg'd therewith, as will cauſe them to ſwim erect, at Top of the Jar. Let this be afterward ſtopp'd with a good yielding Cork, or cover'd with a Leather or Bladder, well tied over the Mouth, and a Preſſure of the Hand occaſionally applied thereon, will cauſe them to ſink; and on Abatement of that Preſſure, they will riſe again at Pleaſure; or by an equal Degree of Preſſure, they may be ſtopp'd, or ſeem to be ſuſpended, in any Part of the fluid Column.

THIS accidental Preſſure is, in Effect, equivalent to the lengthening out the Pillar of Water, in the laſt Experiment: For, by a greater Degree of Preſſure applied, the Air being condenſed in the Image, more Water will be thruſt into its Cavity, which the Air, in its Reſtitution, will thruſt back when that Preſſure is withdrawn. Both theſe Experiments are repreſented under the *Pneumaticks, Fig.* 18. *Plate* 8.

BY the way, it may here be remarked, that there are very few if any Animals of themſelves ſpecifically heavier than common Water. The Subſtances indeed of both Animals and Vegetables frequently are ſo; and the floating of either is generally owing to the Cells or Receptacles in them interſperſed, which in the one are fill'd with Air or Oil, in the other with Air or Reſin, which being all lighter, will ſwim in Water. If then Fleſh and Bones are of themſelves ſomewhat heavier, the Fluids and the Fat are ſomewhat lighter; to which if we add the large Quantity of Air in theſe every where included, as on Cupping, *&c.* evidently appears, they will be found together to make a Maſs ſpecifically a good deal lighter than a comparative Bulk of common Water. Beſides, as the Bulk of the Body is to be increaſed by diſtending the Cheſt in Inſpiration, and taking a good Quantity of Air into it, this is a farther Advantage to the floating Animal.

IT has been tried by a fat Man of ordinary Size, what Weight he could bring up from the Bottom of the *Thames*, ſo as to have the Top of his Head juſt appear above Water. When his Breaſt was full of Air, he was found to riſe with thirteen Pounds of Lead, without ſtriking out in the leaſt, and two Ounces more would have kept him under: But when his Breaſt was not thus diſtended, he could bring up only eleven Pounds in that manner.

IT would be therefore difficult to conceive how People, not incumber'd with their Clothes, ſhould be ſo often drowned as they are againſt their Wills; and, unleſs by ſtruggling unartfully, and admitting Water by their Mouths, they were ſuffocated, the Thing would ſeem impoſſible. One unavoidable Diſadvantage indeed they do lie under, and that is from the ſudden Contraction of the warm Air within the Body, on its firſt Immerſion in cold Water; to ſupply the Place of which, they are apt to diſtend their Lungs immediately, and are in a manner forced to gaſp for Breath, when meeting with a Fluid too groſs for Reſpiration, they fall a Sacrifice to their Fears, for want of that Preſence of Mind which the Brutes, whoſe Apprehenſions of the Danger being leſs, are evidently Maſters of. This, like other Prejudices, we ſhould endeavour to conquer while we are young, before they are too deep rooted with us, and predominate.

ALL Bodies floating on Fluids, may be juſtly compar'd with them; and whenever a Body lighter than a Fluid does float thereon, a Quantity of that Fluid, in Bigneſs equal to the immers'd Part of the Body, is preciſely equal in Weight to the abſolute Weight of the whole Body. A Man of War, for Inſtance, carrying a hundred and twenty Guns, with all its Stores, Rigging, and Appointments, weighs not a Jot more than does the very Quantity of Water which it thruſts away and diſplaces, and which would otherwiſe have occupied the Room of that very ponderous Machine. This Water

being

being of a certain and determined Weight, wou'd naturally have preſs'd on the imaginary Surface of the Fluid, juſt beneath, with its proper Gravity: But as that Part of the Ship which is under Water, falls into the Place, ſubſtituting thereon an equal Weight, the ſame Preſſure, and no more, is ſtill ſuſtain'd by the ſaid Surface. And were it otherwiſe, the Water, being fluid, wou'd continue to move till the Equilibrium was fully made; which always is obſerved to happen when Veſſels of this kind come to be laden deeper.

THE Motion of the Waves in a Gale of Wind, whereby an unequal Degree of Preſſure is accidentally thrown on the ſmooth Surface of the Sea, alſo evidently ſhews us this. But to prove it farther by Experiment; Take a Stick of Wood ſpecifically lighter than Water, and counterpoiſe it in a Pair of good Scales with Water: Immerſe the Stick in a full Jar; Part of the Water will be thruſt out thereby, and run over: Take out the Stick, and the Water in the Scale will be found again exactly to repleniſh the Jar. Which ſufficiently proves, what was before intimated; *That a Quantity of a Fluid, equal to the immers'd Part of a Body lighter than that Fluid, will in Weight equal the Weight of the whole Body.*

HENCE a tolerable Judgment may be form'd of the different Specifick Gravity of all ſuch Bodies lighter than Water, as will not be damag'd by Immerſion therein. For Inſtance; The Denſity and Weight of the ſeveral Sorts of

Wood,

Wood, may this Way be compar'd, by putting Sticks of the ſame Length, equally ſeaſoned or dry, and of the ſame Form and Bigneſs throughout, or priſmatick from one End to the other ('tis no matter whether with regard to each other their Form or the Diameters of their Baſe be the ſame) in a narrow Jar of Water, like that in *Fig.* 1. *Pl.* 1. the better to keep them up on End, noting how far, when gently let down, they will ſink in the ſaid Fluid. And accordingly, a Piece of *Engliſh* Oak a Foot long, will be found to ſink about eighty, Beech ſeventy five, ſome Sorts of Mahogeny ſixty nine Hundredths of a Foot: So that the Denſity of Oak may this Way be found to be to that of Beech, as 80 to 75, or 16 to 15; and to that of Mahogeny, as 80 to 69, nearly as 8 to 7. And by Conſequence, their ſeveral Weights, and perhaps their Strength and Degrees of Service, might pretty well be judg'd of, by inverting the Terms; that is to ſay, ſeventy five Foot of Mahogeny are equivalent to ſixty nine of Beech; and eighty of Beech to ſeventy five of Oak. Their Duration indeed, depending on their Texture and particular Conſtitution, will be another Conſideration.

On the HYDROMETER, *or* WATER-POISE.

THE relative or ſpecifick Gravity of Fluids to each other, may this way alſo be tolerably well diſcover'd, *viz.* by the Immerſion of an Inſtrument called the Hydrometer, or Water-

Water-poiſe, in them one after another. This Machine is uſually made of Glaſs, Ivory, or ſome Subſtance not very porous, or apt to imbibe much Liquor. It conſiſts of a Bole of any reaſonable Size, but the larger the better, as *A*, *Fig*. 2. *Plate* 7. and a long ſmall Stem, as *B*. The Bole is commonly loaded with a little Small-ſhot or Mercury, to cauſe it to ſwim upright; and its Weight is generally adapted to the Liquors 'tis intended to prove. The Neck is mark'd with equal Diviſions, commonly put on the Out-ſide. The large Part or Bole of this Machine is ſuppos'd to be compar'd with an equal Quantity of the Fluid in which 'tis immers'd. The Stem, as 'tis ſmall, happening to be more or leſs immers'd, makes no great Difference. The heavier the Liquor, the more boyant it is found to this Machine; and the lighter, the leſs will it be ſupported therein. In Vinegar or Pickle, for Inſtance, 'twill not ſink near ſo deep as in Spring-water: This again, having more Salts in it than Pond or River Water, wherein they have had more Time to ſubſide (which they conſtantly do, forming thence Slime or Mud fit for manuring of Land) will bear it up better than they. In Wine this Inſtrument will be leſs ſupported; and in ſpirituous Liquors, made more light or ſubtiliz'd by Diſtillation, it will ſink more or leſs according to their Quality or Degrees of Strength.

THE lighteſt Waters are the moſt wholeſome, tho' they are perhaps generally leſs palateable than thoſe that are heavier. Water that has been fil-

filtrated thro' a thick Flannel, or percolated thro' the Pores of a looſe and ſandy Stone, will be very light, clear and good. But Water diſtill'd, tho' it may be very light, yet wanting a due Mixture of Salts, will be both inſipid and unwholeſome. Sir ISAAC NEWTON's Definition of Water is, *That it is a fluid Salt, volatile, and void of all Savour or Taſte.*

SUCH Wines as have a natural Sugar in them, and are therefore more viſcid and ponderous, as Canaries, and what are uſually call'd the rich Wines, ought not to be taken too liberally: They are too nutritive alone, and ought to be well diluted with Water; and ſuch will always be found very buoyant to the Water-poiſe. The lighteſt Wines, that is, the lighteſt in the Balance, are generally the moſt ſpirituous, therefore worſe to digeſt or be overcome by the *Vis Vitæ* of Animals. Witneſs Champaign, Tockay, *&c.* which of themſelves are too ſtrong and noxious, if drunk alone in great Quantities; but if mix'd with Water, in the antient Way, ſo making a ſpecifically heavier Fluid, are ſafe; being brought down thereby to the Condition of weaker Wines.

AND for the ſame Reaſon, Diſtill'd Liquors, having too great a Degree of intenſe Heat in them, can never be fit for common Drinking alone. Theſe Things being mixed with the Blood, and other animal Juices, are rather apt to thicken than render or keep them fluid. The publick Diſcouraging the late common Exceſſes

of

of this Sort, will therefore doubtleſs be attended with very happy Conſequences, and particularly with regard to the Health of thoſe who ſhall be thereby reclaimed.

As to Punch: The Mixture of the Acid and Sugar diſſolved in Water, may poſſibly have been taken at firſt from the diluted Oxymel of the antient *Greeks*, or more probably from the Sherbet now in uſe among many of the *Aſiaticks*; and the Brandy, Rum, Arrack, *&c.* are added to give it a vinous Strength, agreeable to the Taſte and Appetite, or perhaps the Wants, of our northern Climate. In this Mixture the Fluency of the Spirit is pretty well corrected by the Viſcidity of the Sugar, its Levity by the Gravity of the Acid, and the poignant Strength of all theſe Ingredients being lower'd by a ſufficient Quantity of Water, it becomes an artificial Wine, both wholeſome and pleaſant; and 'tis therefore a favourite Liquor with the *Engliſh*.

THE ſpecifick Gravities of Red-wine and Water will appear to be different, if a ſmall glaſs Bolt-head, as *A*, *Fig.* 3. *Plate* 7. full of common Water, be inverted into a Glaſs of Claret, *B*. The Water being heavier, will viſibly deſcend, and take Place at Bottom of the Glaſs; and the Wine being more light, will riſe through the Body of Water by degrees, for juſt the ſame Reaſon as Smoke does in ſerene Air, and take its Place at the Top of the Bolt-head, till at length all the Wine ſhall have taken

taken Poſſeſſion of that Machine, and all the Water of the other; as from their different Gravities they are inclined to do.

IT is a common Experiment, to pour Red-wine upon a Quantity of Water in a Glaſs with a ſteady Hand; putting a Bit of thin Bread or Paper firſt afloat in the Water, to eaſe the Fall of the Wine into the heavier Fluid, that the Section, where the two Liquors part unmix'd, may be better obſerved. Then with a Pipe either the one or the other of them may indifferently be drawn off firſt.

WHEN Water and this colour'd Wine however are heedleſly jumbled together, and have their Parts intangled as it were one among another with a Shock, they then cannot ſo eaſily be ſeparated again, their Tenacity in great meaſure preventing it; they therefore remain thenceforward incorporated together, and as it were one homogeneous Fluid. However, as the Wine and Water thus mixed, make a Body ſtill lighter than Water alone, if the Bolt-head abovenam'd, full of common Water, be again inverted into this Mixture, it will appear to riſe therein as the Wine did at firſt, but not ſo briskly.

The

The PRINCIPLES *on which the* HYDROSTATICAL BALANCE *acts, demonſtrated.*

HAVING before prov'd, That the whole Weight of a Body ſpecifically lighter than Water, is equal to the Weight of a Quantity of Water the ſame in Bulk to the immers'd Part of that Body; it comes next to be conſider'd, *That all Bodies ſpecifically heavier than Water, loſe as much of their abſolute Weight, in Water, as a Quantity of Water in Bulk equal to themſelves ſhall weigh.*

TO prove this Propoſition experimentally; Take a Cylinder of ſolid Lead, exactly fitted to, and filling a hollow Cylinder of Braſs; ſuſpend the Lead at one Arm of a Balance; counterpoiſe it with Weights at the other, of which let the hollow Cylinder, fill'd with Water, be a Part. Immerſe the Lead, ſuſpended as it is, in a Jar of Water held in the Hand, not ſuffering it to touch either the Bottom or the Sides, and Weight will ſoon appear to be loſt; which, on emptying the hollow Cylinder on the other Side of its Water, will appear to be immediately reſtored.

As a farther Evidence of this, let the ſolid Cylinder be ſuſpended as before. Put the hollow one in the Scale on the ſame Side, void of Water, and counterpoiſe them juſtly. Immerſe the

the Lead in a Jar of Water, as before, and the Weight loſt thereby, on filling the hollow Cylinder beforeſaid with Water, will be replac'd.

AGAIN; *The Weight loſt by any Body, on Immerſion, will always be communicated to the Fluid wherein 'tis put.* To prove which, weigh a Jar of Water, and let the hollow Cylinder beforementioned be a Part of the Counter-poiſe. Let then the Lead, held by a String, be ſo immerſed that it may neither touch the Bottom or Sides of the Jar; and the Increaſe of Weight found, will be again exactly counterpoiſed by filling the hollow Cylinder in the oppoſite Scale with Water.

NOW to account rationally for the Loſs of Weight on the Immerſion of the ſuſpended Lead, it muſt be conſidered, That the Solid will then take up a Space in the Fluid, which would otherwiſe have been fill'd by a Portion of Water in Magnitude equal thereto; which Fluid would alſo have been every way bouyed up, and ſuſtain'd in its proper Place, by the Parts of the Fluid adjacent; the Efforts whereof, upon putting in the Lead, are then transfer'd to and act againſt the Sides of the ſolid Matter, thus ſubſtituted, in order to ſupport that.

AND with regard to the additional Weight, or that acquired by the Fluid in which the Lead is immers'd, it muſt be obſerved, That on ſuch Immerſion, the Water is made to riſe in the Jar in a juſt Proportion to the Bulk

of

of the Body immers'd, which then being ſubſtituted in the Place of ſo much Water, may well be conſidered as a like Bulk of Water added; and therefore muſt be expected to preſs the Scale as much as an equal Quantity of Water added would have done.

IT is certain then, that Bodies ſpecifically heavier than Water, when immerſed therein, loſe of their abſolute Weight in Air, what an equal Quantity of Water in the Air wou'd abſolutely weigh: And by conſequence it is equally certain, *That the Difference of the Weight of any ſuch Body, taken firſt in Air, and afterwards in Water, will always be the juſt Weight of a Quantity of Water, equal in Bulk and Dimenſions to thoſe of the Body under Conſideration*; which being the Principle whereon the Experiments on the Hydroſtatical Balance chiefly depend, requires a very particular Regard.

THIS famous Propoſition was firſt found by ARCHIMEDES on the following Occaſion. HIERO, King of *Sicily*, ordered the Workman a certain Quantity of Gold, to make him a Crown. It was indeed well deſigned and finely embelliſhed; but the Artiſt it ſeems had made free with ſome of his Majeſty's Gold, and had ſubſtituted in its Room an equal Quantity of Silver. On Delivery of the Work, there was a Suſpicion of Mal-practice; the Crown was ordered to be ſurvey'd, and the Thing refer'd to

ARCHIMEDES, as a proper Judge of the Caſe, with Inſtructions however by no means to deface the Workmanſhip. It lay long before the ſaid Referee, and the Maker thought himſelf pretty ſecure of his Perquiſite. It happened however one Day, as the Philoſopher was ſtepping into a Bath, that he took Notice the Water roſe in the Bath in Proportion to the Part of his Body immerſed. From this Accident he received a Hint, wherewith he was ſo tranſported, that he jumped out of the Bath, and ran naked about the Streets of *Syracuſe*, crying in a wild Manner, *I have found it! I have found it!*

IN conſequence of this Speculation, he made two Maſſes, of the juſt Weight of the Crown; one of Gold, the other of Silver. Theſe he ſeverally let down carefully into a Veſſel of Water, wherein the Riſe of the Fluid might eaſily be determined by Meaſure. Being of different ſpecifick Gravities, they were conſequently of different Magnitudes, and on Immerſion took up the Room of different Quantities of Water; by comparing whereof with their abſolute Gravities, in the Air, he became Maſter of the Relation, in Point of Weight, each of theſe Metals had to Water, and conſequently to each other. He then ſerved the Crown in like Manner, and by comparing his Obſervations, he at length detected the Cheat, and fairly aſſigned the Quantities of Gold and Silver contained in the Crown reſpectively.

On the Use of the HYDROSTATICAL BALANCE.

THE Hydroſtatick Balance, in order to find the ſpecifick Gravity of Fluids, or how they differ from each other in Point of Denſity, has commonly a Lump of ſolid Glaſs, ſhaped like a Heart, a kind of Wedge, the more eaſily to cleave and ſeparate the Parts of thoſe Fluids in which it ſhall be occaſionally immerſed. Now this being made of Matter not liable to be injured by any Liquor, and of Weight ſufficient to ſink in moſt, is convenient for the purpoſe, and is repreſented as in Uſe by *A*, *Fig*. 4. *Plate* 7. This Machine has a fixed Counterpoiſe for the other End of the Beam, as *B*, which, when the Glaſs is pois'd in rain or river Water, will keep the Balance-beam juſt level, whether it be put at the Top, the Middle, or at the Bottom of the Jar.

NOW all ſuch Liquors as are ſpecifically heavier, that is, more buoyant than common Water, will require Weight to be added on the Side of the immerſed Glaſs, to reſtore the Equilibrium: And ſuch as are leſs ſo, or lighter than common Water, will require Weight to be added to the Counterpoiſe, to bring the Beam, which ought to be ſingularly good and true, to a horizontal Poſition.

IN comparing of two Liquors, in order to find ſimply whether of them is the heavier, 'tis of no great Concern to know what the Bulk or ſolid Content of our Eſſay-bubble *A* is: Becauſe the Grains on either Side added, to bring the Beam again to a Level, will ſufficiently determine how much a Quantity of them, equal to the Bulk of the Bubble, differs from rain or river Water, to which the Machine is commonly adjuſted; which is ſomething more of Satisfaction than from the Hydrometer can be had. But how much the Denſity of the one exceeds that of the other, or generally in what Proportion, cannot be known till the Weight of our glaſs Machine, both in Air and Water, and conſequently the Weight of a Quantity of the Fluid under Conſideration, in Bulk equal thereto, with which it is generally compar'd, be firſt adjuſted and found.

IT may here be remarked, that the Beam of the hydroſtatical Balance can't be well too light, if it be but equal to its Office, without yielding or ſpringing. The Way to prove whether it be true or not, is, when you have found any exact Equilibrium by it, to change both Weight and Scales together, end for end; and then, if no Alteration appears, 'tis perfectly well executed; otherwiſe not.

A ſquare Piece of Paper, weighing but one Grain, may without Difficulty be divided by

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Meaſure into two and thirty Parts of a Grain; and if you deſire your Beam ſhould be affected by the Weight of a few of theſe, the reſt of your Apparatus muſt be very light alſo; leſt the Weight laid on the Point of Support, ſhould make it too ſluggiſh to move ſo free and finely as it properly ought to do.

SUPPOSE then the Weight of our Eſſay-bubble *A*, when taken in the Water, is one hundred and eighty two, and in the Air two hundred and ſix Grains; the Difference, or twenty four Grains, is the juſt Weight of a Quantity of Water equal in Bulk and Dimenſions thereto: Which being known, may be received as a general Standard whereby to eſtimate the ſpecifick Gravity of Liquors by this Machine. For Example; warm a Jar of Water pretty well, it will be thereby rarified, and rendered ſpecifically more light, and of conſequence the Bubble, before adjuſted to that Liquor cold, will on immerſing ſink therein. And by adding Weight on the other Side, we may eaſily learn how much 'tis thereby become ſpecifically lighter than a like Quantity of Water cold; *viz.* merely by deducting the Weight found on Experiment neceſſary to reſtore the Equilibrium, let us ſuppoſe three Grains from twenty four; ſo that the ſpecifick Gravity of the cold Water will be found to be to that of the hot, as 24 to 21, or 8 to 7.

FOR Experiment's ſake, a ſecond Trial may be made the ſame Way, on a Fluid denſer than common Water; as ſuppoſe ſtrong Aſh-lees, replete with a lixivial Salt, in which Caſe we are to add the Difference found on Immerſion of the Eſſay-bubble, ſuppoſe four Grains to twenty four; the ſpecifick Gravity hereof will then be ſignified by the Number 28, and an equal Quantity of Lees will be to common cold Water, as 28 to 24, or 7 to 6; and to an equal Quantity of the Water before warmed, as 28 to 21, or 4 to 3; and thus of any other.

THE ſpecifick Weight of equal Quantities of different Liquors might indeed be alſo found, by filling a ſmall Phial, of known Dimenſions and Capacity, with them ſucceſſively; which ought to be firſt exactly tared or counterpoiſed on the oppoſite Side. Their ſeveral Weights then taken by a nice Pair of Scales, and noted down, may afterwards be compared together tolerably well.

IN like manner might alſo the ſpecifick Gravities of ſolid Bodies heavier than Water be found, was it practicable to reduce them by any Means to ſome certain or determinate Dimenſions, as to the Size of a cubick Inch, or the like: But that being not only laborious, and expenſive, and tedious, but alſo very inconvenient and much leſs exact; the Beauty of the

the hydroſtatick Balance will therefore appear in aſſigning their comparative Gravities, be their Figures never ſo various or irregular, with very great Truth, Eaſe, and Expedition.

FOR the weighing of Solids ſpecifically heavier, or which ſink in Water, hydroſtatically, this Inſtrument is provided with a ſmall glaſs Bucket, marked *C*, *Fig.* 4. *Plate* 7. which in the Air is exactly counterpoiſed by *B*; and in Water, by adding the ſmall Weight *D* on the Bucket-ſide at *E*, to counterbalance the Buoyancy of the Water on the Bucket immers'd. By this Machine Fragments of ſuch Bodies may be weighed indifferently either in Water or the Air; both which, in theſe Experiments, are always carefully to be diſtinctly done; noting their ſeveral Weights.

THE Difference of their Weights thus taken in Air and Water, as has been ſaid, will be preciſely that of a comparative Bulk of Water equal to the Magnitude of the Bodies immers'd. For Inſtance; a Solid, which in the Air weighs an Ounce, may counterpoiſe perhaps only three hundred and twenty Grains in Water; the Difference of which, or one hundred and ſixty Grains, has already been proved, *Page* 129. to be the Weight of a Quantity of Water equal to the Body under Conſideration in Bulk.

TO find then the relative Weight, or the Proportion that ſuch a Body bears to Water, the Rule is: To ſee how often the Weight of an equal Quantity of Water, diſcovered as above, may be found in the abſolute Weight of the ſame Body, taken in the Air; which in the laſt Example will turn out as 3 to 1.

AND again: To compare two ſolid Bodies of different ſpecifick Gravities hydroſtatically, as ſuppoſe Flint-glaſs and Magnet; take Fragments thereof, no matter how various in Weight, or how different in Form. In the Bucket *C* weigh them ſeverally, firſt in Air, then in Water. But previous to the latter, Care muſt be taken to wet both the Bodies and the Bucket very well, that the Air, which is apt to adhere to Solids, and eſpecially to lodge and be retained in their Pores, may be firſt extricated thence; or the Bodies will be thereby more buoyed up than they ought, and the Experiment therefore imperfectly made.

AND again; if thro' the different Denſity of Waters, either from Cold or otherwiſe, our Bucket ſhou'd at any Time happen to be a ſmall matter either too ponderous or too light, this ſhould alſo be brought to Truth and adjuſted before the Operation; either by adding Weight to the lighter Side, not to be brought into the ſucceeding Calculation, or by adding ſomething ſpirituous, if the Fluid be too denſe, or a little Salt, if it prove too rare, till the Balance is well ſettled and brought to its firſt Adjuſtment. In Water then the beforeſaid Frag-

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ment of Glaſs will perhaps fetch up but an hundred and twenty Grains, and the Magnet but ſeventy nine; theſe taken from what they weighed in Air, an hundred and ſeventy one Grains, and an hundred and two, will leave, for Example, fifty one and twenty three, the reſpective Weights of their comparative Bulks of Water: It thence appears, that Glaſs is to Water, as 171 to 51, or as $3\frac{18}{51}$ to 1; and Magnet as 102 to 23, or as $4\frac{10}{23}$ to 1; and by Reduction of the Fractions equivalent, *viz.* $\frac{171}{51}$ and $\frac{102}{23}$ by croſs Multiplication, it will be found, that of conſequence Glaſs is to Magnet ſpecifically, in whole Numbers, as 3933 to 5202, or nearly as 10 to 13; in a reciprocal Proportion.

N. B. *The Truth of theſe Eſſays will appear, by trying the Experiment on two or more diſtinct Pieces of the ſelf-ſame Metal, or Matter, which however different in Magnitude, will be found nevertheleſs to be of the ſame ſpecifick Weight, by the Method now propoſed, if accurately performed.*

AND in this Manner are to be treated all other Subjects that will ſink in Water, and not be damaged by the Experiment, whereby their Goodneſs may in great meaſure be often known: Such as Metals of all kinds; and Foſſils, as Ores, Stones, Gems and Things of like Sort. This Method is of ſingular Service in diſcovering the Difference between Bodies of the ſame Denomination and Kind; for the ſpecifick

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Gravity of ſuch as excel being known, thoſe inferior in Weight may be preſumed to be inferior in Value and Goodneſs: At leaſt, counterfeit Money may by this Method always be certainly known from true.

THE *Africans* are ſaid to be ſo dextrous at this kind of Cheat, and gild ſo artfully, that their bad Money will abide the Touch, and their Gilding even follow the Shears, if the Piece be cut through. But tho' the Money of a baſer Metal may very much reſemble Gold, bear the Touch-ſtone, and even weigh as much in the Air; yet will it never abide the Teſt of the hydroſtatick Balance: For, as it muſt neceſſarily be made of baſer Metal, or Matter leſs compact and more porous, it will always be more buoyed up in Water than genuine Gold in the like Circumſtances would be.

BY the ſame Method alſo, more exactly than by Meaſurement or any other Way, may be found the Cubic Content of any Solid, be it in Figure never ſo oblique or irregular. For, ſince two hundred and fifty three Grains are found experimentally to be the Weight of a cubic Inch of Water; if a Groce of Pipes, for Inſtance, were propoſed as the Subject to be meaſured, and theſe ſhould weigh, ſuppoſe twelve Ounces Troy, leſs in Water than in the Air, the Analogy will then be:

As 253 Grains of Water,
Are to 1 Cubick Inch:
So are 5760 Grains, the Weight of a Piece of Water adequate to the Bulk of the Body under Consideration,
To the Cubick Inches it contains, or 23 nearly of burnt Clay.

Mr. WARD, in his *Young Mathematician's Guide*, gives the following Table of the ſpecifick Gravities; which being ſufficient for common Practice, will here be not improperly inſerted: By Help whereof the Magnitude or ſolid Content of any Thing ſpecified therein, be it in Shape never ſo uncouth, may be found by the following Proportion, from its abſolute Weight in Air only, *viz.*

As the tabular Number,
Is to one Cubical Inch:
So is the abſolute Weight of a Piece of wrought Plate, ſuppoſe,
To the ſolid Inches contained therein.

The TABLE.

The Cubick Inch of	*Ounces Troy.*	*Ounces Avoird.*
Fine Gold - -	10,3592	11,3656
Standard *ditto* -	9,9626	10,9304
Quickſilver - -	7,3844	8,1017
Lead - - -	5,9840	6,5539
Fine Silver - -	5,8500	6,4183
Standard *ditto* -	5,5567	6,0965
Roſe Copper -	4,7471	5,2083
Plate Braſs - -	4,4042	4,8321
Caſt Braſs - -	4,2724	4,6303
Steel - - -	4,1421	4,5445
Common Iron -	4,0313	4,4230
Block Tin - -	3,8615	4,2366
Fine Marble -	1,4294	1,5688
Common Glaſs	1,3608	1,4930
Alabaſter - -	0,9884	1,0844
Dry Ivory - -	0,9621	1,0555
Dry Box - -	0,5432	0,5960
Sea Water - -	0,5427	0,5949
Common Water	0,5274	0,5787
Red Wine - -	0,5237	0,5746
Proof Spirits -	0,4892	0,5368
Dry Oak - -	0,4890	0,5365
Linſeed Oil - -	0,4916	0,5393
Oil-Olive - -	0,4815	0,5283

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HENCE we may obſerve, that Standard, or Guinea-gold, is as 9962; Standard Silver, as 5556; Caſt Braſs, as 4272; and Lead, as 5984, to common Water, which is about five hundred and twenty ſeven of thoſe Parts: So that being weighed therein, Gold ſhould loſe about a nineteenth, Silver little more than a tenth, Braſs about an eighth, and Lead an eleventh of its Weight in Air. And if an hundred and twenty nine Grains of each of theſe, the Weight of an unworn Guinea, be ſeverally weighed in Water, the Gold will, on Experiment, turn out an hundred and twenty two Grains; the Silver about an hundred and fifteen Grains; the Braſs, which takes up more than twice the Bulk of Gold, an hundred and thirteen Grains; and the Lead about an hundred and ſeventeen Grains: And if on the Eſſay they do not ſo, they are either naught, or more hammer'd, and therefore cloſer and more ſolid than uſual.

HAD Capt. DAMPIER known this Method of determining the genuine Value of Metals, he had perhaps ventur'd to traffick with the *Indians* at the *Baſhee* Iſland, for ſome of their yellow Rings; which he ſays in his *Voyages* he had no great Encouragement to do, not being able to determine whether they were Gold or not.

SUCH

SUCH Bodies as will diſſolve, or be damaged in Water, may be weighed in Oil of Turpentine, in which no Salts, Vitriols, or acid Sublimates, will melt, proceeding as with Water; conſidering only, that two hundred and twenty one Grains are a ſolid Inch of this Fluid.

To conclude this Subject: The Equilibrium of Bodies in the groſs Air, if they be very different in Magnitude or Dimenſions, will not continue *in Vacuo*; becauſe when two Bodies compared are unequal in Bulk, the greater protruding more Air from its Place, will be more buoyed up thereby than the other; and when this Support comes to be withdrawn from both, the bigger muſt of courſe preponderate.

THERE are therefore fitting Seaſons when Gold or Jewels may, ſtrictly ſpeaking, be bought or ſold to moſt Advantage. If Gold be weighed againſt Lead; that, as has been ſaid, takes up but half the Room of this; if againſt Braſs, which is lighter, and ſtill more bulky for its Weight, the Gold will of conſequence be leſs buoyed up by the ambient Fluid, than the Weights wherewith it is compared. And, from the exacteſt Equilibrium of this Sort that might be made, was the Air withdrawn, the Weights would certainly preponderate.

NOW, by the Alterations on the Barometer, we know the Air is capable of being on Occa-

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ſions about a tenth heavier at one Time than another. Whenever it is moſt denſe, it will of courſe be the moſt buoyant; and the contrary when it is more rare. If the things compared be ſpecifically of the ſame Weight, they will be no doubt equally affected by any Alteration therein; when they are otherwiſe, a Difference will appear. If it be in your Choice therefore when to buy Gold, do it always when the Air is lighteſt, or in foul Weather; and if you can chuſe when to part with it, let it be in fair Weather, when the Air is the moſt buoyant, and has the greateſt Weight.

BUT for Jewels take the contrary Method; they being nearly of the ſame ſpecifick Weight with Chryſtal, are to the Braſs, againſt which they are uſually weighed, about as 1 to 3. It will be therefore beſt to purchaſe them, and indeed all other light Commodities, when the Air is moſt buoyant, and to ſell them when it is leaſt ſo.

AND for a like Reaſon, the Dealer's Weights ought always to be made of the pureſt Metal, which being never ſo porous as the coarſe, will reduce their Size; and 'tis allowed, that in Traffick the Advantages ought in Juſtice to lie on the Side of the Buyer.

UPON this Principle ſome have contrived an Inſtrument called the *Manometer*; which is no more than a nice Balance-beam, having a hol-

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low Globe or Glaſs hung at one of its Arms, and a Counterpoiſe of Metal, when the Air is in a middle Way, at the other, with Intention to diſcover thereby the Rarity or Denſity of the Air. Whenever the Air became more buoyant, the Globe, being larger in Bulk, and conſequently more ſupported than the Weight, would riſe; and the contrary, when it came to be more rare. The Balance-cock, on a circular graduated Scale, was made partly to point out this Variation. But as this Machine can ſhew nothing more than what the *Barometer* in a much better Manner will do, it is enough to have mentioned it.

PNEU-

PNEUMATICKS.

PNEUMATICKS, a Sister-ſcience of the HYDROSTATICKS, treats of the Nature and Properties of the Air, its Motions and Effects, in the ſame manner as the other does of thoſe of Water. It is commonly received among us for the *Doctrine of the Air*, or the Laws whereby it is condens'd, rarify'd, gravitates, and the like.

The PROPERTIES *of the* AIR *deſcribed.*

THE Air is a thin fluid Maſs of Matter, which hangs about, and revolves along with the Globe of the Earth in its diurnal Motion on its own Axis, and attends it on its annual Journey round the Sun. Let the Body of the Earth be repreſented by a Peach, the Air will be aptly ſignify'd by the Down growing on its Surface.

THE whole Body of the Air, together with the Smoke, Exhalations and Particles of a different Kind floating in it, are in general called the *Atmoſphere*.

THAT the Air is a Body, appears from its excluding other Bodies from the Place where it is. For Inſtance; if we turn the Mouth of an empty glaſs Jar down into another full of Water, but little Water will get Admittance into the ſmaller Veſſel; and that only from the Compreſſure of the Air, by the Weight of the Water endeavouring to enter, and the Air will poſſeſs the reſt of the Room.

THAT the Air is a thin and yielding Fluid, whoſe Parts eaſily glide, and are moved one among another, is not denied by any. It was proved *Page* 108. to be without Tenacity, much leſs can it have any Attraction or Coheſion of Parts, which its Compreſſibility and Elaſticity alſo ſufficiently evidence.

THE Particles of the Air are indeed ſo fine, that they eſcape the Notice of our Senſes; they are not ordinarily to be perceived either by the Touch or the Sight: But yet when a Quantity of it ſhall be thruſt together, as in a tight forceing Syringe, ſtopp'd at the End, the Reſiſtance againſt the Piſton is ſuch, that if the Materials do not give way, no Force whatever will bring that Piſton down. Thus by Force, may Air be ſqueezed together, or compreſſed; and in puſhing down our Piſton, it may be obſerved, we ſeem to work againſt a very ſtrong Spring; which is one very ſenſible Inſtance alſo of the Elaſticity or Spring of the Air.

THAT

THAT it is elaſtick, or endowed with an admirable Spring, appears alſo in Part by its conſtant Endeavour to maintain an equal Degree of Denſity in all its Parts; and by its immediately falling into Motion to make good all Deficiences whenever they caſually happen therein.

THAT it is heavy, appears by its Preſſure on all Bodies expoſed thereto; and eſpecially by its counterbalancing and ſuſtaining all the groſſer Fluids in elevated Pipes to a certain Degree.

THE Weight of the Air was proved by an Experiment propoſed *Page* 12. whereby a Quart of Air, of the common Degree of Denſity, near the Earth, will be generally found to weigh about twenty Grains *Troy*. To corroborate which, Air of the common Degree of Denſity, may in ſuch a Veſſel be ſtill more condenſed by the Injection of other Air from a forcing Syringe, upon which a conſiderable Increaſe of Weight will be found. And thus is the Gravity of the Air, not ſuſpected by the Antients, become inconteſtable with us.

THE World is indebted to GALILEO for this notable Diſcovery. He found by Experiments, that Water might be raiſed by the common Pump to a certain Height, and no farther: Whereas had Nature abhor'd a Vacuum, as the Philoſophers then thought, it might have been raiſed indefinitely, as far as a Vacuum could be made. But this not appearing on the Trial to be ſo, he happily thought of the Counter-balance of the Air's Preſſure, which TORICELLIUS, BORELLI and later Philoſophers, the *Engliſh* eſpecially, have ſince purſued and very much improved thereon.

THESE Gentlemen conſidering, that ſince the Weight of a Column of Air from the Earth to the Limits of the Atmoſphere, was found equal to a Pillar of Water of like Dimenſions, about thirty five Foot in Height, and that as Mercury was fourteen times heavier than Water, 'twas probable one fourteenth Part of thirty five Foot of Mercury would in like manner be an Equipoiſe thereto. Accordingly they took ſeveral Tubes of Glaſs, hermetically ſealed or cloſed at one End, filled them with Mercury, and then inverting their nether End into a Ciſtern of the ſame, found, that Part of the fluid Pillar, when held perpendicular, ſtill flowed out, and that the other Part remained ſtanding, as they expected it would, much about the ſame Height in all. This being noted on the Glaſs, and divers Alterations in the Height of the Mercury frequently appearing, after a long Series of Obſervations, it is at length agreed; That the Preſſure of the Atmoſphere, when leaſt in very foul and ſtormy Weather, is much about equal the Weight of twenty eight Inches of Mercury; and in fine and ſerene Weather, that it will ſupport about thirty one Inches of that Fluid: Between which Extreams, all the Changes that happen

happen in the Weight of the Air near the Surface of the Earth, are generally found to be. And to theſe Experiments is owing the Invention of the Barometer, or Weather-Glaſs; which, being well made, is a very curious Balance for determining from time to time the general Alterations in the Weight of the Air, and conſequently is of great Uſe in foreſhewing what Weather may be expected.

On the BAROMETER.

THE moſt ſimple, and indeed one of the beſt Barometers, is this but now deſcribed, and is what any Perſon may himſelf make, having a clean glaſs Tube, cloſed at Top, more than thirty one Inches long, and of any convenient Diameter; but the larger the better, that the Attraction of Coheſion between the Fluid and the Glaſs may be no conſiderable Hindrance to the Execution and Performance of the Machine. Fill ſuch a Tube with pure Mercury, which may be beſt done by Help of a ſmall Funnel that will ſuffer it to paſs only in very ſmall Drops; by the ſucceſſive falling whereof into the Tube, the Air will be extricated from the Mercury pretty well; and the Column of Mercury viewed thro' the Glaſs, will then reſemble a Rod of Steel finely poliſhed. Stop the End with your Finger, invert it, and ſlip it ſuddenly off into an open Veſſel, having other Quickſilver in it. Part of the Mercury will thereupon deſcend, and fall into the Ciſtern, and the reſt will be ſuſtained in the Tube to the Height of twenty nine Inches and a half above the Surface of the Quickſilver in the Ciſtern, if the Air happens to be of a middle Weight, and the Weather *changeable*. If it be inclined to *fair*, the Mercury will ſtand ſomewhat higher; if *foul*, it will ſettle ſomething lower.

To prove that it is the Atmoſphere's Preſſure on the Surface of the Quickſilver below, which ſupports the Mercury in the Tube; put the Barometer, thus made, under an Apparatus that may be exhauſted of Air; and as this by the Pump is gradually done, the Mercury in the Tube will be ſeen to fall proportionably. When the Air is wholly drawn off, the Mercury will lie quite level at Bottom of the Ciſtern; and when the Air is let again into the Receiver, the Mercury will be preſſed up again thereby, and riſe to the Height it ſtood at before. This Experiment is repreſented *Fig*. 5. *Plate* 7.

THE immediate Cauſe of this Appearance, is doubtleſs from the Inequality of the Air's Preſſure on the Surface of the Fluid. Before exhauſting, the Air preſſed every Part of the Ciſtern of Mercury, except the Spot juſt beneath the upright Tube; the Top whereof was however then equally preſſed by a Column of Air of like Baſe and Weight with itſelf, which, had the Tube not diſplaced and transferred its Preſſure elſewhere, would have been incumbent alſo on that very Spot. During the Exhauſtion, the Air's Preſſure is gradually removed from off both the Mer-

Mercury and the Tube. When the Exhaufting is finifhed, thefe being encompaffed with Space void of Matter, and therefore without Weight, the Mercury remains on a Level, merely from the fimple Direction of Gravity; but when, upon Admiffion of the Air, a cafual Preffure is again laid both on the Mercury in the Ciftern, and the external Part of the Tube thereto expofed, (Vacuity from its Situation and Circumftance being ftill preferved within it) the Rife of the Mercury into the Void fhews the Degree of the prevailing Preffure of the Air and its Limits.

To make this Matter plainer if poffible, let us attend to the following Experiment, made on a Fluid lefs denfe than Mercury. In order to which, exhauft a Receiver, fet on a feparate Plate, of its Air, as reprefented in *Fig*. 6. *Plate* 7. and you will have a portable Vacuum. Screw in a Pipe below; immerfe the End in Water, and on opening a Cock, the Fluid will rife into the Receiver in a very fmart Jet, which if required would mount perhaps thirty Foot high merely from the Preffure of the external Air. And was the fame Experiment to be made on Mercury, the Jet would be found to play juft as high as the Mercury in the Barometer would ftand: Nor indeed is this any other than a Barometer in another Form.

INEQUALITY of Preffure, is in general, we are fenfible, the Caufe of all Motion; and fluid Bodies in particular very readily fhew which Way they are prefs'd, by yielding to the contrary: If the Preſſure comes from the Right, for Inſtance, they give way to the Left; if from above, they always ſubſide; if from below, they conſtantly riſe, that the Equilibrium eſtabliſhed in Nature may be uniformly preſerved.

BEFORE we proceed farther on this Head, it may not be improper, for the ſake of Perſpicuity, here to introduce a ſhort Deſcription of the modern *Air-Pump*.

On the AIR-PUMP.

THE Air-Pump was firſt invented by OTHO GERICK, of *Magdeburg*; but was rendered more practicable by Mr. BOYLE; and it hath ſince his Time been greatly improved. *Fig.* 7. *Plate* 7. is the Repreſentation of the Pneumatick Machine now in Uſe; wherein *A* is a Receiver, ground level at Bottom, ſet on a wet Leather, covering a flat Plate *B*, to be exhauſted of its Air occaſionally; which being a Body dilating by its natural Spring, and therein confined, puſhes gradually from the Receiver, thro' the crane-necked Pipe *C*, as far as the Ciſtern *D*, wherewith the two Barrels *E E* communicate; and into which it gets from beneath the Bladder-Valves tied over the Holes made for that Purpoſe, under either Barrel one.

IN each Barrel is a moving Piſton, leathered upward, that it may ſhut off the Atmoſphere above, as *F F*. Theſe are drawn up and thruſt
down

down alternately therein, by Means of a circular Wheel full of Teeth, *G*, and a pair of Racks, marked *R*, to fit thoſe Teeth, thereby conſtantly moved, the one up, the other down, when the Pump is in Uſe, by means of a Crank of very curious Contrivance, *P*, at every regular Revolution of the Winch or Handle *H*. The Racks are kept from flying off from their Work by Rollers behind, which alſo eaſe the Friction.

IN each of theſe Piſtons is ſuch another yielding Valve placed, opening alſo upwards into a perforated Duct, by which the Air extruded from the Barrel at every Stroke of the Pump, when the Piſtons deſcend, may get away. The Action of the two Valves, belonging to each Barrel, is as in the common Pumps, alſo alternate.

THE upper Air being cloſely ſhut from off the Barrel by the Piſtons and Piſton-valves, whenever thoſe riſe, Room is given for the internal Air of the Receiver to dilate, which by its elaſtick Quality it always endeavours to do, and a Part of it thereupon puſhes out of the Receiver, thro' the nether Valve, into the Chamber of the Barrel, where a Vacuum was left on the Riſe of the Piſton. This, whenever the Piſtons deſcend, they would again condenſe, did not the upper Valve, on the ſhutting of the other, give Way, and thereby ſuffer it to eſcape.

BY this Means do we gradually get rid of moſt of the Air included in a Receiver; and

ſo

ſo long as the Air is denſe or groſs, we part with it apace: But when it is much attenuated, it lifts the Bladder-valves of the Pump but weakly; the Operation then becomes more ſlow; and when it is very much thinned, it will want Spring and Power to lift them at all. For which Reaſon, by the common Air-pump, the Air cannot be perfectly exhauſted from our Receivers, though as near as is 59 to 60 it demonſtrably may, if the Machine be good.

THE Racks and circular Wheel before mentioned, in the ordinary Air-pump, are uſed ſometimes to be turned by the Handle, firſt this way, then that, ſtopping every Time the Rack comes to the Bottom of the Barrel, by which Time in making Experiments is loſt: But the late Mr. VREAM found out a Method of ſinking and raiſing the Piſtons, with a regular uniform going round of the Winch, whereby a Crank was always ſeemingly turned directly forward. Now this Crank being communicated by Straps to the circular Wheel moving the Piſtons up and down, into which they were alſo fixed in a moving Centre, pitched at ſome Diſtance from the true Centre of the Wheel, in ſuch manner that the Straps never paſſed the ſaid Centre; but when by half a Turn of the Winch and Crank, the Rack of one Piſton had been depreſſed, by the other half Turn it was brought up again, and the other Piſton thruſt down: And this was alternately done by the Rolling of the circular Wheel backwards and forwards, moved, as was ſaid before, at every Revolution of the Winch and

Crank,

Crank, always kept in Motion directly forwards. In the Draught this Contrivance is pretty well represented; and it might be applied to the raising of Water with two Pumps, worked by a Water-wheel in the same manner, were there not in Use other Methods for that End less subject to Friction.

To prove that the Air is really exhausted, or at least very greatly attenuated, in the manner before spoken of, by the Air-pump, take a Receiver open at both Ends; the taller the better. Cover it with a Plate, having a wet Leather between it and the Glass; to which let there be an Apparatus with a Hinge fixed, with a Contrivance coming thro' a Collar of Leathers, that it may discharge or let a Guinea and a Feather, put Side by Side thereon, go at the same Instant. Exhaust the Receiver, and let them drop together. Tho' one of these be the densest and most ponderous of all the material Substances we know, and the other one of the laxest and most light, yet shall they in this Case fall equally fast, and visibly come down on the Leather exactly together. Which will demonstrate, that the gross Air, always resisting, and considerably retarding the Fall of light Bodies, is by the Pump really removed; and at the same time shew, that *in Vacuo*, Gravity affects all Bodies equally. This Experiment is represented *Plate* 7. *Fig*. 8.

MOREOVER, by Means of a Barometer communicating with the Receiver, fixed beneath the

the Frame, otherwise called the Gage-tube, marked *I*, we are able to discover the gradual Approaches made towards a Vacuum, by the Rise of the Mercury therein, from the Cistern at Bottom, by the Air's external Pressure, always visibly increasing in a regular and just Proportion to the Abatement and Removal of the Air within; as may be observed in the Experiment of exhausting the Air, in order to bring down the Mercury, mentioned *Page* 150, to very good Advantage.

THE Gage-tube may, on Occasion, be shut off from the Receiver by the Cock *K*; and *L* is another Cock, whereby the external Air may easily either be shut off during the Time of exhausting, or admitted again into the Receiver after 'tis over.

The CASE *of the* BAROMETER *resum'd.*

IT has been already hinted, that the Column of Mercury *A B*, in the Barometer, *Fig.* 9. *Plate* 7. was of a just Weight with a Column of Air of like Diameter with the Orifice of the Tube, reaching from the Cistern *B*, to the the Top of the Atmosphere; which Column *G A*, now pressing the Top of our Tube at *A*, was the Barometer removed, would necessarily press the very Point on which it now stands: But in the present Circumstance, a Quantity of Mercury adequate thereto in Weight, is substituted within the Tube, in the Room thereof; the

the Surface of which, could the beforeſaid Column of Air come at, would by its Weight ſoon depreſs the Column of Mercury kept thus ſtationary in the Tube, by the joint Preſſure of the collateral Columns of Air ſurrounding it, marked in the Draught by the pricked Lines; and had the Tube been cloſed at Top by a Piece of Bladder only, on pricking a Hole therein, this would immediately appear, as may eaſily be tried.

WE hydroſtratically know, That in a recurv'd Tube, fourteen Inches of Water will much about equipoiſe and ſupport an Inch of Mercury. Let this be applied towards explaining the Caſe of the Barometer before us, and an Analogy between the Air in this Caſe, and the Water in that, will appear. For Example; *A B*, *Fig.* 10. *Plate.* 7. is a barometrical Tube, filled with Mercury, ſtanding between *B* and *C*, counter-balanced and ſupported by a Column of Air reaching from the Ciſtern *B*, open above to the Top of the Atmoſphere, ſuppoſe at D. Between *A* and *C* is a Vacuum, into which the Mercury will riſe from the Ciſtern *B*, whenever its counter-poiſing Column of Air *B D*, becomes more heavy; as, on the other Hand, it will fall into the Ciſtern when it grows more light. The Ciſtern *B* is uſually made pretty large, and commonly cylindrical, that when the Mercury falling out of the Tube, may ſpread itſelf on a large Area, and not by its proper Weight act againſt and counter-balance too much of the Column in the Tube ſuſtained, as, was it

ſmall

ſmall or narrow, it neceſſarily muſt do. For the ſtationary Height of the Mercury is always to be reckoned from *E*, lying in the ſame Plane with *B*; whither it will, when at Liberty, riſe from the Ciſtern, as to its own Level.

WAS the Atmoſphere of the ſame Denſity from the Bottom to the Top, it would be no great Difficulty, by the help of the Barometer, to determine its Extent; it could not exceed five Miles and a half at moſt: But as the Air is a dilateable Fluid, expanding itſelf in proportion to the Abatement of Preſſure above, as alſo by the Increaſe of its Spring from Heat and other accidental Cauſes, we are not able to ſpeak of its Height with any great Certainty. Moſt of the Learned however judge it to be ſenſible to the Height of ſixty Miles; others to forty five, ſtill growing thinner and thinner as it leaves the Earth, where the Air is denſeſt, the moſt compreſs'd, and therefore the moſt fit for animal and vegetable Uſe.

AND that the Air is really thus compreſſed near the Earth, will appear on tying up a ſmall Quantity of it in a pliant Bladder very cloſe, putting it under a Receiver, and exhauſting the Air from about it. For when the Preſſure of the outward Air is remov'd, the incloſed Air will dilate itſelf every way, and ſwell the Bladder very much; ſo that if it had happened to be well blown up before, and well tied, it wou'd very probably have been burſt by the Experiment. The like would alſo happen,

happen, at leaſt in ſome Degree, was a Man to carry a flaccid Bladder from the Foot of a Mountain to the Top; it would be ſenſibly found to grow more and more turgid, and that in Proportion to his Aſcent, and the Abatement of the Air's Preſſure from without.

LET the Air then be conſider'd as a ſpungy compreſſible Body, ſomething like Wool: If a Handful of which be preſſed cloſe together, it will, we know, be reduced into a very narrow Compaſs; but when left at Liberty, it will recover its former Bulk, by Virtue of the natural Spring of its Fibres. And accordingly, were Fleeces of Wool laid on the Floor, ſuppoſe ten Foot deep, the nether Parts muſt be more compreſſed than the upper, and that in Proportion to the incumbent Weight: And again, if theſe Fleeces be gradually removed, the Fibres of the Wool being elaſtick, will ſtretch forth, unbend themſelves, and occupy more Space than in a State of Compreſſion they did.

THUS is it with the Air: If we abate the Preſſure by aſcending an Eminence, Doctor SCHEUCHZER's accurate Experiments made on the Mountains of *Switzerland*, inform us, That by the Time a Man is ſeven hundred and ninety Foot above his firſt Level, the Mercury in the Barometer, in ſettled Weather, will have ſubſided an Inch; at the Height of ſixteen hundred and ten Foot and a half perpendicular, it will have ſunk two Inches; at

two

two thouſand four hundred ſixty five Foot and a quarter, the Difference will be three Inches; at three thouſand three hundred and fifty ſix Foot, four Inches; at four thouſand two hundred and eighty ſix Foot, five Inches; and at five thouſand two hundred fifty five Foot and a half high, the Mercury will ſtand ſix Inches below what it would have done at the Level of the Sea: Whence it appears, that the Stages determining the Deſcent of the Mercury (an Inch for the firſt ſix) are ſeverally very different, being denoted nearly by the Numbers 790, 820, 855, 891, 930, 969; which Spaces therefore would continue increaſing till the Atmoſphere above ſhould be of no Weight; by which Time the barometrical Mercury would be of no Height.

ON the contrary, ſhould the Air's Preſſure on the Surface of the Earth be any way augmented, as by deſcending into a deep Mine, by the Time a Man ſhould be ſeven hundred and ſixty Feet under Ground, perhaps, the Mercury will ſtand in the Barometer an Inch higher than it did at the Surface. But ſuch a Deſcent being neither practicable or over-ſafe, and as we have found that Water is about eight hundred and fifty times heavier than common Air, 'twill do as well to immerſe the Barometer, ſtanding according to the Preſſure of the Air on the Earth's Surface at a certain Height, into ten or eleven Inches of Water; and if the Mercury thereupon riſes about an Inch, we may thence conclude, that if the Barometer had been let

down

down ſeven hundred and ſixty Foot below the Surface of the Earth, the Effect had been the ſame.

THE portable Barometer is the propereſt Inſtrument for this kind of Experiments, which differs from the Toricellian only, in its having the ſuperfluous Mercury, or what is more than neceſſary to form the ſtationary Column of the Fluid, inſtead of being in an open Ciſtern, as *B*, *Fig.* 9. *Plate* 7. incloſed in a Box, as *A*, *Fig.* 11. *Plate* 7. in the Bottom whereof is a looſe pliant Leather, having ſo much Play left, that it will eaſily become either concave, and ſo let down the Mercury from the Tube when the Air grows light; or convex, and ſo thruſt up Part of the contained Mercury into the Tube when it becomes more buoyant, and preſſes harder againſt it. Underneath the Box is a Screw fixed, and a falſe Bottom fitting the Leather, whereby the Mercury may, for the Convenience of Carriage, be raiſed to the very Top of the Tube, and kept from jogging to and fro to endanger its breaking.

As Fluids at Liberty and unconfined always endeavour to maintain the ſame perpendicular Height, the barometric Mercury, whatever Inclination be given the Tube, being ſtill under the ſame Degree of Preſſure, will do the like. In which Caſe there will indeed be more Mercury thruſt into the Tube, which being ſlanted, becomes an inclin'd Plane, and which therefore on its Sides is expected to ſupport the

Difference of the Weight of Mercury contained between the perpendicular and ſlope Heights.

ON this Account, ſome have endeavoured to augment, or at leaſt to magnify, the Diviſions on the Scale of the Barometer, that the Alterations happening in the Weight of the Air may be the eaſier perceived; and accordingly have contrived a Tube, running ſtraight to twenty eight Inches, as *AB*, *Fig.* 12. *Plate* 7. and then bent by ſuch an Angle as will bring the upper Part to be about thirty one Inches above the Ciſtern. If the Diagonal *BC* be thirty Inches long, the Riſe of the Mercury one Inch perpendicular, will cauſe it to traverſe ten Inches of the Tube diagonally. But as there muſt conſequently be, in this Caſe, ten times more Friction between the Mercury and the Machine, as well as ten times the Attraction, this Inſtrument is in Practice found ſeemingly leſs exact than the other.

SHOULD the barometrical Tube be taken ſuddenly out of the Ciſtern at any Time, it may be obſerved, that the Column of Mercury, ordinarily ſtanding ſome Inches below the Top of the Tube, will thereupon riſe, and ſtrike againſt it with a kind of Shock. The Reaſon of which is, that by the Suddenneſs of the Motion, Part of the Mercury will be made to quit the Tube, from the *Vis Inertiæ* of Matter; and the Remainder of the Column not being a full Counterpoiſe to the Atmoſphere preſſing againſt it below, 'twill therefore

therefore be puſhed againſt the Head of the Tube with a Force equal to the Difference of the two Weights; juſt as one Arm of a Balance riſes with Force, or kicks up, when its Antagoniſt is over-charged with Weight.

IT might therefore be expected, that the whole Column of Mercury, in this Circumſtance, would be buoy'd up or kept ſuſpended by the Puſh of the Air; and thus it would really happen, as in the pendent Barometer it does, was the Tube ſmall, and held exactly upright; or otherwiſe, one Part of the lower Surface of the Mercury becoming ſomething longer than the reſt, by over-weighing and falling out of the Tube, would diſturb the reſt, and incline them alſo to follow: For the Demonſtration whereof, ſee *Page* 76. before-going. If ſome Water be purpoſely put on the Mercury in making this Experiment, as the Mercury gradually deſcends from the Tube, the Water, by the Weight of the Atmoſphere, will be forced up into the Vacuity and fill the Pipe; which will give us another evident Inſtance of the Air's Preſſure, and intimate the Manner in which it acts in *Hydraulicks*, or the Practice of raiſing Water for Uſe by the various kinds of Pumps.

HAVING mentioned the pendent Barometer, the Deſcription of this Machine, as made by the late Mr. PATRICK, will not be diſagreeable to the Curious. The Tube *A*, *Fig.* 13. *Plate* 7. is ſtraight and ſlender, ſomewhat conical, hermetically ſeal'd at Top, and is commonly five Foot or better in Length. The nether End is open, and always freely exposed to the Air. This is to be filled with Mercury purged of its Air, and turn'd gently down. What Mercury the Air shall not be able to support, will thereupon fall away; the rest will return, vibrate, and hang ready, either to rise in the Tube on any accidental Increase of Weight in the Air, or to sink in it in Case of any Abatement therein; and by due Observation, on a regulating Barometer the Marks may be afterwards added, and the Scales graduated as Opportunity offers.

THIS Instrument has usually two Scales to observe by; at either End of the Column of suspended Mercury one. These are commonly somewhat different in Length, and the Divisions not equal: For as the Tube is a little conical, the Column of Mercury will necessarily be shorter in one Part of it than in the other. The Scales therefore of this Barometer are always to be severally adapted to each Tube.

THE Mercury in this Machine, instead of rising and falling three Inches, as in the common one it does, will move in some ten, in others twenty or thirty Inches perpendicular (according as the Tube happens to be more or less taper) which makes the Alterations in the Air's Weight very perceptible thereby: It is therefore a very good, but not a cheap Barometer; not one Tube in a hundred being fit for the Purpose. If they be nearly cylindrical, or over large, they will not do at all.

Di-

Directions for observing the WEATHER *by the* BAROMETER.

BEFORE we have done with this Subject, it may not be amiss to subjoin the Directions which the said Mr. PATRICK, after long Experience, has given as the standing Rules whereby the Alterations of the Weather might be generally prognosticated by Help of the Barometer, and which are to be rationally accounted for on the Principles herein laid down.

1. THE rising of the Mercury presages in general, fair Weather; and its falling, foul Weather, such as Rain, Snow, high Winds and Storms.

2. IN very hot Weather, the falling of the Mercury indicates Thunder.

3. IN Winter, the Rise of it prognosticates Frost; and if, in frosty Weather, the Mercury falls three or four Divisions, there will certainly follow a Thaw: But in a continued Frost, if the Mercury should rise, it will certainly snow.

4. WHEN foul Weather happens soon after the falling of the Mercury, expect not much of it. And on the contrary, expect but little fair Weather when it follows soon after the Mercury has risen.

5. In foul Weather, when the Mercury riſes much and high, and continues ſo for two or three Days before the foul Weather ſeems quite over, you may expect a Continuance of fair Weather to follow.

6. On the contrary; if in Fair Weather the Mercury falls much and low, and ſo continues for two or three Days before Rain comes, you may then expect a great deal of Wet, and probably high Winds.

7. The unſettled Motion of the Mercury denotes uncertain and changeable Weather.

8. The Words graved on the Plates are not ſtrictly to be minded, tho' for the moſt part the Weather will alſo agree with them, as to the Riſing and Fall of the Mercury: For if it ſtands at *Much Rain*, and then riſes to *Changeable*, it preſages fair Weather, tho' it will be of a ſhorter Duration than had the Mercury been higher. And on the contrary; if the Mercury being at *Fair*, ſhould fall to *Changeable*, it indicates foul Weather; but not ſo much of it as if it had ſunk lower.

In order therefore to paſs a right Judgment of what Weather is to be expected, we ought to know whether the Mercury be inclined to riſe or fall; in determining of which, the following Rules will be of Uſe.

1. IF the Surface of the Mercury in the Tube lies convex, that is, higher in the Middle of the Tube than at the Sides, it is generally a Sign that the Mercury is riſing.

2. IF on the contrary, the Surface of it appears concave, or hollow in the Middle, it is certainly ſinking.

3. IF its Surface ſeems to be plain, the Mercury is ſtationary; or rather if it be a little convex: Since Mercury, being put into a glaſs Tube, eſpecially if it be ſmall, will naturally have its Surface a little convex; becauſe the Particles of Mercury attract each other more forcibly than they are attracted by Glaſs.

4. IF the Orifice of the Tube be ſmall, always ſhake the Barometer when you wou'd obſerve; and if the Air is growing heavier, the Mercury will ordinarily riſe about half a Tenth of an Inch perhaps higher than it ſtood before; if 'tis growing lighter, it will ſink as much. This proceeds from the Adheſion of the Mercury to the Sides of the Tube, which prevents the Freedom of its Motion, till the Parts are diſengaged by the Shock; otherwiſe the Mercury may not move of its own accord, perhaps, till after the Weather it ought to have indicated is paſt. But if the Orifice of the Tube be a Quarter of an Inch or more in Diameter, no ſuch Precaution is neceſſary.

Some EFFECTS *of the* AIR'S PRESSURE *described.*

WHEN the Preſſure of the Air was firſt diſcovered, according to the Fate of all conſiderable Inventions, it met with Oppoſers, who objected, That if the barometrical Column of Mercury was really ſupported by the Air, it ought to have no Weight when proved by a Balance; which on the Trial will not appear.

THE Air's Preſſure, by the forementioned Experiments being undeniably proved, makes this Objection ſcarce worth a Reply. However, to prevent the Triumph of ſuch as had rather contend for Victory, than ingenuouſly ſubmit to Conviction, and own the Truth, we anſwer: That the Materials of which the Barometer is made, are all equally preſs'd, and equally buoyed up by the ambient Air, as well ſeparate, as when put together; they are therefore, in either Circumſtance, of the ſame abſolute Weight. And tho' the Column of Air, *Fig.* 10. *Plate* 7. *B D*, or one in all Reſpects equal thereto, does certainly ſuſtain the Column of Mercury *E C*, in the Tube, which has a Vacuum of no Weight above it; yet as there is a Column of Air *A G*, very nearly of equal Weight with *B D*, preſſing on the Head of the Tube, and not to be removed thence; therefore it is that on the Experiment, no Difference in Point of Weight appears. Whereas, was the Ex-

Experiment to be made on a Tube that would reach beyond the Limits of the Atmoſphere's Preſſure, or could the Preſſure of the comparative Column of Air *A G* by any Means be removed from off the Head of the Tube, no doubt a conſiderable Difference, equal to the Weight of the Column of Mercury ſupported, would then be found.

IN like manner, the Pillar of Mercury in the pendent Barometer, which is evidently ſupported by the Preſſure of the Air beneath, is no manner of Weight on the Hand; but yet, as a counterpoiſing Pillar of Air muſt be allowed to depreſs the Top of the Tube without, juſt as much as the Mercury therein ſupported may be allowed to weigh, no Difference in point of Weight can appear; and our Senſes may be admitted eaſily to deceive us in this Caſe, as to the Thing we do certainly lift.

THE determinate Quantity of the Air's Preſſure depends on the State thereof at the Time of Trial. When 'tis heavieſt, fourteen Pounds eleven Ounces Avoirdupoiſe is found to preſs on every ſuperficial Square Inch contained in all Bodies expoſed thereto; and fourteen Pound one Ounce when it is lighteſt. At a Medium, a circular Inch is ſubject to the Weight of about twelve Pounds, ſo much being required to raiſe the Piſton of an exhauſting Syringe, well clos'd at Bottom; which therefore we may take as the general Standard for finding the Quantity of the Air's Preſſure on any circular

Plane

Plane whatever (ſince the Areas of Circles are proportionate to the Squares of their Diameters) by this Analogy:

As 1, *the Square of the Diameter one Inch,*
Is to 12 *Pounds, the Preſſure thereon:*
So is the Square of any Diameter propoſed,
To the Preſſure on the Area of the Circle correſpondent thereto.

To prove this Fact; take a Pair of braſs Hemiſpheres, ſuppoſe three Inches and a half over. Put a Ring of wet Leather between their Edges, which ought to fit each other very well. Exhauſt the Air from between them, and they will require a Pull, as by the Steel-yards may be tried, of near an hundred and fifty Pounds to part them; and yet they will fall aſunder by their own Weight *in Vacuo*. The firſt of theſe Experiments is repreſented *Fig.* 14. the other *Fig.* 15. *Plate* 7.

The Weight of the Air will be always ſenſibly felt, on drawing up the Piſton of an exhauſting Syringe, as above: Since it will be forced down by the Preſſure of a Column of Air correſpondent thereto in Diameter, of the Height of the whole Atmoſphere; and if its Bore be three quarters of an Inch in Diameter, the Hand that makes the Experiment will find very near the Reſiſtance of ſeven Pounds if the Weather be inclined to Fair. But yet, whenever this Machine alſo is put under a Receiver, and the Air exhauſted from about it, the beforeſaid Weight there-

thereto annexed will evidently ſink: But when the Air is re-admitted, and comes again to preſs the Piſton on one hand, and againſt the Weight on the other, it will riſe and return to its former State.

AND ſince ſo great a Force as twelve hundred Pounds is required to ſeparate two circular Planes of but ten Inches over, kept together merely by the Force of the Air, it is thence eaſy to judge of the very great Preſſure lying conſtantly on the Body of a middle-ſized Man, the Surface whereof will be found ordinarily to meaſure to about twenty ſquare Feet. This, from the evident Experiment beforementioned, can never be leſs than forty thouſand five hundred Pounds; but on occaſions may amount to forty two thouſand three hundred Pounds, or one and twenty Tons and one ſeventh.

THE general Preſſure of this Fluid may be aptly compared to a ſtrait and general Bandage, made equally on every Part of the Body, the Sum total whereof would amount to the Preſſure juſt named; which if laid on any particular Part of the Body, would doubtleſs inevitably cruſh it: But as the Body is in every Part loaded alike, 'tis embraced, and as it were bolſter'd up by it on every Side.

THIS external mighty Force would be inſufferable, and even fatal to us, was not the Air we breathe taken into our Lungs, mixed with the Blood, and after that circulating with the

the Maſs of Fluids throughout the Body, of equal Force with the external, and therefore able to repreſs and counter-balance the enormous Preſſure from without: Juſt as the Air on the Right Side of us, bears againſt and reſiſts the Preſſure made by it on the Left, whereby we are freed from the great Suffering and Violence which otherwiſe we ſhould ſoon be ſenſible of to our Coſt.

To evidence the Truth of this: Take only an open circular Glaſs four or five Inches over, covered with a ſtout Bladder, like the Head of a Drum. So long as the Air preſſes this Membrane on both Sides equally, it is obſerved to lie ſtreight, at reſt, and truly level; but it can no ſooner be ſet on the Pump, and Part of the Air exhauſted, but the outward Air will viſibly depreſs the upper Surface of the Bladder into a concave Form. On letting the exhauſted Air in again, it will immediately return to its former Situation; but ſhould it be continued, by the Time the under Air is greatly attenuated beneath, and the Reſiſtance of it nearly removed, the yielding Subſtance will probably give way to the upper Force, in a very audible Manner. For as there is a Vacuum made within the Glaſs, the whole Body of the adjacent Air, on the Burſting of the Bladder, will by its natural Spring immediately move, to make good the Deficiency: And ſo far as the Air ſhall be ſenſibly ſhaken by the Suddenneſs of the Shock, ſo far the Sound of the Burſting will be heard, like the Noiſe of Fire-arms, and for ſomewhat a like Reaſon. On

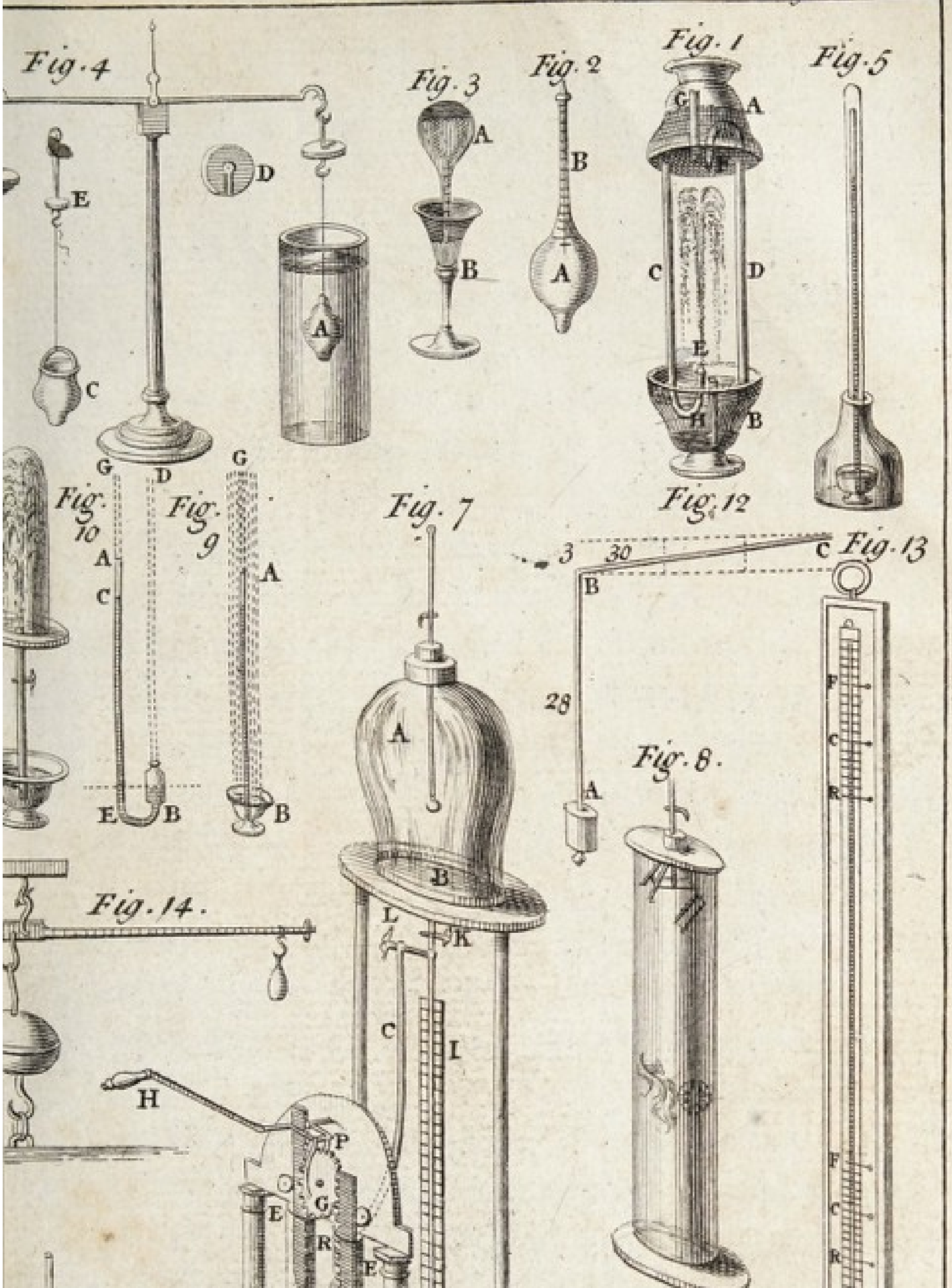
Fig. 4
E
D
C
A
Fig. 3
A
B
Fig. 2
B
A
Fig. 1
G
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Fig. 5
Fig. 12
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Fig. 10
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Fig. 9
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Fig. 7
A
B
L
K
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H
P
G
E
R
F
D
Fig. 13
3
30
C
B
28
A
Fig. 8
F
C
R
Fig. 14.
11
A
Fig. 15.

J. Cole Sculp.

On the Art of Diving.

ANOTHER Way of conſidering the Preſſure of the Air is, by comparing it with its adequate Weight of Water. It is known to counterpoiſe at a Medium, about thirty three Foot of Sea-water, a cubic Foot whereof weighs experimentally ſixty four Pounds; of conſequence therefore, the Body of this Fluid muſt preſs at leaſt with the Force of two thouſand one hundred and twelve Pounds on every ſuperficial Foot near the Surface of the Earth, where, as has been ſaid, the Atmoſphere is generally the moſt compreſſed. Should however, any Quantity of this Fluid be by any Means conveyed to the Depth of thirty three Feet of Salt-water, it would, lying under the Weight of a double Atmoſphere, be there doubly compreſſed, and forced into near half the Space it took up on the Surface. Should it be farther immerſed to the Depth of ſixty ſix Feet, its Dimenſions would be ſtill much more contracted, as being under the incumbent Weight of a treble Atmoſphere; it will then be found to take up but one third of the Space it held at firſt: And at ninety nine Feet below the Surface, it will be crouded into one fourth of the Room it at firſt took up.

For this Reaſon, the Divers, who are obliged to go down to great Depths in Water, if they have only Air of common Denſity in their

their Bodies, which is commonly conveyed to them ſucceſſively in Pipes from the Surface, always find themſelves greatly oppreſſed by the Weight of the Water then above them. A Perſon, who from the Surface of the Earth having only common Air in the Veſſels of his Body, is but ill provided to ſuſtain a double or a treble Weight from without; and the additional Preſſure will doubtleſs be a great Incumbrance to him, how equally ſoever the Weight may be diſtributed and laid on every Part.

'TIS a common Experiment with the Sailors, to ſink a Bottle well cork'd, with only common Air in it, to a good Depth in the Sea, that on pulling it up they may find, as they generally do, the Cork forced into the Bottle by the external Preſſure of the Water.

A noted Diver, not long ſince, in thirteen Fathom Water, having the Trunk of his Body cas'd in Armour, had his Arms, which were only covered with Leather, ſo ſqueezed, that the Circulation was almoſt ſtopped, and the Blood was forced out of his Eyes, Noſe and Ears, by the very great incumbent Preſſure, which had nearly cloſed his Blood-veſſels. He lay ſix Weeks by the Hurt he received in this Experiment. And tho' he ſaw a Caſk of Dollars but at a ſmall Diſtance from him, it was not in his Power to get at it; and his Companion, venturing a little farther, was near expiring when he came up, and actually died in three Days time.

IN

IN order therefore to remedy this great Difficulty, and to render Pearl and Coral-fiſhing, and the Recovery of Things loſt by Shipwreck, more practicable, the Diving-bell was invented; which is a ſtout Machine, made of Wood or Copper, bell-faſhion, about eight Foot high, and as much in Diameter at Bottom; this Form being the moſt advantageous of any for the Purpoſe, becauſe of its great Capacity downwards, whence it may happen, that when the Bell is really half full of Water, it may not exceed perhaps two Foot deep in the Machine. It has Seats within, for the Divers to reſt themſelves upon. It is hung round on the Out-ſide with Weights, ſo diſpoſed as to make it ſink with the Mouth downwards, in a perpendicular Poſition. The Model of the Bell *A*, and the Utenſils, you have repreſented *Fig.* 1. *Plate* 8. which being put into a large Jar of Water, anſwers all the Experiments perfectly well.

THE real Machine, having three or four Men in it, with proper Inſtruments for the Buſineſs propoſed, may be let down by the Yard-arm of a Ship, upon the Wreck or Veſſel loſt, to the Intent that the People within may break up the Hulk, and faſten Ropes to Cannon, Caſks, or any other Thing worth bringing up; and then the Sailors above, on a proper Signal given, ſtand ready to weigh them up with Tackles, by Force of Hands.

As the Machine is lower'd in the Sea, the Air

Air within will of courſe be gradually compreſſed by the Weight of Water above conſtantly endeavouring to puſh into the Bell, and will conſequently riſe therein by Degrees; ſo that at thirty three Foot deep, it will be one half, at ſixty ſix Feet, two thirds, and at an hundred Foot, it will be, as aboveſaid, about three quarters full of Water, agreeable to what was offer'd of this kind, *Page* 64. This Condenſation of Air will not however by its increaſing Preſſure greatly affect the Perſons in the Bell, tho' it really be of equal Force and Reſiſtance to the whole Weight of Water whereby it is compreſſed: Becauſe as it is always to be let down ſlowly, the People have Liberty to reſpire the Air condenſed during the whole Time of its Deſcent.

FROM the Capacity of the left Ventricle of the Heart, whereby the Blood is thrown out into all Parts of the animal Syſtem between every Pulſe, ſeventy five of which are generally made in a Minute when the Body is in Health; and as the Quantity of Blood requiſite to fill all the great Veſſels in a human Subject, is uſually eſtimated at about twenty Pounds, Anatomiſts thence judge, that the Circulation of the greateſt Part of the Maſs of Blood, thro' the Lungs, muſt be performed in about five or ſix Minutes. The Divers, in their Deſcent, are from hence internally provided by Degrees, to ſuſtain the great and prevailing Preſſure from without, to which the internal Air muſt be neceſſarily a proper Antagoniſt at all times, and *in Equilibrio* with it, or elſe moſt fatal Effects would immediately follow.

AND

AND as this Machine is to be deliberately lower'd, ſo is it to be raiſed, leſt the Air taken into the Mens Bodies, at the Bottom of the Sea, in an extraordinary Degree of Compreſſure, ſhould by its natural Spring evolve itſelf too ſuddenly, in caſe that Preſſure is precipitately withdrawn; by which Accident, rending the Coats of the Veſſels might bring on immediate Death.

THE Diving-bell thus anſwer'd the Intention of the Contrivers pretty well; but ſome Inconveniencies ſtill attending it, Dr. HALLEY undertook to improve it. As it contained but four or five Hogſheads of Air perhaps at firſt, when it came to the Bottom of the Sea theſe were reduced into the Bulk perchance of one. Now by Experience it is found, that a Man requires about a Gallon of freſh Air to ſubſiſt on a Minute, and leſs than a Hogſhead will ſcarce ſerve him an Hour: Becauſe the ſulphurous Effluvia from the Blood either abſorb or vitiate the wholſome Quality of the Air, or, by blunting its Particles, render it in Time effoete, unfit for Reſpiration, and even poiſonous.

A ſecond Objection to the original Diving-bell was, the Want of Light. This obliged them to take down Candles. And a lighted Candle ſpoils as much Air as a Man may uſe: Which is proved, by ſetting one under a glaſs Receiver, repreſented *Plate* 8. *Fig.* 2. full of

 com-

common Air, on a wet Leather, to prevent a Supply; which, when either consumed or vitiated, the Candle soon of itself goes out. And no doubt but an Animal in like Circumstances, would sicken and faint in a very short Time; whence Mr. PAT. GORDON, in the fifteenth Paradox of his *Geographical Grammar*, asserts, *That there is a remarkable Place in the Globe of the Earth, of a very pure and wholsome Air to breathe in, yet of so strange and detestable a Quality, that it is absolutely impossible for two of the entirest Friends that ever breathed, to continue in the same in mutual Love and Friendship, for the Space of two Minutes of Time.* This must be where they had scarce four Gallons of Air, or that Quantity of Space more than their Persons would possess.

A third Objection to the original Diving-bell was, That when the Air made use of became hurtful to Life, there was no way of getting rid, or of shifting it; and the former Quantity of Air being thus reduced by Compression to the Compass of one Hogshead, four Men and a couple of Candles could scarce subsist therein ten Minutes: Which being too short a Time to pass up and down, and do much Business in the Diving-way, the Invention in this Particular fell also very short of Perfection.

THE Doctor removed the first of these Objections, by fixing a Cock in the Head of the Machine, to let out the vitiated or corrupt Air, when necessary, as at *B*. This succeeded very well.

The

The warm Air being lighter than the cold, always roſe above, and was therefore firſt puſhed forth. Nor was the Preſſure of the Water on the Hole of the Cock above, able to confine it in the Bell; becauſe the Column of Water condenſing the Air, and endeavouring to puſh in at Bottom, was about eight Foot longer, and conſequently much heavier than the Column preſſing on the Cock at the Head of the Machine.

WHENEVER the corrupt Air was let looſe, the Surface of the Sea was put all in a Foam: For as the Air, in its natural Degree of Compreſſure on the Surface of the Earth, unwinds or expands itſelf to very large Dimenſions; when rid of that Preſſure, it will doubtleſs act in the ſame Manner, to a ſtill greater Degree, when contracted into one fourth of the Space: And a Portion of Air, at the Depth of a hundred Feet, about the Bigneſs of a Hazel-Nut, might become perhaps as large as an Orange at the Surface; whence the Appearance juſt mentioned may very reaſonably be ſuppoſed to proceed.

TO ſupply the Bell with freſh Air, the Doctor contrived to have a Veſſel ſomewhat like a Barrel, with one Head only, or in Fact a ſmaller Bell, as *C*, *Fig.* 1. *Plate* 8. kept going continually between the Surface of the Water, where it ſtill took in freſh Air, and the principal Machine. This Veſſel being ſunk a little lower, had the Air therein more compreſſed than that in the larger. Into the Head of the ſmaller was fixed a ſtrong leather Pipe, with a Cock at the End, which one of the Divers took and turned whenever they wanted a Supply of freſh Air, which was eaſily received into the larger Machine. This Contrivance not only afforded them a continual Supply of wholſome Air; but by its elaſtick Power emptied the Bell of Part of its Water, and conſequently gave them more Room to move and act in.

A ſtrong Lens, eight Inches over, was fixed at the Head of the Machine, as *D*, to give them Light, with the convex Side downward, in order to ſpread the Light as much as poſſible within the Bell: Which ſo well ſucceeded, that the Doctor ſays he has read a *Gazette* at the Bottom of the Sea in calm Weather; but in a Gale of Wind, the Rays of Light being frequently broken by the Motion of the Water, his Cabbin was then ſomewhat darkened.

THIS ingenious Gentleman at length brought Matters to ſo great a Degree of Perfection, that he could detach one of his People from the principal Machine, to any proper Diſtance, with ſomething like an inverted Hand-baſket of Lead on his Head, as *E*, ſo ſhaped that he might ſee his Way, and what lay before him. In the Top of which was fixed a flexible Pipe, like that belonging to the Veſſel, for tranſmitting freſh Air when wanted. The Perſon, by turning a Cock, could ſupply himſelf from the Bell, if he mounted a little higher than the Place of Communication, whence the Air would

would then naturally riſe into this his Helmet; and being denſer than the Air us'd and ſpoil'd, would therefore extrude it. And this was ſo contrived, that had any Accident happened to the Perſon ſent out, or if he neglected to turn his Cock, and ſo endanger the Bell by the Loſs of Air, the People within had another Cock at command, by ſhutting whereof the ill Conſequence of ſuch an Accident might have been avoided. And as ſuch a Perſon came gradually into Air of a fit Denſity to repel the very great Preſſure of the Water in ſo conſiderable a Depth, he had of courſe reſpir'd it ſufficiently to fortify his Body againſt the external Preſſure at that particular Depth of Water, and therefore could not be oppreſſed by its Weight on his quitting the Bell.

THE Dreſs of the People who practiſe this Trade is generally made of thick Flannel, which being once wet, and the Water warm'd by the Heat of the Body, it will afterwards ſcarce feel any Cold from moving about in the Water; becauſe the warm Water, lodged next the Skin, will always keep the ſame Place.

THOSE who go down in this Machine generally for ſome Time complain of a Pain in their Ear; which is by ſome thought to proceed probably from the extraordinary Preſſure of the Air condenſed on the *Membrana Tympani*, or a fine Membrane covering the Cavity, or Drum of the Ear; which is a ſmall Aperture, imagined by ſome Anatomiſts to be cloſ'd with a Valve on the hither Side. Within this Membrane there can only be common Air, (for the Circulation of the Blood in these Parts is very slow) and without it is Air considerably condens'd, whereby the said Valve is supposed to be depressed, and the Part being exceeding nervous, might consequently create the Patient a great deal of Pain. But when the Condensation of the external Air becomes strong enough to push down this Valve, the Pain then ceases, and the Patient recovers his former Hearing.

WHETHER there be any such Aperture in this Membrane, is not very certain, nor is it of any great consequence to the present Point, since by the *Eustachian* Duct passing from the Mouth immediately to the Cavity of the inner Ear, there is as free a Communication as can be expected thro' so small a Canal. And hence it is observable, that such Persons as are hard of Hearing, when they are more than ordinarily attentive, are very apt to open their Mouths, that they may thereby catch as many of the Rays of Sound as they can, in order to assist their Hearing. The Trouble therefore that the Divers feel at first in the Ear, proceeds more probably from some Difficulty the Air may find in working itself, on the first Compressure, through the *Eustachian* Tube; and their growing easy afterwards, may arise from its taking afterwards the due Effect, and restoring the Equilibrium interrupted in that Part.

HOWEVER that be, one of these Divers imagining

gining himſelf more cunning than the reſt, thought to keep away the Ear-ach, by ſtopping his Ears full of chew'd Paper; but he fell ſhort of his Expectation: For as the Preſſure increaſed, the Membrane was not only preſſed as before, but the Wad of Paper was depreſſed along with it; ſo that the Surgeon had a great deal of Difficulty to get it out again.

BEFORE we quit this Subject, it will be proper to give a ſhort Deſcription of the Caſe, or Suit of Armour, made Uſe of for diving in ſhoal Water, where indeed Wrecks commonly lie, intended to defend the Head and Trunk of the Diver from the external Preſſure, ſo that his Ribs may move, and he be able to fetch his Breath.

THE ſide Sketch of this Contrivance is given *Fig*. 4. *Plate* 8. and by *Fig*. 3. is repreſented the Diver therein equipp'd for Service, at Bottom of the Sea, let down thither by a Rope faſtened round the Neck of the copper Machine, which ſeparates at the Waiſt to receive his Body, the two Parts of which are connected by Straps of Iron ſcrew'd down, when the Diver is in, before and behind. Between the Place of the Right Arm and the Waiſt, is a Piece of Copper, which draws out of a Grove, to admit that Arm after the reſt of the Body is in. This Grove is made Water-tight. On each Side of the Head-piece is fixed a Tube, to which ſeveral Lengths of ſtiff leather Pipe, diſtended by Rings at proper Diſtances, may be ſcrew'd occaſionally, according to the Depth of Water thro' which the Air is to be conveyed down from the Surface. In Front of the Head-piece is fixed a ſtrong convex Glaſs, for ſuſtaining the Preſſure of the Water, ſo that the Operator may ſee what he is about. Juſt below his Elbows, where the Blood-veſſels lie pretty deep, and under his Knees, are girt leather Bags, fit to keep out Water; for tying which to the copper Machine there is left a ſmall Necking.

PEOPLE have been in this Machine forty Minutes at a Time, in a moderate Depth of Water, and have done Buſineſs upon a Wreck: But as there cannot be a free Circulation of Air thro' the Pipes of Conveyance, they are therefore obliged to uſe Bellows, and ſuch like Contrivances, to promote it. Provided the Buſineſs be of ſufficient Importance to defray the Charge of the Bell, nothing anſwers the Intention ſo well.

Some Effects of the ATMOSPHERE'S PRESSURE *on* ANIMAL *and other* BODIES.

THE Alteration in the Air's Preſſure upon our Bodies, is in general very ſenſibly felt by us. In clear ſerene Weather, when it acts with the greateſt Weight, we uſually find ourſelves more vigorous, chearful and alert: In foul and cloſe Weather, when the Air is more light, we are moſt commonly ſupine, dull, and languid.

In the former Caſe, the Fibres of our Fleſh are braced up well, and made very tenſe, and of conſequence the Channels of the circulating Fluids muſt be contracted by the greater accidental outward Preſſure, aptly compared to a general Bandage on the Body; whence they muſt move, in equal Times, with more Velocity than when the Coats of the Veſſels, for want of a proper Preſſure, are diſtended and relaxed. And that this is the Caſe, appears in Part from an overſtrain'd Limb's receiving immediate Strength and Relief from being bound up.

THE Lunaticks are a notable Inſtance of the Change of Weight in the Air. At New and Full of the Moon, when her Attraction, in Conjunction with that of the Sun, raiſes the groſſer Fluids in the Tides, it alſo generally cauſes an Alteration in the Gravity of the Air and Weather, ſhewn after by the Barometer; whence the Blood of theſe People is made to circulate with an accelerated Force, and then they become extraordinarily affected.

THE Old and Infirm are ſo many ſenſitive Barometers, and are generally very early in the Notices they give of the Alterations of the Weight of the Air, and conſequently of the Weather. Rheumatiſms, Gouts, Achs, Megrims, Shooting of Corns, and the like, are with them certain Indications of Rains, Snows and Storms. Nor are the Young and Healthful wholly inſenſible of theſe Changes, tho' the whole Texture

ture of their conſtitutional Syſtem of Fibres be in fine Order, replete with Juices, tenſe and elaſtic; whereas thoſe of the Antient are thro' Age and long Uſe become more dry and ſapleſs, hard, tough, unpliant and wanting of Spring. The Sufferings therefore of theſe are always greater, from this accidental Difference of Preſſure, than the other, and are doubtleſs proportionable to their Complaints.

THO' the Preſſure of the Air be ſufficient to produce the great Effects before-mentioned; yet is the Force thereof ſuſtained by temper'd Clay, thin Glaſs, and the moſt tender Bodies, without any Alteration in their Figure at all, merely from their being equally preſs'd thereby on every Side: But no ſooner can this Preſſure be abated on one Hand, or increas'd on the other, than a ſenſible Change will immediately follow.

OUR Receivers in general, when they are firſt ſet on the Pump, preſs it only with their abſolute Weight; but if the internal Air, by a Turn or two of the Winch, be attenuated, its Preſſure on their Surface will cauſe them to adhere to the Plate, ſo as not eaſily to be ſeparated from it. The Cauſe is plain.

A Receiver being placed on the Leather, the Air within, as well as that without, lies under equal Degrees of Compreſſure, and like a Multitude of little Springs, wound up or bent as many different Ways, ſupports the Weight of the upper Air. This inferior Air reſiſts, and in its

its turn repreſſes the inner Surface of the Receiver, and the Leather whereon it ſtands, with a Force juſt equal to that exerted by the Atmoſphere on the Out-ſide of the Receiver and the Pump; whence proceeds a perfect Equilibrium between them. But we no ſooner give one Stroke of the Piſton, and extract Part of the inward Air, but that Equilibrium ceaſes; and as the Exhauſtion is carried on or continued, the growing Preſſure of the one, and the decreaſing Reſiſtance of the other, make the Difference at length very notable; and ſuch as will be extremely ſenſible to the Hand of a Perſon covering a ſmall Receiver, two Inches over, open at both Ends, whilſt gradually exhauſted of its Air.

ANOTHER remarkable Effect, produced by the different Preſſures of the internal and external Air, may be obſerved on exhauſting a ſquare Bottle of its Air. This will be beſt done under a Receiver. The Phial is to have a leather Valve ſo diſpoſed as to ſuffer the Air to paſs out freely during the Operation, but not to let it enter the Bottle again when it comes again to be admitted into the Receiver; the Preſſure whereof will immediately ſqueeze the Bottle to Atoms.

IT may here be remarked, that flat Bodies are not ſo able to reſiſt a Preſſure as are the round of equal Thickneſs; becauſe all the Parts of theſe are diſpoſed as in an Arch, and ſo ſuſtain each other in a much better Manner than is poſſible by Bodies of any other Shape.

ANO-

ANOTHER Instance of the Inequality of this Pressure, may be given, by increasing it within a Bladder, fastened at the End of an injecting Syringe, into which, by repeated Strokes, let a Quantity of Air be successively thrown. When the Power of the Spring is such, that the Weight of the Air of common Density without, and the Cohesion of the Parts of the Bladder become jointly unequal thereto, this Membrane will burst, and the inclosed Fluid will then get loose, and shake the adjacent Air so as to affect our Nerves perhaps with the Sensation ordinarily called a Noise.

THIS Experiment will also intimate to us the surprizing Effects fluid Bodies produce, in dilating Cavities, when push'd thro' small Channels. In this Case the Particles of Air thrust into the Bladder with a pretty good Force, insinuate themselves, and act as does a driven Wedge in dividing a hard Body. Which too is commonly the Case, it may be observed, in such Apoplexies as are fatal. Some of the small Blood-vessels break in the Head, and, in the Course of the Circulation, repeated Pushes being made through the fractur'd Pipe, the Brain at length comes to be so compress'd by the extravasated Blood, as to be no longer able to perform the due Secretions of the animal Spirits, whence immediate Death ensues.

A Stream of Air driven thro' a small Channel, will both raise and sustain a considerable Weight;

Weight; and the ſmaller the Hole, the greater will be the Effect in a reciprocal Time. An eaſy Blaſt from the Lungs will raiſe about ſeven Pounds; but the Breath of a ſtout Perſon, blowing with all his Might, above twenty Pounds.

ONE large Bladder blown, may raiſe a Weight as high as ſeveral ſmall ones; but the neceſſary Expence of Breath for this Purpoſe, in either Caſe, will be very different. For Inſtance; two Bladders ſimilar in Figure, but of half the Diameter of a large one (ſince Spheres are geometrically demonſtrable to be in Content proportionable to the Cubes of their Diameters) will require but a quarter of the Breath to diſtend them, as will the greater; and yet will they jointly act in a quarter part of the Time, and produce a proportionable Part of the Effect. This Experiment is commonly apply'd to the Explication of muſcular Motion, and is repreſented *Fig.* 5. *Plate* 8.

On MUSCULAR MOTION.

THE Muſcles of the Body, in general, are thoſe Flakes of Fleſh which appear when the common Teguments of the Body are removed. They cover the Bones, and not only conduce to the Comelineſs of the animal Figure, but are ſo many moving Powers, by which a very great Number of diſtinct Motions may be made, differing from each other in in their Forces, Directions, and various Effects.

OF the Muscles, some are round, some oblong, some flat, and others circular, some are simple, but most of them compound. The simple Muscles ordinarily consist of a Belly, red and fleshy, and generally of a Pair of Tendons placed at the Extremities, white and of a closer Contexture; both Parts whereof seem to be no other than Bundles of parallel Fibres, divisible with Care to a great Degree of Fineness; the minutest Sub-division whereof, or Fibril, seems to be a Muscle in Miniature, and to have its Belly and two Tendons like the Muscle itself. Not but that some of the Muscles, and consequently their Fibres, have but one Tendon, being in that Case fleshy only at the other End.

THE compound Muscles have their different Series of Fibres, not parallel (tho' the Fibres that severally constitute them are so) but often inclined, and lying in different Directions to each other, and are, as well as all the rest, curiously adapted to the Purpose they are designed to execute.

THE Tendons are, for the generality, inserted into two of the Bones; one fixed, the other moveable: The first is termed its Origine; the second its Insertion.

As the Muscles contract, they draw the moveable Bone or Part, this way or that, according to the Direction of the Fibres of which they are com-

composed; and as they diminish in Length, their Bellies are observed to increase in Thickness, tho' the Muscle itself enlarges not its Dimensions; but its Bulk is, on Experiment, found to be rather less. And this has been made evident, upon a lusty and muscular Person's moving and clasping his Fingers, when his Hand and Arm were curiously inclosed in a glass Vessel filled with Water, having a small Tube inserted in the upper Part, that so, by the Rise or Abatement of the Water therein, this Matter might be critically examined.

THE Veins, Arteries and Nerves (the two first of which being the Channels which conduct the Blood to and from the Heart, the Source of Life; the other being the Conveyance of the animal Spirits from the Seat of Perception, the Brain) are divided and universally distributed all over the Muscles; since no one Point of the Flesh can be prick'd, but Blood will thence follow, and Sensation there be raised.

NOW the Action of a Muscle seems wholly to depend on the Non-obstruction of the Nerves: For if the Nerve of any Muscle be tied, the Muscle immediately ceases to act; and if it be cut thro', it does so for ever. Muscular Motion must therefore be affected by some Agency, communicated by the Nerves to the moving Part.

IT has been also generally received, that the same Effect will happen on tying or cutting the chief Artery of a Muscle; but this has been found

not

not to ſucceed, when try'd on a Dog, unleſs the *Aorta* or principal Artery of the whole Body was tied. For the ingenious Dr. LANGRISH informs us, that he has tied up, and below the Ligature divided, four large Arteries of a Spaniel, who found no Sort of Defect or Inconvenience in his Muſcles from the Operation when his Wounds were well: By which Time indeed the lateral Communication of the neighbouring Arteries might poſſibly be ſo enlarged, as from thoſe Arteries to ſupply the Muſcles hinted at with a free Influx of arterial Blood, after their own Veſſels had been deſtroy'd; and which always muſt happen, we know, in ſuch Subjects as ſurvive the Loſs of a Limb.

THE Manner in which the Learned generally conceive muſcular Motion to be performed, is from the progreſſive Motion of the nervous Juice, increaſed and on Occaſions forwarded by the Determination of the Will, to a certain Part, in an undulating Manner. And the muſcular Fibres, open to this Influx, receiving thereupon a larger Quantity of the nervous Fluid, grow more turgid, and cauſe a Contraction, which the continued Circulation of the Blood and other Juices aſſiſts and promotes, till the intended Motion is brought about and executed. And what favours this Conjecture is, the Contraction of a dead Muſcle, which is always raiſed by the Injection of Liquors.

THIS muſt be confeſs'd a plauſible way of ſolving this very difficult Phænomenon; but when

when we consider how great and surprising Things are done by People in a Fright; when the Muscles act almost instantaneously with the very Apprehension of Danger, without any Reflection made, or seeming Action of the Will perform'd at all; it may be doubted whether these sudden and prodigious Effects are brought about in the steady, uniform and regular Way before proposed.

BESIDES 'tis well known, that muscular Motion in the Heart of the Eel, the Salmon, and Frog, will continue after they have been a long Time, several Hours perhaps, out of the Body; and when their Pulsation has even then ceas'd, that it will be resumed and repeated, on their being warm'd a-new, or pricked by a Needle. But the most remarkable Phænomenon of this kind is, the Twisting and Twining of the Viper, which will continue for many Hours after the Head, Heart, Entrails and Skin are taken from it. Nor is it in the least satisfactory to alledge, as is commonly done, that the Fluids in these Animals are more viscid, and are therefore longer retained in the Vessels of these Creatures than in those of others, to produce the said Effect, after all the Conveyances of the animal Spirits are intercepted, and even their very Source destroyed.

WE cannot therefore but own, that the Business of muscular Motion is not yet so well understood as 'tis hoped it may hereafter be, when the Industry of After-ages, assisted by the Obſervations of the foregoing, ſhall have made a greater Progreſs therein.

IT may however here be remarked, that extreme Cold is always a conſiderable Hindrance to muſcular Motion; a Swelling from extravaſated Humours, which fill the Interſtices, and prevent the Corrugation and Contraction of the Fibres, does the ſame. Great Tremors, ſuch as thoſe of the muſical Strings, which vibrate with a prodigious Degree of Swiftneſs, and when play'd on, very commonly affect the Ends of the Fingers of the Performer with Numbneſs. Laying hold on the lower Part of a ſpringing Piece of Metal, when filed in a Vice, will very ſoon produce the ſame Effect; as alſo does the Touch of the *Torpedo*, a Fiſh which has a Pair of Muſcles on his Back, compoſed of very large and ſtiff Fibres, which being touched, he naturally moves to and fro with ſuch Swiftneſs, that it numbs the Hand, and immediately impairs muſcular Motion therein. It may then be a Queſtion, whether muſcular Motion be not produced by the Nerves alone; ſince whenever they are diſconcerted, diſturbed or obſtructed, by certain Accidents, a Blow on the Head perchance, or the very Apprehenſion of great and eminent Danger, ſuch eſpecially as produces Amazement and Diſmay, will on Experience, we ſee, effectually cauſe all muſcular Motion to ceaſe.

BORELLI, and other ingenious Authors after him, by the Help of a fine Imagination,

rather

rather than from any thing that ſeems to favour it in Fact, or proceeds from Obſervation, have conjectur'd, that the long parallel Fibres which compoſe a Muſcle, were, beſides being together incloſed in the common Membrane of the Muſcle, connected alſo by tranſverſe Fibres, croſſing the longitudinal ones, and dividing them at very ſmall Diſtances, into a great Number of ſmall Cells, Veſicles or Bladders; and this Way have they endeavoured to explain the Mechaniſm of muſcular Motion. The Thought is philoſophical, and pretty enough, which they thus purſue.

A Bladder, void of Air and flaccid, they conſider as a Muſcle in its utmoſt Elongation; when inflated, as a Muſcle contracted. Being empty, it may be perhaps eight or nine Inches long, and then barely ſuſpends the Weight *A*, *Fig.* 5. *Plate* 8. Being replete with Air (blown thro' the Pipe *B*, the End of which is covered with a Valve, to eaſe the Lungs, and prevent the Return of the Air when the blowing ceaſes) it will raiſe the Weight to a certain Height. The upper and nether Parts of the Bladder repreſent the Head and Tail of the Muſcle, and the Weight intimates the Force wherewith it acts.

ACCORDING to *Fig.* 5. *Plate* 8. we know that by one Bandage put about the Middle of our inflated Bladder, as at *C*, the Weight will move in a quarter of the Time, and with a quarter of the Breath requiſite to fill the

Cavity of the whole without a Ligature, and that a fourth Part of the Effect will be produced thereby. Now ſhould the Bladder, thus divided, be again ſubdivided with Bandages at *D* and *E*, the whole will become a String of ſmall Bladders, each being a fourth of the Diameter of the firſt, which being blown up, will raiſe a certain Weight in a ſixteenth Part of the Room and Time that the large one will.

AND 'tis reaſonable to believe, that if one Bladder of a certain Content will when inflated raiſe a Weight to a certain Height, two communicating will produce double the Effect, and ſo forward. And was a Chain of Bladders, thus circumſtanced, equal in Bulk, and like in Figure, joined together, the Space through which the Weight would be raiſed by them, muſt be proportionable to their Number, or, which is the ſame Thing, to the Length of the String. And if a determined Weight may be raiſed a certain Space by one Bladder, or one String of Bladders, double the Weight will be raiſed by two ſuch; and conſequently the Weight raiſed by a Muſcle will be in Proportion to the Number of its Fibres, *viz.* its Thickneſs: And the abſolute Strength of one Muſcle is to that of another as are their Weights or Bulk.

WAS it not for the forementioned Contrivance, or ſomething equivalent, in the Conſtruction of the Muſcles, all animal Motion muſt be exceeding deliberate and ſlow, and a

Snail

Snail or Tortoiſe might be reckoned, and perhaps juſtly, very nimble Creatures.

On the HEART, *and* CIRCULATION *of the* BLOOD.

MUSCULAR Motion in general is voluntarily, it being in the Will and Choice of an Animal, in Health and unconvulſed, whether he will move any Part of his Body, or whether he will give it this or that Direction or not. But the Heart is a compound Muſcle exempted from that Law, which during Life, whether we will or not, inceſſantly moves, and at every Pulſe receives Blood from the Veins which it again throws out along the Arteries to the very Extremities of the Body, where the Arteries divide either into lymphatic Veſſels, into excretory Ducts, or capillary Veins, too fine for Sight. Here the Blood and Juices are ſtrain'd, abſorbed, and again collected by the ſmaller Ramifications of the Veins, by which they are again conducted back to the Heart, where the ſame Proceſs being repeated, the animal Syſtem is thus preſerved often a hundred Years. So curious a Piece of Pump-work cannot but deſerve a little of our Attention.

THE Heart lies almoſt tranſverſely on the Diaphragm, hereafter deſcribed, *Page* 207, the greateſt Part of it is found in the left Cavity of the Thorax or Cheſt, wherein it is ſuſpended at Liberty by the Blood-veſſels, with which alone it is connected. Its Baſis is toward the right, and its *Apex* or Point inclines to the Left, where uſually we feel it beat. 'Tis incloſed within a fixed Bag, called the *Pericardium*, having in it a ſerous Liquor, in which it floats: to the end that its Fibres might not only be kept always warm, moiſt and ſupple; but alſo that by performing its Functions in a denſer Fluid, its Motions might be rendered thereby more regular and ſteady.

IT is of a conical Figure, and its fleſhy or muſcular Parts conſiſt of ſeveral different Orders of Fibres, ſo directed and diſpoſed as either to contract or dilate it, which they do by turns, regularly, and without Intermiſſion, as has been ſaid, from the very Beginning to the End of Life.

IN the Contraction of the Heart, the Point is drawn up a little towards the Baſe; in its Dilatation or Reſtitution, the *Apex* returns to its natural Situation. The firſt of theſe is by Anatomiſts termed the *Syſtole*, the latter the *Diaſtole* of the Heart.

WITHIN the Heart are two Cavities, termed Ventricles. They are divided by a ſtrong *Septum* or Partition, the Place and internal Direction whereof is marked on its Surface, *Fig.* 6. *Plate* 8. by the white Line *E P*. At the Entrance of either Ventricle is a hollow Ap-

Appendix, a kind of Bag of a looſer Texture than the Heart. Theſe are called the Auricles, with which the Ventricles, thro' Valves of an admirable Texture and Diſpoſition, reſpectively communicate. The right Auricle is there denoted by *B*, into which Blood is admitted from the *Vena Cava* whenever the Heart contracts; this, both aſcending from the Parts below, and deſcending from thoſe above, marked *A A*, conducts the Blood, collected by the leſſer Veins from all Parts of the Body, to the Heart, into which it diſcharges its Contents at *N*, where is an excellent Contrivance, which hinders the direct Shock of the two confluent Streams, as in the Figure is expreſs'd; tho' this is much more perceptible in Brutes than human Subjects. The Place of the right Ventricle, marked *Q*, is between *C* and the *Septum Cordis*; into which the Blood laſt received by the Auricle is admitted whenever the Heart dilates. *D* is the Section of the pulmonary Artery, whereby the Blood is thrown from the right Ventricle into the Lungs, which are ſpread without the *Pericardium* on either Side of the Cheſt, and being divided into ſeveral Lobes, *viz.* three on the right and two on the left, when inflated, they wholly fill the *Thorax*. Theſe, by Conſtruction and Texture, ſeem to be a vaſt Collection of ſmall Veſſels, thro' which the Blood being puſh'd with ſome Force and Rapidity, becomes attenuated, and there meeting with the cool Air continually inſpired, is thereby rectified, refreſhed, and is then immediately gathered up by the pulmonary Veins, the numberleſs Ramifications of which terminate in four Canals, which conduct the Blood from the Lungs into the left Auricle of the Heart, in its *Systole* or Contraction. This Auricle is signified by *F*, and the Inlets of the pulmonary Veins thereinto by *R R*; two of which lying backwards, are in our Draught only prick'd.

AT the succeeding Restitution or *Diastole* of the Heart, the Blood last received from the Lungs is admitted into the left Ventricle, the Place of which is between the *Septum* and the left Side of the Heart, denoted by *S*; and by the following Contraction it is thence thrown into the great Artery, or the *Aorta*, marked *G O*; from the several Branchings or Ramifications whereof it is distributed to every Part of the Body respectively. *H, I, K, L, M*, lead it away to the Head, Arms, *&c.* and from the Continuation of *G O* (carried and directed downwards, to moderate perhaps the prodigious Force of the Heart) the Trunk and lower Parts of the Body are supplied with arterial Blood, by distinct Canals branched off here and there, to the very Extremities of the Body, at every *Systole* or Contraction thereof.

IT must not however be imagined, that one and the same or a single Portion of Blood, received at first from the *Vena Cava*, is thence circulated alone to the *Aorta*, by the six distinct Steps or Stages beforementioned. But as a constant Supply is wanted for the Purposes of Life, the Circulation is to be supposed continual, and that at every Motion of the Heart all

all the four Cavities are more or leſs employed, *viz.* In the Contraction both Auricles not only receive Blood from the Veins with which they reſpectively communicate, but the two Ventricles at the ſame Time alſo expel into their reſpective Arteries the Blood which they had but juſt before received, in the Reſtitution of the Heart, from the Auricles, which are then only empty'd into them: So that whenever the Ventricles dilate, the Auricles contract, and the contrary, by the alternate, conſtant, uniform, and regular Motion of the Heart.

THE Arteries are ſtrong conical Ducts, larger towards the Heart, and leſs towards the Extremities of the Body, of an elaſtick Nature, and which dilate when the Heart puſhes Blood into them (this ſtrictly is called its Pulſe) and contract immediately when that Puſh is diſcontinued. The Veins, like the Arteries, are alſo Tubes of a conical Figure, and their Office is to collect and return the Blood in an even Stream, as has been ſaid, to the Heart, from the Extremities, whither it had been carried by the Arteries.

IN this, as indeed elſewhere, moſt admirable ſeems the Artifice of Nature. The Arteries are found conical as they leave the Heart; the Puſh thereby made, is in part then moderated by the Reflexions of the Fluid neceſſarily produced by the inclined Sides of thoſe Canals, to the End that Time and Opportunity may be thereby given to the ſeveral Ramifications and Outlets all along the *Aorta*, many of which are very ſmall, to gather

ther up ſuch Part of the fluid Stream as may be wanting for the Nutrition of the Parts to which they ſeverally belong: Whereas the Veins are obſerved always to enlarge themſelves as they approach toward the Heart; that the returning Stream, when the impelling Force is greatly abated and almoſt ſpent, may, by paſſing thro a Tube filled with a Fluid only, meet leſs Reſiſtance than muſt needs have been found from a continued Friction along the Sides even of cylindric Veſſels.

THAT this ſucceſſive Circulation of the Blood is no Chimera, may be evident from obſerving the Courſe of it in the tranſparent Membranes of Animals, with the Microſcope; whereby the Globules of Blood may be diſtinctly ſeen in the Arteries to flow one Way, and in the Veins the contrary.

BESIDES which, whenever an Animal is opened alive, if a Ligature be made on an Artery, it always ſwells between that and the Heart, its Beatings become a great deal ſtronger, and the Blood ſpouts out of it with a ſurpriſing Force, if an Opening be there made: Whereas when a Vein in that Caſe is ty'd, the Part which is between the Ligature and the Heart is found empty, lax, and yields no Blood when opened.

THE Section of the Arteries is always ſmaller than that of the Veins; and of conſequence the equal Stream, being in theſe more confined, is

obſerved

obſerved to be more rapid in them. *Fig.* 7. *Plate* 8. is the Repreſentation of the Veins and Arteries filled with the Globules of the Blood circulating in one of theſe Animals; the Figure of which is drawn round, becauſe the Spot of reflected Light, by which theſe Things are to be obſerved, exhibits ſuch a View. The Places marked *DDD*, are thoſe where the Veins and Arteries were ſeen viſibly to communicate.

THE Truth of it will alſo farther appear from obſerving the Veins on the Back of the Hand, if the Skin be clear. Theſe Tubes are furniſhed at fit Diſtances by ſemilunar Valves, which on proper Occaſions ſhut downwards or towards the Extremities, to take the Weight of the aſcending Fluid from off the Trunk of the Veins laterally, which would otherwiſe be found inconvenient, and give the Body ſome Pain. And the immediate Relief and Eaſe we find on our lying down, ſhews, that the Abatement of this Preſſure, even with theſe Contrivances, is not inconſiderable.

STROKE then your Finger down toward the Knuckles pretty hard, and 'tis odds but you'll paſs by ſome or other of theſe Valves; the conſequence of which will be, that the Vein above the Valve will be full of Blood, and between it and your Finger empty: on removing whereof it will however fill immediately, and the Circulation will appear then to proceed as uſual. Or elſe, putting down a Finger in the

ſame

ſame Place to ſtop the Courſe of the Circulation in the Vein, ſtroke the Blood lying between your Finger and the Valve upward, the ſame thing will happen. In order therefore to breathe a Vein, a Bandage is to be made in any convenient Part; and the Courſe of the Blood continually forwarded from the Arteries into the Veins, being thereby partly ſtopped, the Vein will ſwell below the Fillet, never above it, unleſs in the Neck: Which alſo plainly intimates the Courſe of the venal Blood to be from the Extremities of the Body toward the Heart directly.

Of DIGESTION, SANGUIFICATION, *and* NUTRITION.

HAVING dipped thus far into the animal Oeconomy, the Curious will not be diſpleaſed with a ſhort Account of Sanguification, or the Manner in which a Digeſtion of the Aliments received into the Stomach, furniſhes Matter to repair the Decays of Nature, and ſupply the Body with neceſſary Nutriment and Strength.

SOLID Food being taken in by the Mouth, reduced to a certain Degree of Fineneſs by the Teeth, and at the ſame time mixed with the Spittle (a limpid Humour ſecreted or ſeparated from the Blood by particular Glands for that Purpoſe) is tranſmitted thro' the Gullet, which is a Paſſage behind the Wind-pipe leading into the

the Stomach, lying beneath the Midriff, and ſituated chiefly on the left Side of the Abdomen or lower Belly, where the Parts are farther opened and divided by the Juices ſecerned by the Glands of the Stomach, and by what we drink.

HENCE it is gradually paſs'd into the ſmall Guts; where meeting with two other Secretions from the Blood, namely the Bile or Gall, and the pancreatic Juice, the one contained in a Bag annexed to the Liver, and the other ſupply'd from a particular Gland, it is elaborated by the vermicular or worm-like Motion of the ſmall Guts, continually promoted alſo by the Act of Inſpiration and Expiration, into a ſtill ſofter Subſtance.

FROM the ſmall Guts, the finer Parts of the Aliments, called the Chyle, are collected and abſorb'd by the lacteal Veins, opening into them, and by theſe are tranſmitted to the Receptacle of the Chyle, a ſmall Knot or Bag placed near the Loins; being forwarded thither, not only by the continual vermicular Motion of the Guts abovementioned, but it is aſſiſted in its Progreſs onward alſo by the Power of the Attraction of Coheſion in the lacteal Veins themſelves, which are exceeding ſmall Tubes, and ſcarcely ever viſible in cold Subjects.

HENCE in the Progreſs of Digeſtion it is again puſhed upward along the thoracic Duct, alſo ſmall, as high as the Shoulder; being for-

forwarded in its Aſcent thither by the continual beating of the great Artery, or the *Aorta*, near which it is for that Purpoſe rightly placed.

IT is thence emptied into the left ſubclavian Vein; after which it proceeds regularly with the Maſs of Blood to the Heart, and thenceforward continues to circulate with it, till by Degrees it becomes aſſimilated firſt, then perfect Blood, and ſo helps to ſupply from time to time the natural Secretions, to nouriſh the Parts, to ſerve the Uſes, and repair the Decays of the animal Syſtem.

AND truly admirable is the Diſpoſition of Parts in this whole Machine; admirable the Execution of all its Functions; the Impulſe given from one Part always begetting Motion in another, that on the next, and ſo on thro' the whole Body. From the Circulation of the Blood, the very Being and perhaps the Motion of the animal Spirits are derived; from the Influence of thoſe Spirits over the muſcular Fibres, very probably ariſes all muſcular Motion; from muſcular Motion the Circulation of the Fluids is maintained, in a great meaſure otherwiſe ſtagnant; and from this Circulation all the neceſſary Secretions for the Continuance of Life are made, and the Veſſels of the Body are thereby kept ſupple, and preſerved in a fit Diſpoſition and a Readineſs for Motion and Uſe.

On ANIMAL INSPIRATION *and* EXPIRATION.

THE Buſineſs of Reſpiration, wherein the Air is principally concerned, will properly come next under Conſideration. And this conſiſts of two Parts, Inſpiration, whereby Air is taken into the Lungs; and Expiration, whereby it is thruſt out of them. Theſe are in ſome meaſure performed by the Power of the intercoſtal Muſcles acting on the Ribs, diſpoſed in Form of a ſemicircular Arch, and articulated with the *Vertebræ* of the Back behind, and connected with the *Sternum* before; which are the two Pivots or Centres on which they are made to move.

THE Diaphragm or Midriff is a Partition drawn quite croſs the Body, intirely dividing the Cheſt, containing the Heart and Lungs, from the Abdomen or Belly, wherein the Liver, Stomach, Guts and Bladder are contained. This is a Muſcle whoſe central Parts are tendinous; the reſt is fleſhy, having its Fibres diſpoſed like Rays all round a Center. By its Diſpoſition and Structure it is capable of Expanſion, whereby it becomes concave below, and of Contraction, whereby it becomes flat; which it alternately does, and thereby becomes the principal Agent in the Article of Breathing.

IN Inſpiration, the Ribs being rais'd as above, the Diaphragm is drawn up, and made flat; by the Complanation whereof the Cavity of the Thorax or Cheſt is enlarged, and the Air therein included, having no ſort of Communication with the outward Air, is thereupon inclined to dilate: To prevent which, and preſerve the Equilibrium, the Air from without of courſe preſſes down the Wind-pipe, and dilates the Lungs inſtead.

IN Expiration the Ribs fall; the Diaphragm, againſt which the Liver, Stomach and Inteſtines in the Abdomen alſo preſs, again expands, becomes concave, and contracts the Capacity of the Thorax; upon which the Air therein incloſed, being compreſſed, bears againſt the Surface of the Lungs, cauſes them to contract, whence the Animal is made to expire; and this is repeated every time we take Breath: In doing whereof the Lungs are perfectly paſſive, and play only in conſequence of the muſcular Motion before deſcribed, aſſiſted by the Action and Influence of the Atmoſphere upon them.

THE Diſpoſition of the Lungs in the Buſineſs of Reſpiration is well repreſented by the Machine *Fig.* 8. *Plate* 8. wherein *A* is a blown Bladder tied faſt on the End of a Pipe *B*, denoting the Wind-pipe, and communicating with the outward Air. *D* is a lax or looſe Bladder, fixed to the Bottom of the Glaſs, and is in

lieu

lieu of the Diaphragm. The Air between the two Bladders in the Glaſs intimates that ſuppoſed to be pent up in the Cavity of the Thorax. This artificial Diaphragm being by the Hand puſhed inwards, the Air incloſed in the Glaſs will be condenſed, and bearing againſt the Surface of the artificial Lungs, will compreſs them ſo as to force out their inward Air; as it in real Expiration happens: And again, being pulled outward, the contrary Effect will appear, as in real Inſpiration it is. Both Actions are repreſented by *Fig.* 8 and 9. *Plate* 8.

WHENEVER any Animal, not of the amphibious Kind, or one not living indifferently either by Land or Water, or Inſects, are in the pneumatick Engine deprived of their outward Air, the internal Air, in the Cheſt confined, will naturally dilate, and for Want of a Counterpoiſe to ſupport and keep the Lungs diſtended, theſe will contract; upon which the Blood-veſſels thereof will be all compreſſed and cloſed, and the Circulation being thus ſtopped, the Animal will immediately fall into Convulſions; and without ſpeedy Relief by the Admiſſion of freſh Air, to counterbalance the ſaid Preſſure on the Lungs, certain Death enſues.

THE Manner in which this is done, is aptly expreſſed by *Fig.* 10. *Plate* 8. from which if the external Air, and with it the communicating Air contained within the Bladder, be exhauſted, that confin'd between the Bladder and the Bottle will by its Spring dilate, and thruſt the Bladder, here alſo repreſenting the Lungs, on a Heap.

IT may moreover be here remarked, that there is a natural Contractility in all muſcular Fibres, or a Propenſity to contract themſelves; and that whenever they are freed from the Counter-action of ſome adequate Force, which, in the preſent Caſe, the Air conſtantly received by the Wind-pipe always proves, that alone might be ſufficient to produce the Effect here propoſed.

IT may alſo be farther remarked: That if any Animal has never drawn Breath, the Lungs, being in that Caſe ſpecifically heavier, will ſink in Water: But after it has breathed, the Veſicles of the Lungs being diſtended with admitted Air, will always ſwim. By this Method the Surgeon can poſitively ſay, whether an Infant ſuſpected of being murdered, was ſtill-born or not.

On ANIMAL SUCTION.

A Creature not an Hour old is Maſter of this needful Piece of Philoſophy. Leſt a wrong Idea however might be affixed to a good and uſeful Word, it may be proper firſt to ſettle what by Suction is really to be underſtood.

IN order to this, we may take a Cupping-glaſs; put it, the Mouth downwards, under a Receiver open at Top; but which may on Occaſion be cloſed clofed by the Hand, as *Fig.* 11. *Plate* 8. Exhauft them then together, and on fhaking the Pump, the under one will freely move; the other, preffed by the Weight of the Atmofphere above, will adhere to the Leather faft enough.

NOW were our Glaffes fixed down to the Plate of the Pump by any Power of Suction, they would in this Inftance both be fo; which is contrary to Fact. However, if we catch away the Hand from the Hole of the Receiver in this Circumftance, and fuddenly admit the Air upon the Cupping-glafs from above, that Machine will then be fixed down by the Weight of the Atmofphere, thrown upon it all at once, and the Receiver will then be at full Liberty: Which to a Demonftration proves, that it is no Property in Suction, but the Air's Preffure only, by which the groffer Fluids are made to move. And this is alfo farther evinced, by the Experiment mentioned in the *Hydroftaticks*, *Page* 48.

AN Animal therefore, upon applying his Mouth to fuck, does no more than diftend his Cheft, much as in the Cafe of Infpiration, whereby, ftrictly fpeaking, the Air is drawn, or fucked into the Lungs; at which Time, the rarer Air within not being a Counterpoife to the denfer Air without, the Water from the Spring, the Milk from the Breaft, and the like, are forced into the Mouth: Whence again, by working the Pump-work of the Parts of the Throat, qualified to act on that Occafion as a double Valve, or one that will both ſuck and force, the Riſe of the Fluids firſt into the Mouth, and then their Deſcent into the Stomach, is alternately promoted.

On the SPRING *or* ELASTICITY *of the* AIR.

THE Preſſure of the Air having been already undeniably demonſtrated, let us next conſider its Elaſticity.

As the Air is a Maſs of fluid Matter, generally yielding to all Impreſſions, it may be eaſily condenſed, and by Injection from a forcing Syringe, be crouded into Veſſels of Strength ſufficient to bear the Force of ſuch Compreſſure. In the Wind-gun, for Example, which is a Machine ſhap'd like a Fuſil, into the Chamber whereof Air may be injected by a proper Syringe, till it is twenty times perhaps of the Strength and Tenour of our Atmoſphere, and able to throw a Bullet, by its Spring, thro' a Board ſeveral times ſucceſſively, whenever Part of it ſhall be let go, or ſuffered to ruſh forth, on the Fall of the Cock: But yet the aerial Particles, in the greateſt Degree of Compreſſure poſſible, ſhall not be ſo wedged together, as to come to a general Contact: For that would entirely deſtroy their Spring; which in the Nature of Things is impoſſible to be done.

COMMON Air near the Earth, by the working of the pneumatick Engine only, and without

out any extraordinary Degree of Heat to heighten its Spring, may be very much dilated (according to Mr. BOYLE's Experiments, certainly thirteen thouſand, and probably four times as much) yet ſhall its Parts even then not want for Spring, tho' it muſt be exceeding weak.

THE Expanſion of the aerial Particles will be better underſtood, if with Mr. BOYLE we conceive them, fine as they are, and imperceptible to Senſe, to be like ſo many little Watch-ſprings, coil'd round and contorted, but infinitely more perfect; ſince theſe are found to act every way, and every way alike, in a ſpherical Manner; and by a certain Rotation round their Centres, beat each other out of their proper Spheres of Activity.

SIR ISAAC NEWTON, in his *Principia*, ſays; *That if a Fluid conſiſts of Particles repelling one another with a Force reciprocal to the Diſtance of their reſpective Centres, ſuch Fluid will have a Spring reciprocal to the Space in which it ſhall be compreſſed*; which is certainly applicable to the Air. For the component Particles of this Fluid endeavour to expand and recede from one another with a Force ſo great, that the greateſt Compreſſure is not able to overpower it, or ſo to condenſe them, as to drive them within the Sphere of each other's Attraction, and prevent or overcome their Elaſticity.

THE more the Air is compreſſed, and its Denſity encreaſed, the more elaſtick ſtill it is;

 be-

becauſe the nearer its Particles are ſqueezed together, the more they repel, and endeavour to fly from and avoid each other. And let the compreſſive Power be ever ſo great, or continue ever ſo long, the Moment it is removed they will expand and recede from one another with a Velocity proportionate to the Degree of the Compreſſion; that is, the Force, by which the Particles of the Air fly from each other, increaſes in the ſame Ratio as the Diſtance in which the Centres of the Particles are diminiſhed; or, in other Words, the repelling Force is inverſely as this Diſtance.

THE Particles of Air are much compreſſed near the Earth by the incumbent Weight of the Atmoſphere above, which being removed, they immediately evolve themſelves, and extend what was but a Spherule at firſt, to a Sphere of large Dimenſions; as will be evident from inverting a Bolt-head, or if you pleaſe a *Florence* Flaſk, almoſt full of Water, into a Jar, having little Water in it. For, on exhauſting the ambient Air, which before buoyed it up therein, it will all gradually ſink down into the Jar; and the ſmall Portion of Air, which before poſſeſſed but a little Room, will dilate, on the ſinking away of the Water, fill the whole Flaſk, and in the Courſe of Exhauſtion, perhaps ſome of it may be ſeen alſo to riſe and bubble thro' the Water thus all brought down into the Jar. This Experiment is repreſented *Fig.* 12. *Plate* 8.

As

As another viſible Inſtance of this Spring, we may take a tight Veſſel, as *Fig*. 13. *Plate* 8. and fill it about a quarter Part with Water; ſcrew into it a Pipe, reaching nearly to the Bottom, into which afterwards inject a Quantity of Air, which at every Stroke of the Syringe will be forced thro' the Body of the Water, and being the lighter Fluid, will take Place above. The Spring of the Air thus injected will by Degrees become very conſiderable, bearing hard againſt the Top and Sides of the Veſſel on one hand, and on the Surface of the Water on the other: So that upon opening the Cock, it will thereby be forced up in a very ſmart Jet; and when the Water is all puſhed out and ſpent, the Air will follow in a vigorous Blaſt.

MUCH the ſame Effect might alſo be produced, by Air of the common Degree of Denſity, in rarefied Air, as will appear from making the Experiment on a fit Machine for the Purpoſe, by only exhauſting Part of the Air from the Receiver; the Figure whereof is repreſented *Plate* 8. *Fig*. 14.

BUT certainly to determine what the natural Power of the Spring of the Air is near the Earth, put a Quantity of Quickſilver into a circular Phial. Screw a Tube, open at Top, and upwards of thirty one Inches long, into its Neck. Place it under an Apparatus that may be exhauſted. Which done, the Air pent within the Phial will expand, and by the Power of its Spring, raiſe the Mercury to the ſame Height within a Trifle as in the Gage-tube it does, from the Preſſure without: And 'twould raiſe it quite as high, but that the natural Spring of the Air, when Part of the Mercury comes thus to be thruſt from the Phial into the Tube, by that Expanſion muſt be ſomewhat weakened. Nor can the Force of the Air's general Spring, and its Preſſure, be reaſonably any other than equal; ſince the Action of the one, and the Re-action of the other, are according to the Laws of Nature always equal and contrary. This Experiment is repreſented, *Plate* 8. *Fig.* 15.

A notable Inſtance of the Power of this Spring, may alſo be given, in its raiſing a conſirable Weight; which is to be done by tying up a Quantity of Air in a ſtrong lax Bladder. Let this be either ſuſpended in a larger Receiver, with the Weight at the End, as ſuppoſe that repreſented by *Fig.* 5. *Plate* 8. or for Convenience rather let it be thruſt into a wooden Hoop, to confine and keep it from ſpreading ſide-ways. On this let the Weights be laid, as *Fig.* 16. *Plate* 8. Exhauſt the Receiver of the ambient Air, and that incloſed will by its Expanſion viſibly raiſe the Weights with a great deal of Eaſe.

ANOTHER Evidence of the Power of this Spring may be had, by confining the Air within a ſquare Phial, not over-ſtrong, which when the Atmoſphere's Preſſure above is removed, will throw the Sides outwards. To preſerve the Receiver whereupon from Damage, a ſmall wire Cage is commonly put over it, as in *Fig*. 17. *Plate* 8.

THE following is an entertaining Experiment made on the alternate Contraction and Expanſion of the Air. This was before hinted in the *Hydroſtaticks*, *Page* 118. and is here repreſented *Plate* 8. *Fig*. 18. Take a ſmall glaſs hollow Image, that will ſwim in Water, having a Hole made into the Cavity at Foot. Put it into a Jar of Water, under a Receiver. Exhauſt Part of the Air, and on admitting it ſuddenly again, Water will be thereby preſſed into the Cavity, and filling it in good Meaſure, will make it probably ſpecifically heavier than an equal Bulk of Water; then 'twill ſink. This done, attenuate the Air in the Receiver a ſecond Time; upon which the Air remaining in the Body of the Image, will by dilating puſh forth a Part of the Water, cauſing it to emerge. And thus may it be made to riſe or ſink in that Fluid, as often as the Experiment is repeated, as at the Word of Command.

THE Uſe of the Air-veſſels in Fiſh is ſomething of the Way of the preſent Experiment. The Fins of theſe Creatures are not alone able to give them a due Command of Motion in all Depths of Water; they have therefore a Bladder of Air within them, ſo diſpoſed, that by contracting or dilating thereof by the Power of their Muſcles, aſſiſted by the Preſſure from without, they can at all Times ſink into the Deep, or riſe to the Surface of the Water,

with

with great Readineſs and Eaſe. But when an Animal of this ſort comes in a Jar of Water to be *in Vacuo*, the Air in the Veſſel beforeſaid will ſo expand, as to keep him wholly above Water, whether he will or not, to his great Pain and Inconvenience.

For the ſame Reaſon, a Piece of ſoak'd Spunge, when firſt put into Water, will perhaps ſwim only near the Surface; but when the Air, on exhauſting, has freed itſelf from many of the ſmall Veſicles which it before poſſeſſed, and of which that Plant is full; and when, by a ſudden Re-admiſſion of the Air into the Receiver, Water is forced into them inſtead, 'twill then probably ſink: But on repeating the Exhauſtion, it will again riſe; unleſs there ſhall be no Air remaining in thoſe Cells, to expand and make it once more ſpecifically lighter than an equal Bulk of Water.

For a like Reaſon, Timber dug out of Bogs and other moiſt Places will ſeldom ſwim in Water; the Particles whereof having by various Accidents, in a great Length of Time, wholly diſlodged the Air from the Vacuities of the Wood. Whence it alſo appears, that even Wood itſelf is no otherwiſe comparatively lighter than Water, than as it has many Pores filled with Air, which is a Body many times lighter.

There is a ſmall Quantity of Air commonly incloſed at the bigger End of an Egg, between the Duplicature of the Film that lines it, which being dilated by the Warmth of the

Hen

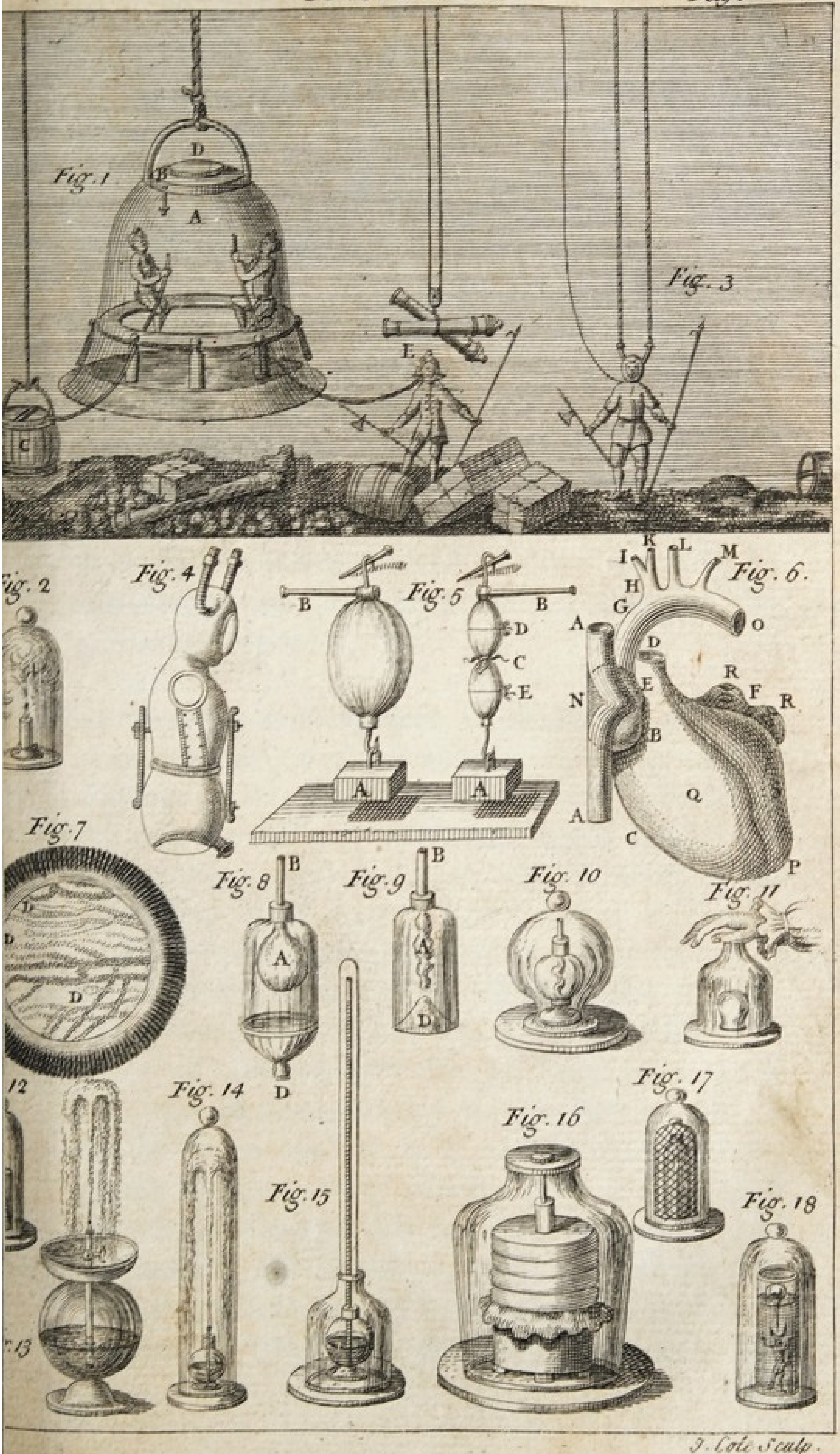
Fig. 1
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Fig. 10
Fig. 11
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Fig. 14
Fig. 15
Fig. 16
Fig. 17
Fig. 18
13

J. Cole Sculp.

Hen ſitting, generally preſſes the Contents, and ſo contributes to the Formation and Production of the Chicken. This little Portion of Air, on opening the ſmaller End of the Shell, turning it down into a Jelly-glaſs, and exhauſting the outward Air, will not only expand ſo as to ſeparate the ſaid Membrane from the Shell, to which it uſually adheres, but will even thruſt both White and Yolk quite thro' the Hole into the Glaſs; which on re-admitting of the Air into the Receiver, will thence be made to retire, being forced by its Weight again into the Shell. The Expanſion of this included Air will ſtill be more evident, if half the Shell be cut away, the Contents removed, and the Experiment repeated.

BEFORE this Subject is diſmiſſed, the Deſcription of *Hero*'s Fountain, playing by the Spring of Air condenſed by Means of a Stream of refluent Water, will, 'tis hoped, not be unacceptable. *Fig.* 1. *Plate* 9. repreſents a tin Machine, conſiſting of two equal Veſſels *A* and *B*, both Air-tight, and communicating by the ſide Pipe, marked *C*. The Veſſel *B* has a Pipe leading from the upper Baſon of the Machine *E*, into which the Jet falls, quite thro' *A*, and reaching nearly to the Bottom of *B*. By Water poured in at *E*, as the Air has leave freely to eſcape thro' the Opening at *F*, *B* may thereby be charged half full, or more; which upon turning the Machine, will deſcend thro' *C*, and charge *A* in the like Manner. The Pipe *C*, continued nearly to the Top, will alſo prevent

vent the Return of the Water when the Machine is ſet again on its Baſis. This done, *A* will be charged with part Water, part Air, and *B* will contain Air only. Then on pouring as much Water again in at *E*, as will fill the Tube; and the Weight of the Water contain'd between *E* and *D*, endeavouring to force its Way into *B*, the Air both in *A* and *B*, as they communicate, will be condenſed in a certain Degree, and this preſſing the Surface of the Fluid in *B*, the Jet will begin to play above thro' *F*, with a Force equal to the Difference of the Reſiſtance of the common Air, into which it riſes, and the Puſh of the denſer Air in the Machine incloſed. And this Cauſe being all along uniformly continued by the conſtant deſcending of the Jet-water at *E*, the Effect will not ceaſe, till *A* ſhall have parted with moſt of its Water, and then the condenſed Air will follow it likewiſe thro' the Jetting-pipe *F*, as in a Blaſt.

The Manner of CUPPING.

THAT there is a Quantity of Air contained in the Fleſh and Humours of the Body, will alſo appear in part from the Protuberance immediately riſing on the Diſcharge of part of the Atmoſphere's Weight in Cupping. In doing whereof, the Operator generally takes a ſmall Glaſs cloſe at Top, and holding it a little over the Flame of a Lamp, the Air being heated, its Elaſticity is thereby increaſed, and a Part of it is accordingly thruſt out. The Glaſs being ſuddenly then clapped on the Part

to

to be cupped, the inward Air in cooling condenſes and contracts, and the Glaſs conſequently adheres to the Fleſh in Proportion to the Difference of the Preſſures of the internal and external Air. The Protuberance of the Fleſh becomes hereupon pretty conſiderable within the Glaſs, for two Reaſons : One, from the Preſſure of the external Air, which endeavours to thruſt as much of that yielding Subſtance into the Glaſs as it can ; and the other from the Expanſion of the Air contained in the Fluids and Fleſh, which cauſes it to riſe undoubtedly ſomewhat higher therein than it would otherwiſe have done. The Glaſs being removed, the Part is immediately to be wounded by a Scarificator, which is a kind of Lancet with many Points, and then the Glaſs being a ſecond Time heated, and applied thereon as before, Blood and Seroſities from the ſame Cauſe, are forced from the wounded Veſſels into the Glaſs; and when one has done its Office, and drawn ſufficient, another is apply'd, till the intended Quantity be taken.

IF inſtead of putting the Glaſs, when warmed, on the Fleſh, it be put for Experiment's ſake into a Plate of Water, the immediate Riſe of the groſſer Fluid into the Machine, will preciſely ſhew to what Degree the Air therein was rarified by the Flame; this always pretty much depending upon the Dexterity of the Performer.

THE beſt Way of Cupping is by the exhauſting Syringe, tho' the generality of Operators

tors do not as yet chuſe it. By Flame, the Air of a Cupping-glaſs cannot be well rarified more than one half. By the Syringe, a very few Strokes will nearly exhauſt it. The Difference of the Preſſure in both Caſes muſt be very conſiderable. If the Cupping-glaſs be two Inches over, it has been proved, *Page* 170. that the Preſſure from without may in the firſt Caſe be perhaps twenty Pounds; in the ſecond, it may ſometimes exceed forty. The Blood-veſſels in the Fleſh may be able to ſuſtain the firſt Preſſure pretty well, but will certainly be cloſed under the latter, by which the Efflux of the iſſuing Fluids muſt needs be ſtopped. One Stroke on the Syringe, perhaps half a one, may produce the intended Effect in this Operation; and two or three may defeat it, for want of Judgment.

On the RISE *of the* SAP *in* PLANTS.

FRUITS alſo contain a great deal of Air, as may be demonſtrated by placing a ſhrivelled Apple under an exhauſted Receiver, which will thereupon immediately become fine and plump; and if the Fruit be over-mellow, the Skin will probably burſt, and Part of the Pulp will be puſhed forth in Froth.

THE Air contained in Fruits doth not a little contribute to their Growth, Perfection and Maturity, as will appear from conſidering the Manner in which the Progreſſion of the vegetable Fluid is effected.

IF

IF we take a ſmall glaſs Bolt-head, heat the Bole of it at the Candle, and put the End of the Stem immediately into Water; that Fluid, on the cooling of the Machine, will be made viſibly to riſe up the Stem into the Head, on the Condenſation of the Air before expanded by the Heat.

THIS Experiment will in ſome ſort intimate to us the Progreſs and Riſe of the vegetative Sap, with the Cauſe of ſuch Riſe. The Head of the Machine repreſents the extreme and tender Parts of the Plant; the included denſe Air, the Fluids lodged in thoſe Extremities, and in general, thoſe contained in the Cells of the whole Tree. The Heat apply'd, denotes that of the Sun in the Day-time, which not only immediately acts upon and attenuates the Viſcidities of the Sap, but alſo ſerves to dilate and enlarge the Cavities of the Plant, which makes it enlarge and ſhoot. The Liquor riſing in the Stem of the Glaſs, ſignifies that of the Juices imbibed from the Earth by the Fibres of the Root; whence they paſs by ſmall Canals up the Body of the Tree, forwarded probably alſo by the Attraction of Coheſion within, as well as by the Preſſure of the Atmoſphere without, eſpecially when the Fluids come to ſhrink and be again condenſed in the more tender Parts of the Plant, by the ſucceeding Cold of the Night. Whence it happens, that Plants which towards Evening, being exhauſted of their Juices by a too vigorous Perſpiration in a hot and ſultry Day,

Day, ſeem to languiſh and droop, but during the Night they recover, and again hold up their Heads without being watered at all.

WHAT greatly contributes alſo to the Motions of the vegetative Sap, is the great Mixture there doubtleſs is of Air in moſt of the groſſer Fluids, which in the exhauſted Receiver will viſibly ariſe out of them like Steam, and get away; as may at any time be try'd on White-wine, or indeed any tranſparent Liquors that have undergone any Degree of Fermentation. Theſe are always replete with Air. Small-beer in particular is very much ſo; the Particles whereof *in Vacuo* evolve themſelves and get away, notwithſtanding the Viſcidity of that Liquor, very notably. It may be obſerved alſo, that all Liquors by this kind of Operation become vapid and dead.

IT may be farther remarked, that the Bubbles compoſing the Froth produced by theſe Experiments, always throw themſelves into the Form of an hexangular Solid, which is the only Polygon whoſe Sides would every where meet ſo as to leave no Vacuities between. The tubular Cells, made by the Bees in forming their Combs, are conſtantly of this Shape. Thro' Ducts of this kind, thoſe Animals can paſs with more Convenience and Freedom than if they had been either ſquare or triangular; and had they been of any other Form, they would have been incompact, and leſs agreeable to the Sagacity and Contrivance of thoſe curious and ſedulous little Creatures. WA-

WATER, even when cold, will viſibly yield a good Quantity of Air, when the Atmoſphere ceaſes to preſs on its Surface with all its Weight: But whenever the Spring of the incorporated Air ſhall be heightened by any Degree of Heat, it will appear to boil in the exhauſted Receiver, and that ſo ſmartly, as ſometimes to make it flaſh over the Cup.

IT may in making this Experiment be obſerved, that in this Ebullition of the hot Water, Part of the Heat will leave the Water, and be communicated to the Receiver: Whence it will appear, that Heat and Cold are not conveyed to Bodies by the means of the Air. Beſides, it is found on Experience, that Heat is propagated thro' a Vacuum with the ſame Eaſe, and in the ſame Manner, as thro' the Air: For if a Thermometer be ſuſpended *in vacuo*, it will undergo preciſely the ſame Variations with one hung near it in the open Air.

On the THERMOMETER.

WITHOUT entering upon the Nature of thoſe primary Qualities of Bodies, Heat and Cold, Points very much controverted among the Learned, we for certain know, that 'tis the Property of Heat to dilate, and of Cold to contract, all natural Bodies whatever.

THAT they have this Effect upon the most rigid, as Metals, *&c.* appears from the common Experiment, of exactly taking the Length of a Bar of Iron cold, as between the two Cheeks of a Lathe; heat it a little and it will be so expanded in Length, and proportionably in Breadth, that it will evidently exceed the former Measure. And that these Accidents produce the same Effect on fluid Bodies, was before fully proved by the Experiments made on the hydrostatical Balance, mentioned *Page* 133. The sinking of the Water-poise deeper in all Liquors that are warm, in general shews them to be dilated, from their being in that Circumstance less buoyant than when condensed by Cold.

AND that Heat and Cold will act on the Air in like manner, will appear on filling a Phial one fourth Part with Water, suppose, or Mercury. Then screwing a Tube of some Length into the Neck, reaching nearly to the Bottom, as *A B*, *Fig.* 2. *Plate* 9. Blow a little Air thro' the Tube, which will lodge in the upper Part of the Phial; the Spring whereof will cause the grosser Fluid to rise, suppose to *C.* Immerse the Machine in cold Water, and the Air in the Phial will immediately contract, shewn by the Descent of the Fluid from *C* perhaps to *D.* Take it again out of the Water, and lay a warm Hand on the Bottle, it will soon dilate, and push the Fluid up the Stem, perchance to *E.*

IF a Flaſk of Water, filled to half the Neck, be however immediately ſet on the Fire, the Fluid will at the very firſt ſeem to ſink therein, occaſioned probably by the Expanſion of the Glaſs being thin, and the Enlargement of its Capacity by the ſudden Heat; but in a very little Time it will riſe again, and continue ſo to do, by the ordinary Action of the Heat applied. But if a few Drops of Oil of Vitriol be put into ſuch a Flaſk, the Parts of the Fluid will be conſtricted thereby, and as it were condenſed, ſhewn by the ſinking of the Fluid in the Neck of the Glaſs, as it really thence becomes more cold.

IT may here be obſerved by the by, that in thin Glaſſes Water may be boiled with great Eaſe, and without Damage to the Glaſs; whereas thoſe that are thick moſt commonly fly. In ſuch the two Surfaces are neceſſarily at ſome Diſtance; and the outer Parts being dilated when ſet on the Fire, before the Heat can poſſibly have penetrated to and affected the inner, two powerful Forces pulling different Ways are conſtituted thereby, which ſoon demoliſh the Glaſs or other brittle Bodies on which the Experiment ſhall be made: Whereas both the inner and outer Surface of ſuch Bodies as are thin, lie ſo very near each other, that they, being heated and cooled much at the ſame Time, are therefore preſerved.

OUR Organs of Senſation being in a State of conſtant Mutability, are very unfit to direct us in giving a poſitive Judgment of the Degrees of Heat or Cold in any Medium; for the Breath, which in the Summer ſeems cool to the Fleſh, in Winter appears to it warm: And if we put a very warm Hand into Water moderately heated, and afterwards a cold Hand into the ſame, it will appear warm to this, but cold to that. But in this Matter the Thermometer will moſt certainly aſſiſt us.

THE Machine moſtly in Uſe for this Purpoſe, was invented by the *Florentine* Academy *del Cimento*, and is ordinarily a ſmall thin glaſs Ball, having a long hollow narrow Stem. The Air being thence extruded by Heat, 'tis filled to a certain Height and Degree, according to the then Temper of the Air at that Time, with coloured Spirit of Wine, Quickſilver, or Linſeed Oil; Fluids not ſubject to freeze. This done, the upper Part of the Tube is by a Lamp ſealed up with ſome common Air unavoidably left in it, and by the Heat of the Lamp ſomewhat rarefied. This on Occaſion will probably aſſiſt the Motion of the fluid Column, that is, hinder it from dividing in the Tube, when the Body of the Spirits come to contract; upon which, otherwiſe a Part of it might be apt to hang by the Way, and never regularly again move with the reſt (the Tube being commonly ſmall, and the Attraction of Coheſion between that and the Spirit therefore pretty ſtrong) as is often done, it may be obſerv'd, in ſuch Thermometers as from whoſe vacant

Part

Part the Air is pretty well extricated. In which Caſe there is no better Way of uniting the Spirits ſo divided, than by tying the Thermometer on a Board, and whirling it briſkly about at the End of a String; the centrifugal Force of which will probably bring the disjoined Parts again to move and act together.

AIR included, will, on the dilating of the Spirits, indeed be a little condenſed in theſe Machines; and therefore the curious Artiſt uſually makes an Allowance for it, by placing the Diviſions of the Scale at different Diſtances. For by the upper Part of a Scale, equally divided, it might indeed be diſcovered, that the Heat of the Medium was increaſed; but it would be difficult from it to judge how much.

THE original Air-thermometer had a Tube unſealed at Top, which tho' it might ſerve the preſent Occaſion tolerably well, in aſcertaining how much the Heat of the Hand or any Liquor into which it might be put, exceeded that of the Air; yet would it but uncertainly determine the Degree of Heat in the Air in general: Becauſe, being expoſed to the Atmoſphere, it would alſo be affected by its Preſſure, and of conſequence riſe ſometimes too much, ſometimes not enough; it is therefore at preſent not in Uſe.

THIS leads me however to deſcribe a very uſeful Machine, contrived by Dr. HOOK, called from its Uſe, the *Marine Barometer*, consisting entirely of two Thermometers of equal Length, thirty Inches apiece perhaps, fixed in the same Frame side by side, as *Fig.* 3. *Plate* 9. One of which was exactly the Thermometer now in Use; the other differed from it only in having an Opening at *D*, whereby it was exposed at Foot to be acted on by the Gravity of the Air, as well as affected by its Temperature with regard to Heat and Cold. Let us suppose these two Machines put together and filled, when as to each of these Circumstances the Air was in a middle Way; that is, the Weather about *Changeable*, the Air at *Temperate*, and let them be fitted up with proper Scales and Indices thus distinguished. If then the Pressure of the Air happened to be augmented, and its Temper not altered, the Consequence was, that the Liquor rose in *B*, as suppose to *E*; but kept stationary in *A*. This intimated the Air to be more ponderous, and consequently that *Fair Weather* might be then expected. Whereas had the Thermometer *A* risen by an Increase of Heat in a like Degree, as suppose to *e*, it would have indicated the Weather indeed to be warmer, but in the self-same Disposition with regard to Weight, as when the Instrument was first adjusted: And had they sunk in the same Degree, as to *G g*, just the contrary. These Alterations were easily to be observed thereon, by help of a sliding Index fixed to a Wire, as *H*.

THE unavoidable Wasting of the Spirits, thus exposed to the Air at *D*, especially in hot Countries,

tries, was an Inconvenience that the late Mr. PATRICK removed, by ſubſtituting Quickſilver in the Room. His Method was this: *A*, *Fig.* 4. *Plate* 9. is a glaſs Veſſel, capable of holding a certain Quantity of Air. *B*, in the inverted Neck, is a ſmall Ciſtern of Mercury, covered toward the Glaſs with a porous and light kind of Wood, to keep it from ſhogging to and fro in Carriage, thro' which however the Spring of the Air included in *A* might at all times eaſily act, and by its Spring preſs on the Surface of the Mercury. Theſe in his Machine ordinarily lie out of Sight; but the recurv'd Tube *EF*, communicating with *B*, and thro' which it may be eaſily filled with Mercury to the Level *B D*, where indeed the graduated Scale ought to begin, is produced to View, and is denoted in the Draught by the Letter *E*, *Fig*. 5. *Plate* 9. which is a Draught of the Inſtrument connected and put together. *H* is the Stem of a common Thermometer, appearing alſo to Sight; the Ball and upper Part whereof are bent backward and diſpoſed of within. *G* and *K* are two fixed Scales unequally divided, both marked with the Diſtinctions and Terms of the Thermometer only. *I* and *L* are two ſliding Scales, properly divided, marked like the Barometer exactly, with the Indications of the Weather, and the ordinary Diviſions, *viz*. Inches and Decimal Parts, from twenty eight to thirty one; between which, as has been ſaid, the Mercury in the common Barometer uſually ſtands. Theſe belong, as the fixed Scales do, to either Tube one.

Now if theſe Machines be put together, when the Air is in a middle State with regard both to Heat and Weight, the tinged Spirit in *H* will of itſelf naturally ſtand againſt *Temperate* on *K*. And by blowing or forcing Air into *A*, thro' the Body of the Mercury, by the Aperture at *E*, the Spring thereof may be ſo increaſed, as to throw the Mercury from the Level *BD*, *Fig.* 4. to the ſame Height on *I*, as the Spirit ſtands on *K*. Things thus adjuſted, ſhould both Machines then riſe or fall equally, 'twill only indicate a Change in the Temper of the Air as before: If unequally, it will ſignify, that an Alteration in Point of Weight has alſo happened therein, the Degree of which is by this Inſtrument to be readily diſcovered, thus:

Slide the moveable Scale on the Side contrary to that on which you begin your Obſervation, till the Index thereof points out on its correſponding fixed Scale, the ſelf-ſame Diviſion as that againſt which the Section of the Fluid on the Part of the Inſtrument firſt obſerved happens then to ſtand: Upon which the Section of the Fluid on the Side thus adjuſted, will point out the Inch and decimal Part, marked on the Scale laſt moved, at which the Mercury in the common Barometer ſhall then ſtand. An Example may render this familiar. The Mercury, for Inſtance, in *E* ſtands, let us ſuppoſe againſt forty, on *G*. Let *L* then be moved till the Index thereof points likewiſe at forty on *K*; when the Section of the Spirit will,

will, on its moveable Scale *L*, indicate what Weather may be expected, with the Inches and decimal Parts, at which the Mercury then ſtands in the Toricellian Tube; and thus *vice verſa.*

As the Obſervation may at any time be taken on either Side of theſe combined Thermometers indifferently, they will always certainly agree as to the Weather: But with regard to the Temper of the Air, that will eaſily be known by Inſpection, from the Spirit-ſide of the Inſtrument alone. This Machine is ordinarily about a Foot long, is very manageable, eaſily carried, and equally uſeful either by Land or Sea.

ACCORDING to the Improvement laſt mentioned, and contrary to the Uſage of all other Barometers, the Mercury ſinks in token of Fine Weather, and riſes on the Approach of Foul: Becauſe the Air's Preſſure coming on it from above, the Tube *I* being open at Top, the Air included in the Veſſel *A*, *Fig.* 4. *Plate* 9. beforemention'd, is either therein compreſſed on the Acceſſion of new Water, or dilated on the Abatement thereof; and this will be evidently ſhewn by the Riſe or Fall of the Mercury in *E*, whenever it ſhall happen.

THE Scales of this Inſtrument are larger conſiderably, and the Diviſions more diſtinct, than thoſe of the common Barometer; ſince the Temper as well as the Weight of the Air are concern'd in its Performance. Dr. HALLEY had one of them

them with him in his *South-Sea* Voyage. He gives it a good Character, and ſays, he met with no Storm which was not evidently foreſhewn by it.

On the HYGROMETER.

THIS Inſtrument ſhews the Diſpoſition of the Air as to Moiſture and Dryneſs, and may be of good Uſe in judging when it may be proper to air Rooms for the ſake of the Furniture, and may be very eaſily made ſeveral Ways.

FIRST, either by ſuſpending a little Weight at the End of a well-twiſted elaſtic String, ſuppoſe a Whip-cord; or elſe by fixing ſuch a Weight in the middle of ſuch a String, horizontally hung looſely over a couple of Tacks. The Moiſture in the Air will generally contract the Cord, and raiſe the Weight; and in a dry Seaſon it will naturally lengthen and lower it. The Weight in this Caſe may ſerve as an Index, and a few Marks made on a perpendicular Scale, will ſhew the Variations of the Air in theſe Particulars very ſenſibly. The Effects of which may in a little Time be diſcovered, by taking it, if portable, into a damp Vault, and afterwards ſetting it near a Fire.

THE twiſted Beard of a wild Oat, with a ſmall Index fixed to it, and a circular Scale, will make an excellent Hygrometer: For it will move by the Humidity of the Breath, while

while you look at it, unleſs particular Care be taken to prevent it.

CAT-GUT will alſo ſerve this Purpoſe very well, as may be obſerved by the coming forth of the *Man* or his *Lady*, depending on ſuch a String, from the *Dutch* Toy, called the *Weather-houſe*, now well known here in *England.*

WHEN the Air is moiſt, the Particles of Water floating abundantly therein fix on all Bodies expoſed thereto; they enter the Pores of ſuch as are of looſe and open Texture, and conſequently dilate and ſwell them very much. Hence wooden Doors, Drawers, and the like, are generally found to ſtick in moiſt Weather. If Wood be not painted, it imbibes them as faſt as they fall: If it be painted, it ſettles thereon; and in damp Weather, the Wainſcoat ſtands on a Dew, and the Moiſture ſometimes gutters down in Drops. Glaſs, Marble, and other denſe Bodies, of a ſmooth Surface, ſhew us this on every Occaſion; but Cordage and the laxer Bodies admit them into their Vacuities with Eaſe, and ſo produce the Effect here propoſed.

THAT there is a good Quantity of Water in the common Air at all Times, appears from the *Halo*, always ſeen in a clean Receiver while exhauſting, if the Candle be placed on the oppoſite Side. The watery Particles, diſperſed every where more or leſs throughout the whole Body of the Atmoſphere, according to the Dif-

ference

ference of its Denſity, being intimately mixed therewith, and thereby ſuſtained, are generally too minute to be viſible: But when the Air comes to be attenuated to a certain Degree, they begin to fall, and running precipately together, become apparent and evident to Senſe. The whole Glaſs, on ſuch an Occaſion, ſeems filled with a Miſt, and the Candle view'd thro' it appears to be encircled with a coloured Ring; but when the Air is wholly exhauſted, theſe ſmall Drops being no longer ſuſtained, either fall to the Bottom, or are ſeen to ſettle on the Sides of the Glaſs in a kind of Dew.

THIS will alſo farther appear from the Dew that, in hot Weather eſpecially, ſeems collected on the Outſide of a Glaſs, or other ſmooth Veſſel, upon the ſudden pouring in of cold Water. By the great Degree of Cold, the watery Particles in the adjacent Air are at once condenſed on the Surface, and become immediately viſible thereon. The like alſo is obſerved to happen in very cold Weather, from a Condenſation of the aqueous Particles interſperſed in the Air within a Room: Which, if the Weather be inclined to Froſt, will ſoon cruſt over the Glaſs with Ice; but if it be open Weather, they ordinarily gutter down in Drops.

WARM Air, it may be obſerved, will always receive, imbibe and diſſolve more Water than cold, in the ſame Manner that warm Water takes in more Salts than will a like Quantity cold. This appears to be ſo, from the

the Moiſture of the Breath, wholly inviſible in Summer-time, it being then eaſily received into and incorporated with the warm Air: But quite otherwiſe in Winter, when being condenſed, as it proceeds from the Mouth, by the circumjacent Cold, it is with more Difficulty received therein; and therefore the Breath then remains viſible, after Expiration, for ſome Time.

ON the contrary, Water, according to Dr. HALES, will abſorb good Quantities of Air: For if Water be well boil'd, and left to cool, it will be pretty well purged of its Air. Take then a glaſs Phial thereof, ſtop and invert it, leaving a Portion of Air of the Bigneſs of a Hazle-nut ſuppoſe thereon; in twenty four Hours time, this will wholly diſappear. Put in more Air, it will decreaſe in more Time, and at length be wholly incorporated with the Water, increaſing the Bulk of it proportionably. But when the Water is well impregnated, and as it were ſaturate therewith, it will take in no more.

On the ORIGIN *and* PROGRESS *of the* WINDS.

THE Air has been proved by many Experiments, to have in it a very fine and lively Spring; whence it endeavours, being either contracted or dilated, to return to its natural Degree of Denſity wherever it ſhall be. But as a farther Inſtance of this, we may exhauſt any Veſſel of Part of its Air; apply the Flame of a Candle to the Mouth, and on opening a Cock, the outward Air will forthwith ruſh in, and by the Motion of the Flame ſhew it does ſo. And again, if the Air be condenſed in the Veſſel, the included Air will puſh out, and puff the Flame outwards, till the Degree of its natural Denſity within, is juſtly equal to that of the circumjacent Air without.

FOR this Reaſon, the Air within a Houſe, will always be of the ſame Weight and Force with that without; ſince it cannot but very freely communicate therewith by the Windows and Outlets. It will therefore equally preſs on all Bodies, and will evidently raiſe the barometrical Mercury as much within Doors as it would abroad. For ſhould the Elaſticity of the Air at any Time be increaſed by ſome accidental Heat within the Walls, or ſhould the Air be occaſionally condenſed by any extraordinary Degree of Cold without, a juſt Equilibrium will ſtill be maintained between them, and the Barometer will be equally affected, notwithſtanding thoſe Alterations; the ſame Quantity of Matter being in either Caſe incumbent thereon.

THE due Conſideration of this Endeavour of the Air to maintain an Equilibrium in all its Parts, will aſſiſt our Conceptions very much in tracing out the natural Cauſe of the Winds.

ALL Fluids, by the Laws of Hydroſtaticks, endeavour to remain in a State of Reſt, and by conſequence immediately move, to make good the Defect, whenever this Reſt is interrupted: The Atmoſphere then is naturally inclined to maintain a peaceful Situation, in form of a hollow Sphere or Shell, all round the Earth; but various Accidents often conſpire to diſturb its Repoſe, and ſometimes put it into very violent Motions.

OF theſe accidental Cauſes, none procure ſo conſtant and certain Alterations in fluid Bodies, as Heat and Cold. It has been already hinted, that a Gallon of Water may be ſo dilated by Heat, as to make near fourteen thouſand times that Quantity of Steam; and it is evident to every Eye, that in boiling only, Water often enlarges its Dimenſions very much. A Gallon of Water, over a briſk Fire, for Inſtance, will eaſily fill a two Gallon Veſſel, and be made even to overflow; to which the Air incorporated with the Water may perhaps not a little contribute. Nor is there any Room to doubt, but was a Bladder of Air thruſt into boiling Water, the Spring of it would be ſo heightened by the ſudden Heat, as to burſt the Bladder immediately.

NOW as the Sun continually ſhines on a great Part of the Earth and its Atmoſphere every Day, his Beams heat and exhale Vapours from the one, and rareſy and expand the other,

other, according to the Degrees of Heat, in the ſeveral Latitudes of the Earth received. Between the Tropicks his Rays are always vertical, ſtriking perpendicularly on one Part or other of the torrid Zone continually; of conſequence therefore, the Air muſt be very much heated and expanded there. In other Climates the Heat of the Sun is greater or leſs, according to their Situation and the Obliquity of their Aſpect with regard to him; and the Rarefaction of the Air in either Caſe, is in ſome ſort proportionable to the Degree of Heat to which it is expoſed.

FROM this Expanſion of the Air, Motion is therein produced, the Parts adjacent being conſequently thruſt thereby out of their Places. This is every Day done, till the Sun has paſt the Meridian; when his Heat abating, the Air, before heated and rarefied thereby, comes to be gradually condenſed by the ſucceeding Cold; and then, according to the Nature of Fluids, the denſer and heavier croud again into the Vacuities made: And thus a Flux or Current of Air is produced, or what we call a Wind rais'd.

A DIGRESSION *concerning* FAULTY CHIMNEYS, *&c.*

TO make this familiar by a common Experiment, let us turn our Thoughts on the Wind-ſtove, which has a Plate to ſlip down before the Cavity of the Chimney, in order

order to contract the Channel, and confine the Stream of Air, by which the Fire is to be blown up. We know, that when this Plate is down, if the Fire be well kindled, the Air will rush thro' the Bars like a Torrent, and make the Coals burn with great Vehemence; but if the Fire be low, the Stream that sets into the Chimney will be scarcely perceptible.

Now it is plain, that the Air both in the Room and Chimney, before any Fire was kindled, might very probably be in a State of absolute Rest; and did not the Heat of the Fire attenuate the Air about it, it would so continue: But being expanded thereby and rarefied, it becomes lighter than the Air adjacent, and consequently emerges, by hydrostatick Laws. This then mounting up the Chimney with the Smoke, the denser Air, by its greater Pressure, rises out of the Room continually, to supply the Vacancy. And thus, for the same Reason that blown Bladders rise in Water, a successive Flow of Air, or a Wind, by this kind of Stove is successively propagated.

BY a Current of Air, or a Wind of this sort raised, the Machine called the Smoke-jack is turned. It consists of a circular Set of Vanes, disposed like the Sails of a good Wind-mill, obliquely to the Course of the Wind, in an Angle of about fifty five Degrees, if made to do their utmost. These are fixed into a vertical Shaft or Spindle, communicating with a little other simple Wheel-work, coarse and fit for the intended Purpoſe; which, when the Fire is clear and hot, it drives very briſkly: Whence it appears, that it is the Stream of the heated Air, and not that of the Smoke, which acts ſucceſſively on the Vanes of this Machine, in much the ſame Manner as does a Stream of Water againſt the Blades of an Oar, or the Floats of a Water-wheel.

AN entertaining Experiment, to like Purpoſe, might be made by a paper Lantern adorned with Figures, fixed to a very light circular Frame of ten Vanes, diſpoſed in the Manner aboveſaid, each of them four or five Inches long, and about one and a half broad. Under this Machine, the Center whereof is to be hung on a fine Pivot ſet upright, a lighted Candle is to be put (not too near the Centre) the Flame whereof, we may obſerve, commonly ends in a Point; the adjacent Air being thereabout very much heated; on which account, the Flame alſo, endeavouring to riſe with it, is protracted or drawn out, and becomes pointed in the Part where the Heat is moſt extreme. The Air thus rarefied, will riſe ſteadily within the Paper, and giving ſucceſſive Shocks or Strokes to the Vanes, will by Degrees make the Machine turn about pretty briſkly, and always the ſameWay. The Experiment is repreſented, *Plate* 9. *Fig.* 6

FROM the ſame Principle alſo is promoted the Circulation of warm Air, thrown into Rooms, after it hath been heated, undulating

thro'

thro' hollow iron Plates, diſpoſed generally in the Back and Sides of the Chimney. This is commonly let into the Room, or a Set of Rooms, through an Opening made ſomewhere above the Fire-place, and the Conſumption thereby made, is conſtantly replaced by a Stream of Air, riſing thro' a Pipe, which conducts it from abroad. In this Caſe the heated Air, firſt occupying the upper Part of the Room, deſcends by Degrees as low as the Opening of the Chimney, thro' which, having performed its intended Office, it aſcends along with the Smoke. And this Circulation of Air contributes very much to the Salubrity, as well as to the Pleaſure of the Place.

IT may here be obſerved, that all Obſtacles to any Current of Air, when raiſed, put it to the Spring, and very much diſturb its Progreſs, by throwing it often into Whirls and Eddies. And the Commotions therein produced by theſe fixed Objects, very often interrupt the peaceful Riſing of the Smoke in Chimneys; an Inconvenience very rarely to be got over, unleſs the Funnels can be ſo raiſed, as that they may deliver their Smoke beyond the Reach of the diſturb'd Air.

WE frequently ſee a Chimney do its Office very well, except when the Wind is ſome one Way; that is, when the Air about the Chimney-top is by ſome Means or other ruffled or over-much agitated, *viz.* It is either thrown too fiercely on the Chimney, by the Length and

Strength of the Guſt, or perhaps down it; but more generally, it is reflected from ſome Part of the Roof or the adjacent Buildings, or elſe it is abſolutely commanded by ſome Eminence that over-tops it. For Example: The Wave of Wind *A*, coming over the high Wall *B*, will pour down and prevent the regular riſing of the Smoke from the Chimney at *C*, *Fig.* 8. *Plate* 9. whereas it might have been ſhelter-ed perhaps from this Inconvenience, had it been placed more advantageouſly ſomething nearer the Object, as at *F*, or have eſcaped per-haps the Fury of the Blaſt in good meaſure, had it been removed to *G*. In the Choice of a Si-tuation for a Houſe, particular Regard there-fore ſhould be had to the Expoſition of the Chimney-tops, and proper Care taken that they be neither commanded by any thing very much above them, or that the Roof and the adjacent Buildings be ſo diſpoſed, that the Air about their Tops may probably not be diſturb'd by Reflexion, eſpecially when high Winds are abroad.

SOME Regard is alſo to be had to the Diſ-poſition and Make of the Chimney. As to the firſt; it ſhould, if poſſible, never be placed be-tween Doors, into which briſk or boiſt'rous Winds may blow. This will interrupt the regular Riſing of the Smoke, and often force it out of the Chimney. As to the ſecond; it ought to be ſo built, as to leave no undue Vacancies in the Funnel, or under the gather-ing Wings. Theſe are often Lodgments for Air, that may frequently be diſturbed, the ir-

regular

regular Motion of which muſt affect the Riſe of the Smoke very much. 'Twill therefore be always right, not only to lead the Smoke as directly and as ſtreight into the Funnel as poſſible, but alſo not to have that Funnel over large. For the ſame Reaſon, falſe Backs, and Holes made above the Fire-place in a Chimney, are little better than Receptacles for cool and agitated Air, and are ſeldom known to remedy the Inconvenience found, nor is it likely they ſhould.

CONTRACTING the Funnel or Section of the Chimney occaſionally, as is practiſed by Mr. PHILLIPS and others, who with Judgment undertake to remedy this Inconvenience, is a very good Way. When the Fire is juſt lighted, before the Air in the Chimney is much rarefied, and when there is a large Column of Smoke to be carried off, the whole Area of the Funnel, commonly left from ten to twelve Inches ſquare, is not too much for the intended Purpoſe. But as the Fire kindles, and gives more Heat, the Channel may on Occaſion be contracted to very good Purpoſe; and ſo as to be ſomething like, if not nearly equal to the confining the Draught of Air in the Wind-ſtove at Bottom.

A Contrivance of this Sort alſo, to ſhut it quite, might be added, of very great Uſe and Service whenever a Chimney ſhould happen to be on Fire, that by wholly ſtopping the Draught of Air, it might be put out.

IF a Chimney, not commanded by an Eminence, or in an inconvenient Situation, or otherwiſe injudiciouſly executed, as above, does not draw well, 'tis commonly for want of a free Succeſſion of Air to ventilate or fan the Fewel, and replace the Expence of Air that ought to mount up the Chimney, as beforeſaid, on account of the Heat, in a due Proportion. The making a Hole therefore beneath the Grate, with which the Air from abroad, or ſome other Room, may have free leave to communicate, will very much help it. This will not only duly ſupply the Fire with Air, and increaſe the Heat that Way; but it will render the Flux of raw cold Air, (which will otherwiſe neceſſarily enter by the Creviſes, and both cool the Room and the Perſons in it very much) leſs wanted; this Contrivance would conſequently greatly contribute to the Warming the Place, and of keeping its warm Air therein.

AND here it may be remarked, that 'tis more prejudicial to Health, to ſit near a Window or Door in a Room, where there are many Candles and a Fire, than in a Room without: For the Conſumption of Air thereby occaſioned, will always be very conſiderable, and this muſt neceſſarily be replaced by cold Air from without. Down the Chimney can enter none, the Stream of warm Air, always riſing therein, abſolutely forbids it: The Supply muſt therefore come in wherever other Openings ſhall be found. If theſe happen to be ſmall, and the Con-

Consumption large, let those who sit near them beware: The smaller the Flood-gate, the smarter will be the Stream.

To prove this by Experiment, we need only hold a Candle to the Key-hole of the Door of the Room, where a good Fire is, and a constant Stream of Air will be found to enter plentifully thereat. Besides, it may easily be remembered, that in sharp Weather, when we have had a brisk Fire before us, our Heels have been often ready freeze, merely from the successive Flux of cold Air continually drawing toward the Fire to make good the Waste, or what goes up the Chimney. And for this Reason it is that publick Assemblies generally procure the Professors of Medicine a great many Patients. To which indeed might be added, the alternate Heats and Colds unavoidable in such Places, which are nearly equivalent to the very great and sudden Alterations of the Weather that generally give People Cold.

WAS a Man, even in a Sweat, to leap into a cold Bath, or jump from his warm Bed in the intensest Cold, even in a Frost, provided he do not continue over-long therein, and be in Health when he does this, we see by Experience that he gets no Harm. If he sits a little while against a Window, into which a successive Current of cold and fresh Air comes, even in Summer-time, his Pores are closed, and he gets a Fever. In the first Case, the Shock the Body endures is general, uniform, and therefore less fierce; in the other, a single Part, a Neck or Ear perchance, is attacked, and that with the greater Violence probably, as it is done by a ſucceſſive Stream of cold Air. And the Cannon of a Battery, pointed againſt a ſingle Part of the Baſtion, eaſier make a Breach, than were they directed to play ſingly upon the whole Face, and will admit the Enemy much ſooner into the Town. But to return.

The CASE *of the* WINDS *continued.*

IN the Burning Zone, where the Heat of the Sun is moſt conſtant, as well as moſt extreme, the Courſe of the Winds is obſerved to be the moſt uniform and regular, whether we conſider them as continual or periodical.

OF the firſt ſort is the Eaſterly Wind, blowing conſtantly between the Tropics, in ſome Places as far as thirty Degrees on either Side of the Line, in others not ſo much: Of the ſecond ſort are the Land and Sea-breezes, which in thoſe Climates regularly blow from Sea to Land in the Evening, and from Land to Sea in the Morning.

THE daily Revolution of the Earth being from Weſt to Eaſt, upon her own Axis, the ſucceſſive Rarefaction made in the Atmoſphere by the Heat of the Sun, will be according to his apparent Courſe from Eaſt to Weſt; and as the Air, thus rarefied, comes by his Departure to cool, and be again condenſed, the Motion of it will follow the Rarefaction con-

tinued

tinued Weſtward, and thus is an Eaſterly Wind there perpetually propagated.

SOME indeed have aſcribed the conſtant and perpetual Eaſt-wind, thus blowing near the Equator, to the diurnal Rotation of the Earth about its Axis from Weſt to Eaſt, whence they conceived, that the Air on its Surface might ſeem to move the contrary Way, as being, from the *Vis Inertiæ* of Matter, in ſome ſort left behind. But as here are alſo found Winds that blow on other Points of the Compaſs; and as the Air is known to preſs on the Earth by its Gravity like other Bodies, to reſt upon it, and there being nothing to hinder it from freely moving and revolving with it, (which by the way muſt very ſoon happen) this cannot be the Cauſe of the Eaſterly Winds in thoſe Parts.

DID the Sun never depart from the Equinox, the Wind would very probably there never vary from the Eaſt Point: But we find that as he draws towards the North, in the Courſe of his Declination, as far as twenty three Degrees and near a half, the Rarefaction of the Air ſhifts Northward after him, and the Wind conſequently follows, in the compound Direction from the North and the Eaſt, ſo long as the Sun continues North of the Line, that is, from *March* to *September*. And when his Declination is Southward, between *September* and *March*, for the ſame Reaſon the Flux of the Air is accordingly leſs or more Northerly; and in the Southern Hemiſphere juſt the contrary happens. Which

being

being agreeable to Fact, off at Sea, in all the vast *Ethiopick* and *Atlantick* Oceans, where there is nothing to interrupt, it makes the Physical Cause of Winds, here proposed, more than hypothetical.

THE Reason of this Variation is obvious. The equatorial Parts being hotter than any other, the Air in both the Northern and the Southern Hemispheres ought equally to tend that Way, and it generally does so when the Sun is in or near the Equinox. But as he declines toward the North Tropick, the Northern Current of the Air meeting in its Passage with the Eastern, produces a North-east Wind on that Side; as the Southern Current, joining with the same on the contrary Side of the Equator, there forms a South-east Wind.

THERE is no Doubt, but that if the whole Surface of the Globe was Sea, the beforesaid Wind would blow with the same Regularity, in those Climates, quite round the Globe: But in regard great Continents do often interpose, and break the Continuity of the Oceans, Respect must also be had to what will follow from the Nature, Situation, and Disposition of their Soil, and other Accidents, which are capable of interrupting the steady Course of the Winds, and of making it in many Places variable and uncertain.

To account in particular for the Land and Sea-breezes, which alternately are observed to

set

ſet on and off the Coaſts in hot Countries, it will not be unnatural to ſuppoſe, That ſince the Water is found to imbibe and tranſmit many, or moſt of the Rays of Light falling thereon, and the Land to reflect them, that the Air, during the Heats of the Day, muſt be much more expanded and rarefied over the one, than is poſſible over the other: Beſides, the Sea can yield none but unactive watry Particles, in Exhalations; whereas from the Earth, nitrous and other heterogeneous Particles may be exhaled, which meeting in the Atmoſphere, and fermenting with each other, may greatly contribute to heighten the Spring, and conſpire with the Heat to increaſe the Air's Elaſticity, and cauſe it to riſe more briſkly above the Land. The denſer Air from Sea then, ſetting in upon the Coaſt, will become a comfortable Sea-Breeze to the Inhabitants all Day; and the Air thus rais'd, and perhaps heaped above the Land, cooling by the Chill of the ſucceeding Night, may thence recover Denſity and Weight ſufficient to thruſt back the Air from Sea, and returning the Way it came in, may become a Breeze from Land.

AND hence one might think, that the Progreſs of the Sun from Eaſt to Weſt ought to produce rather a Weſt than an Eaſt Wind: Since it ſhould ſeem, that the Air being denſer in the Weſtern Hemiſphere, from the longer Abſence of the Sun, than in the Eaſtern, over which it had more lately paſt, might be apt to produce a contrary Effect to what is really done. And this would doubtleſs happen,

was

was the Point of the greateſt Rarefaction that to which the Sun ſhould at any Time be vertical. But as the greateſt Heats are obſerved commonly to be rather two Hours after that Time, or ſome thirty Degrees to the Eaſt of that Point, the Proceſſion of the Sun toward the Weſt is in Favour of the Eaſtern Current of Air, two Ways: Firſt, as it meets with the Weſtern Current making toward it, and diminiſhes its Efforts in the Courſe of the ordinary Rarefaction; and, ſecondly, by this Point's ſhifting of itſelf conſtantly Weſtward, whereby a new kind of Impetus is given to the Eaſtern Current, which being thus put in Motion, continues it regularly forward, and ſo gathers Power ſufficient to overcome the former, and drive it before, in its own Direction.

BESIDES, the more general Cauſes of the Winds hitherto inſiſted on, *viz.* Heat and Cold, there may particular ones alſo be aſſigned. Such as, 1. The Approach or Elongation of the Moon in her Circuit round the Earth, and even her Attraction in the Meridian, may be reaſonably judged to raiſe a Swell of the Air, no leſs than of the Water, in the Tides. 2. Certain Exhalations, that riſe out of the Earth ſometimes and occaſionally, in certain Places, in Earthquakes eſpecially, and from Volcano's. 3. The Fall of great Quantities of Rain, Hail, or Snow, cauſing thereby a ſudden Condenſation or Contraction of the Air where they are. 4. The ſudden melting of Snows, *&c.* on the higher Mountains, cauſing the great Condenſation of Air near them ſuddenly to ceaſe. 5. Burning Sands,

Sands, that often retain the ſolar Heat to a Degree incredible to thoſe who have not felt it, cauſing thereby a more than ordinary Degree of Rarefaction in the Air adjacent. 7. The Oppoſition of high Mountains, that reflect the Winds, and alter the Line of their Direction, and ſuch like. All which particular Cauſes may happen either to conſpire with, and ſtrengthen the general Cauſes before-cited; or may oppoſe in part, or leſſen their Efforts, according to the Diverſity of Time, Place, and Circumſtance, in the Courſe of Things.

To theſe Particulars, and ſuch as theſe, is owing the manifeſt Irregularity and Uncertainty of the Winds in Climates far diſtant from the Equator. Nor can it be Matter of Wonder, if in high Latitudes the Winds be found variable, ſince between the Tropicks (where it might be leaſt expected, on account of the ſteady conſtant Heat of the Sun) in certain Places from one Diſpoſition or other, Alterations are found in the general Eaſterly Winds themſelves. For Example; in the Southern Part of the *Indian* Seas, and far from Shore, the Wind blows always from the Eaſt or thereabout, according to the ordinary Courſe thereof, in and about that Latitude: But 'tis obſerved, that in the North Part thereof, the Wind blows regularly from the Eaſt, as in other Places adjacent, but one half the Year, and then turns and blows directly from the Weſt, for the other ſix Months; and theſe Variations, in particular Places, ariſing from particular Cauſes, are termed

Monſoons:

Monsoons: That is, when the Sun draws toward the North Tropic, the ſeveral Countries lying near the Coaſts in the Torrid Zone, becoming hotter, reflect more Heat than the Seas beyond the Equator, which the Sun has left; the Winds therefore, inſtead of blowing thence to the Parts under the Equator, blow the contrary Way: And when the Sun leaves thoſe Countries, and approaches the other Tropic, the Winds turn about, and blow from the oppoſite Point of the Compaſs. The Regularity of theſe Winds making them more than ordinarily uſeful in Navigation, they are from thence called the *Trade-Winds.*

North of the Tropick of *Cancer*, it may be obſerved that the Moon has often a conſiderable Influence on the Winds, which in the Compaſs of fourteen Days, or half the Lunation, ordinarily make an entire Revolution, and blow from all the Points of the Compaſs. At New, the Wind being at North, it paſſes on to the Eaſt in a few Days, then to the South, and ſo on to Weſt, and returns to the North about the Full, in ſettled Weather. In unſettled Seaſons, the Winds will often vary, and run a little backwards, apparently againſt the Courſe of the Sun, as from Weſt to South-weſt, and ſo to South: However, they ſeldom veer quite round in this Manner, but ſtop at ſome of the intermediate Points.

With Regard to the Variety of Winds, by the Curious obſerved to blow, at the ſame Time, in in different Places of the Earth, this may proceed from ſeveral Cauſes, worthy of Attention. As firſt; It being plain, that the Winds always move in the Direction of a great Circle, or one that would, was it continued, divide the Globe into two equal Parts; and did the Wind proceed from any one of the cardinal Points, that is, either from the Eaſt, Weſt, North or South, it would then retain its Name over a great Part of the Globe: But ſhould the Wind proceed in any other Direction, it will ſeem very different in whatever diſtant Places it ſhall paſs over. Becauſe every one acquainted with the Principles of Geography knows, that all Rhumbs, which give Denomination to the Winds, between the Equinoctial and the Poles, are not ſtreight, but ſpiral Lines. For Inſtance; ſhould a Wind ſet out from the Equator, in the Direction of an Angle of forty five Degrees; in order to retain the ſame Name, South-weſt for Example, it ought to croſs the Meridian of every Place, it ſhall paſs over in the ſame Angle: But if it keeps right forward, that is impoſſible; becauſe the Meridians are not parallel, but inclined Lines, all meeting in a Point in both the Poles: Wherefore the Wind that is termed South-weſt in one Latitude, will always carry a different Name in another.

A ſecond Cauſe of this Variation of Winds, obſerved in diſtinct and different Places, may be from the adjacent Air's being thrown into a kind of an Eddy, by the Paſſage of a furious Blaſt, over a particular Track of Land: As in Rivers,

Rivers, when the Stream is rapid in the Middle, the Side-water is always puſhed obliquely towards the Banks.

A third Cauſe may be, when in two Places, at a great Diſtance from each other, there happens at the ſame time to riſe great Quantities of Exhalations from the Earth, able not only to diſturb, but drive the Air into Motion all round them. In ſuch Caſe, there muſt neceſſarily riſe two Winds, meeting each other in a contrary Direction to the very Point of their Congreſs.

THE fourth and laſt Cauſe uſually aſſigned for this Phænomenon, is the Oppoſition of high Mountains, which reflect the Winds, and gather and turn them into a Courſe often very different from their firſt Direction. An Example of this we have in the Lake of *Geneva*, which ſpreads itſelf between two Ridges of Hills for twelve Leagues together. Here there are never known to blow any other than two Winds, that is, either up or down the Valley. The like happens, as the Seamen well know, off of *Genoa*, and ſeveral Places in the *Mediterranean*; when ſailing with a ſteady Wind under Shore, they often meet with a Flood of Air, or a Squall of Wind from the Openings of the Valleys, as they paſs, directly croſſing perhaps the main Current of the Wind at Sea.

A Gentleman who had uſed to convoy the *Greenland* Trade aſſerts, That about the Iſland

of

of *Spitsberg*, is fixed a vaſt Ridge of Mountains of Ice, to which, from the Diſtance perhaps of fifteen Leagues, he has frequently, out of Curioſity, taking the Opportunity of a Wind blowing right upon them, endeavoured to ſail towards; but when he was about half way, he found he always loſt his Wind, and what did blow, was rather againſt him. This was occaſioned, no doubt, by the Reflection of the Wind thrown directly on thoſe Eminencies.

ABOUT *November*, it may be obſerv'd, that we who live in a conſiderable Northern Latitude, are frequently viſited with high and boiſterous Winds. This may poſſibly proceed in part from the general Condenſation of the Air in the North frigid Zone, where they begin about that Time wholly to loſe Sight of the Sun. It may, in part, no doubt, alſo proceed from the Exploſions of fermenting oily Matter, which, after a hot Summer, may be diſpoſed to riſe from the Earth in ſundry Places when that Heat is abated, and occaſion ſomething like the Winds which are found to iſſue from the Mouth of Caverns, either when the Spring of the internal Air is heighten'd, as is ſaid, or when the external is render'd leſs denſe; much as a Blaſt of ſtrong Air will be puſhed from Water boiling in the Eolipile. The Experiment to be made on which Machine is this: Take a globular Veſſel of Copper, having a ſmall Pipe ſodered into its Side. Heat this Machine pretty well, and invert the Stem into Water: As the Eolipile cools, the heated Air will contract, and the Water will riſe into the Cavity, and fill it in a Degree proportionate thereto; perhaps three quarters full. Then ſet it on a Chafing-diſh of hot Coals upright; as it heats, the Steam will iſſue from the Pipe in ſo violent a Blaſt, that will blow a Torch or Brand, held in the Way, like the Bellows of a Forge. This Experiment is repreſented *Plate* 9. *Fig.* 7. Should the Eolipile be reverſed when the Water boils, a ſmart Jet of Water would be thrown out of the Pipe by the Repellency and Force of the confined Steam: And was the Machine filled with Spirits inſtead of Water, it would in like manner preſent you with a noble Jet of Fire.

SOMETHING like this Experiment may be obſerved to happen in burning green Wood. The Fluids contained in the Cavities and the Fibres thereof, being dilated by the Heat of the Fire, puſh briſkly forth: They often rend and burſt the ſolid Wood to make their Way, and then iſſue in a Blaſt. The Action of the little Candle-bombs is alſo on the ſame Principle. Theſe are pretty ſtrong Bubbles of Glaſs, having a ſmall Quantity of Water incloſed, which being ſtuck near the Wick of a lighted Candle, when the Water comes to be much heated, will ſo expand as to burſt the Glaſs with a ſurprizing Noiſe and Force.

FROM ſome Cauſe ſimilar to this, we endeavour to account for the Origin of tempeſtuous Winds; ſuch, for Inſtance, as are obſerved to

blow,

blow, about once in ten Years, in the *West-Indies*, near the Islands called *Antilles*; *viz.* about *Cuba*, *Jamaica*, *Porto-Rico*, the *Caribbees*, *Lucayes*, *Stotovento*, and *Bermudas*: Hurricanes which blow, for the Time they last, with incredible Fury, lay Waste the Countries, and make strange Havock at Sea.

As Earthquakes are often felt there at the same Time, and Innundations often follow, 'tis more than probable, that great Quantities of nitrous and sulphurous Matter, fit for Explosion, being brought up to a fit Disposition by Fermentation (hereafter to be more fully explained under its proper Head) may get loose; and thus by the springing of Mines as it were of fermenting Matter, successively in several Parts of the Ocean thereabouts, the Devastation here described may be occasioned: And that not only with Regard to the Commotion of the Air and Waters, by driving away the Parts contiguous to these Explosions, in a very violent Manner; but also with regard to the great Havock made among the Shipping, and even the Fish, which are always found dead in those Parts, in great Quantities, after a Calamity of this Sort has happened: Animals, which were it not for some external Violence, proceeding from the very Bottom of the Deep, might be very well imagined to be shelter'd from any Inconvenience that might arise from the Agitation of the Winds or Waters above. Besides, these Hurricanes now and then present the Geographer with a new Iſland, and ſometimes they ſink one upon him, or take away a Part of the old. Which is alſo an Evidence, that the Cauſe of theſe very extraordinary Diſturbances proceeds immediately from the Bowels of the Earth; as indeed all outrageous Storms of Wind may, from a Parity of Reaſon, be very well preſumed to do.

THE Motion of the Winds is generally in Waves, as appears by the Sound of Bells, which in ſmall Intervals of Time are frequently obſerved either to increaſe or be diminiſhed in the ſame Place very ſenſibly, juſt as the Guſt directs it either to this Place or that. The Motions of the Waves of the Sea, evidently impelled thereby, often demonſtrate this: Since they do not all break on the Shore in the ſame, but very different Places. It farther appears by the Effects often left by this kind of Storm; where, in the Compaſs of a ſquare League, we ſhall often find many Trees left ſtanding, when many others, of equal Strength, and the ſame in Kind, have perhaps been over-turned. The Dancing of the Mercury in the Barometers of curious Make, on theſe Occaſions, is another Evidence alſo of the unequal Compreſſions of the Air, under this Circumſtance: It likewiſe intimates, that Part of the upper Air is ſometimes removed by the violent Guſts in a Storm, which on their Abatement ſoon returns.

WHEN two great Winds happen to be inclined

clined to each other in an Angle of about fifteen or ſixteen Degrees, 'tis certain they condenſe the Air at the Place of their Congreſs, and, according to the Rules of Percuſſion, make it flow almoſt a third Part faſter than either of them ſingly did. Suppoſing then that each of theſe Winds were going with the Velocity of twenty four Foot in a ſecond, as *A* and *B*, *Fig.* 9. *Plate* 9. which is the uſual Velocity of offenſive Winds, againſt which it is troubleſome to walk; the Wind compounded of theſe two, will proceed after their Confluence at *C*, with the Velocity of about thirty two Foot in a Second, toward *D*. This appears from common Experience, as well as the Rules of Motion; and may be ſeen repreſented by the floating of a Paper, whenever there is a Fall at *London-Bridge*, or at any Sluice of Water.

WHERE Winds are of equal Strength, and directly oppoſite, they on Meeting deſtroy each other's Force, and there produce a Calm; but the Air will there be accumulated: Whence 'twill follow, that to preſerve the Equilibrium, the Air muſt flow back either Way, above the main Current, and occaſion thereby two other contrary, but more gentle Winds, to blow from this Place above.

Dr. DERHAM, in a curious and accurate Diſcourſe on the Motion of Sound, takes occaſion to ſay ſomething of the Velocity of Winds; which, from many Trials, he concludes, cannot poſſibly move, in the greateſt Storms, above fifty or ſixty Miles an Hour; and that an ordinary briſk Wind may proceed probably at the Rate of about fifteen Miles an Hour. The Courſe of ſome is however ſo gentle, as not to exceed a Mile an Hour.

IF a boiſterous Wind meets ſide-wiſe with another more weak, it carries away the Air neareſt to it, and turns it round with a certain Velocity, and this we call a Whirl-wind. This ordinarily goes on with the ſtronger Wind, and carries with it whatever is not very heavy.

TO ſomething of this Kind is aſcribed that extraordinary Meteor often ſeen at Sea, and ſometimes at Land, very dangerous to Ships, and whatever happens to be in its Way, called the Water-ſpout. 'Tis moſtly obſerved in hot dry Weather. Its firſt Appearance is in Form of a deep Cloud, whoſe upper Part is white, the lower black. From the lower Part hangs, or rather falls, what we properly call the Spout, reſembling a conical Tube, biggeſt above. Under this Tube is always a great Boiling, and Flying-up of the Sea-water, as in a Jet. For ſome Yards above the Surface of the Sea, the Water ſtands as a Column, from the Extremity whereof it ſpreads and goes off, as in a kind of Smoke. Frequently the Cone deſcends ſo low as to touch the Middle of this Column, and continues for ſome Time contiguous to it; though ſometimes it

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only points to it, at ſome Diſtance, either downright or aſlant.

IT is often ſcarce diſtinguiſhable, whether the Cone or Column appear firſt, tho' generally the Boiling or Flying-up of the Water has the Priority, and this immediately precedes its being form'd into a Column. Generally the Cone does not appear hollow, till towards the End, when the Sea-water is thrown violently up the Middle of it, as Smoke up a Chimney. Soon after, this Canal diſappears, but the Boiling up of the Water continues ſome Time afterwards; and ſometimes till the Spout forms itſelf, and appears anew, which it will do, on Occaſions, ſeveral Times in a quarter of an Hour.

THE real Cauſe of ſo uncommon an Appearance, and ſo dangerous to approach, is as yet but little known; but Mr. DE LA PRYME, from a neat Obſervation of two or three of theſe Spouts in *Yorkſhire*, conjectures, that they are a Gyration, or whirling of Clouds, impelled by contrary Winds, meeting in a Point or Centre, and falling down in a great Tube, ſomewhat like ARCHIMEDES' ſpiral Screw, where the greateſt Condenſation and Gravitation is, by its working whirling Motion, abſorbing and raiſing the Water with a prodigious Force; thus deſtroying Ships at Sea, or rending off Arms of Trees, Thatch of Houſes, *&c.* as it has ſometimes, in paſſing over them, done at Land.

THE Diſſolution of theſe Spouts may be aſcribed to the Weight of the great Quantity of Water they generally have taken up, which impedes the Rapidity of their Motion, whereon their Force and even Exiſtence depends. When they break, they let go their Contents, which overwhelms whatever is found underneath. To prevent the ill Conſequences whereof, our Seamen, when near, endeavour to diſturb and break them, by Noiſes, and the firing of great Guns, which puts the circumjacent Air into a Tremor and a Motion different to and oppoſite in ſome ſort to that whereby they are impelled.

To conclude this Subject; it may be remarked in general, That tho' it is difficult to aſſign a phyſical Reaſon as yet, for all the Varieties that happen in the Syſtem of the Winds, by Reaſon of the Multiplicity of Accidents that happen in the natural Courſe and Circumſtance of Things; yet thus much do we know for certain, that in hot Climates, where Exhalations are more copious, Hurricanes, Tornadoes, and more violent Storms, are common and ordinary. In the temperate Zones, where the Heats are leſs powerful, theſe Appearances are not ſo frequent or ſo furious. And in cold Countries, where, for want of Sun, the Air is always pretty denſe, the Winds blow more gently, and move with greater Steadineſs than they are found to do in any other Parts of the Earth.

The great Service the Winds are of to Mankind, in the Way of Mill-work and Machinery, will ſcarce bear the Mention, when we conſider the vaſt Advantages the World derives from Trade and Navigation. By the Subſerviency of the Winds, Ships of prodigious Burden are conveyed round the Globe with Speed, Certainty and Eaſe. The Earth is diſcovered by this means, the Nations are civilized, and the Redundancies of one Country made frequently to ſupply the Deficiencies of another. This again bears but a very ſmall Proportion to the general Benefit theſe Tides of Air are of, in tranſporting to us thoſe Particles of Humidity from the Ocean, which form the Clouds, and which water and fertilize the Earth. Were it not for theſe frequent Commotions in the Air, the Salubrity of it could not long continue: For all the noiſome Steams and offenſive Vapours, that riſe over popular Places eſpecially, would there hang, and ſtagnating, would render this common Magazine of ſubtile Bodies, a Maſs of corrupt, putrid and infectious Matter.

On the Natural Cauſes of Thunder, Lightning, *and* Meteors.

Having occaſionally mentioned the Effects of fermenting Matter, in producing Earthquakes and extraordinary Storms of Wind, our next Enquiry may be, how far the

the ſame Cauſe may be concerned in the Production of Thunder and Lightning, and the other Meteors appearing in the Regions of the Air.

FROM Obſervation, the Atmoſphere may very well be conſidered as a common Receptacle of all the Vapours exhaled from the Earth; and we ſee Effluvia from an infinite Number of other Bodies do aſcend therein continually. All manner of Scents, for Inſtance, whether proceeding from grateful or fœtid Bodies, the Steam and Smoke of things burnt or melted, the Fogs and Vapours ariſing from damp and watery Places, the Emanations from nitrous and ſulphureous Subſtances, thoſe iſſuing from acid and alkaline Bodies, and, in a word, whatever may be called volatile, riſes in the Air, and therein finds a Place according to their ſeveral Weights, as in a common Magazine.

SULPHUREOUS Steams riſe from Volcano's, evidently in great Abundance; the Parts of which are ſo very fine, and have ſuch a Repellency in them, that they will continue to riſe even in an exhauſted Receiver, as may be try'd, by writing ſomewhat on a Paper with ſolid *Phoſphorus*, which is a chymical Preparation from human Urine, uſually kept in Water to prevent its Evaporation and Waſte. This being put under a Receiver, will ſoon become viſible, and riſe into a kind of lambent Flame, emitting great Quantities of Steam, but will not ſcorch the Paper; and if you

you exhauſt the Receiver, the ſame Appearance will continue with very little Variation.

VARENIUS, in his *Geography*, obſerves, that when the Spices in the Iſlands, where they grow, are ripe, the Seamen can perceive it, merely by the Smell, at the Diſtance of ſeveral Leagues. In the *Azore* Iſlands, ſuch is the corroſive Quality of the Air, from the various Effluvia mix'd therewith, that the Iron, and even the Stones of the Buildings there molder very ſoon: Whereas in the Province of *Chili*, in *America*, the Quality of the Air is ſo very mild and friendly, that though one puts up a Sword into a Scabbard moiſt, there will never be found any Ruſt upon it. Theſe different Effects undoubtedly proceed from the different Particles of Matter wherewith the Air in thoſe Places happens to be impregnated.

THE Effluvia emitted from Bodies, may be reduced to two principal Claſſes, the Acid and the Alkaline, though ſome there be that appear to be neutral. The firſt generally proceed from Subſtances that affect the Taſte in a piercing and pungent Manner; the Points of which are therefore preſumed to be ſharp, rugged, and much broken. The ſecond often riſe from the Subſtances formed of Particles appearing to the Tongue tart, rough and deterſive. Theſe are ſuppoſed by ſome to differ from each other both in Nature and Form: Since, whenever two Fluids of theſe kinds are mixed

mixed together, a ſtrange Conflict and Commotion immediately enſues.

THIS may poſſibly not only proceed from the Ineptitude of the Parts of their conſtituent Particles for uniting and coaleſcing; but alſo from the alternate Attraction and Repulſion of their Parts: And it is not improbable, but that there may be a Polarity in many other Parts of Matter, as well as in the Magnet and Iron, in which they are certain and inconteſtable. That there is ſuch a Property in ſeveral fixed and chryſtaliz'd Salts, is pretty apparent, by their always ranking and diſpoſing themſelves in one certain unalterable Manner, as often as they are reduced from a fluid to a fixed State.

AND to this ingenite Property of Attraction and Repulſion, it may with ſufficient Probability be preſum'd, that the inteſtine and fermentative Motion ariſing from the jumbling together and mixing of theſe kind of Bodies, is principally owing. The acid Particles, for Inſtance, in mixing Juice of Lemons and Salt of Wormwood, may be well conceived to attract ſome of the ſaline Particles ſtronger than before, and to repel others with as great a Force, according as their Poles in ſuch Mixture chance to meet, and be obverted to each other: Hence ariſes a great Commotion between the acid and alkaline Corpuſcles, and from their leaping and bounding alternately into and out of each other's Sphere of Activity, being themſelves probably alſo of an elastic Nature, which must necessarily encourage an Ebullition, and often bring on an Effervescence, that may continue till all the Particles, both acid and alkaline, have met each other at their proper Poles of Attraction; which is no sooner done, but the Ebullition ceases, the Mixture subsides, and the jarring Particles then seem united in a friendly manner.

AND here it may be observed, that the Affair of Fermentation is, by the generality of the later Philosophers, allowed to be one of the obscurest Processes in Nature; and in a great Measure a Mystery, to which their Principles of Inequalities in the Attractions of Cohesion of Bodies do not fully reach: For Instance, in the Degree of Fermentation caused between Solids and Fluids, in order to procure their Dissolution, the Particles of the former are by them supposed to attract those of the latter with greater Force, than either those of the Fluid or of the Solid attract one another; whence the said Effect is thought to be produced. And with Regard to the Fermentation of Fluids with Fluids (or the Cause of the great Variety of beautiful Motions, which for a long Time together appear in Liquors, which either ferment of themselves, as Must or new Wine, or that become defecated by the Addition of Yeast or other fermentable Matter) they do so lamely account for the intestine Commotion, the Bounding and Resilition of the small and insensible Particles of those Bodies, arising without any mechanical apparent Cause, and producing such

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considerable Alterations therein, even tho' the Elasticity of the Air be admitted into the Process, that the abovementioned Hypothesis may be receiv'd, at least till Principles shall be discover'd, that will better correspond with the notable Activity of fermenting Matter, than a sluggish Inequality of Attractions and Cohesions seems to do.

IT may however be objected, that this of fermenting with an Acid is sometimes but a fallacious Criterion of an Alkali: For Oil of Vitriol is the strongest and most concentrated Acid we know, and therefore whatever ferments with it should be of an alkaline Nature: Whereas 'tis certain that it will ferment with some Bodies that seem to be neutral, and even with some that are allowed to be acid. From a Mixture of simple Water, Quicksilver, Nitre, *&c.* only an Effervescence and Heat ensues; and these are, properly speaking, neither acid nor alkaline. Nor does the strong Acid beforenamed, mix, without some Commotion, with Rhenish Wine, and many other confessedly acid Liquors.

IN answer to this, it may be offered, That tho' the Bodies mention'd may appear to be wholly of the neutral kind, it is not improbable but they may be heterogeneous, at least in some Degree: And tho' the Acid and the Alkali may so far predominate in some, as evidently to distinguish to which Class they belong; or they may be so happily mixed in others as to render that Matter

ter difficult; yet when either of theſe come to be reinforced by the Addition of freſh Matter of either kind, and a Commotion and Conteſt happens to be renewed, it may prove no more than that the Diſcordancy of the Particles oppoſite in Nature is continued, which before were quieſcent, as being then equally matched, and in the State of two equal and oppoſite Forces, mutually deſtroying each other.

VOLATILE Salts, ſuch as are extracted from Hartſhorn and the like, are of the alkaline kind. Theſe are known eaſily to evaporate and be diſſolved in the Air; not only by the ſtrong Smell continually ariſing from them, but alſo the Abatement of their Quantity, if they be left any Time unſtopped. Acids do the ſame thing, but in a leſs Degree; as may be inferr'd from the ſour Smell hanging about, and riſing from Vinegar, Spirit of Salt, and Things of that Tribe: And theſe being diſtinguiſhable by the Smell, all Bodies that on the Mixture with them, ſhall ferment, may be preſumed in general to be of the alkaline Kind.

PARTICLES of Matter, ſuch as theſe, either riſing of themſelves, as being leſs denſe than the Air, or exhaled from different Soils in the various Parts of the Earth, by the Heat of the Sun, however peaceful and innocent in their own Nature they may ſimply be, yet meeting with and being mix'd with other Particles of a different and a diſagreeing Kind, may begin of themſelves to ferment, and may ſo

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briſkly operate on each other, as to produce very ſurprizing Effects; of which any one will be convinced, that has ſeen the Mixture of two Liquors of this Kind, from the ſudden Ferment and Diſcordancy produced thereby; as of Spirit of *Nitre* or *Aqua Fortis*, and the Spirit of *Sal Ammoniac*, or Salt of *Tartar*. Even the Effluvia from theſe Bodies meeting in the Air, begin a Degree of Effervеſcence, and thence become ſometimes viſible. Hence it is reaſonable to ſuſpect, that our ſtinking Fogs, which have uſually alſo ſome Degree of Heat in them, are thus produced by the Mixture of Vapours of different Kinds, riſing from the Earth on certain Occaſions.

THE Salubrity then or Unwholeſomeneſs of the Air, in general, proceeds no doubt from the different Combinations of the heterogeneous Particles, that conſtantly make their Way into it: And healthful Seaſons and Situations greatly depend on the Effluvia ariſing from the Soil of the neighbouring Places, or what happens to be wafted in the Winds. Many of which, tho' innocent and wholeſome in themſelves, yet being mixed, may become hurtful to Life; and, on the contrary, ſuch as are prejudicial thereto, may chance to be joined with Effluvia from Matters of a different kind, ſo as to have their Malignity mitigated, and may thereby become indifferent, and even healthful.

AN Inſtance of the latter Sort may be produc'd from crude Mercury, and the Effluvia raiſed from Vitriol,

Vitriol, common Salt, and Nitre, none of which are poiſonous alone; but when they come to be mixed in the Air, being ſublimated by Fire, become the moſt deadly of all Poiſons, namely the *Corroſive Sublimate*. And from Chemiſtry we farther learn, that this very pernicious Poiſon, being raiſed again in like manner, that is, re-ſublimed with other Quickſilver, loſes by Degrees its noxious Quality, and becomes the good and wholeſome Medicine called *Mercurius dulcis*, or *Calomel*.

IT may here be obſerved, that raiſing any of theſe Subſtances into the Air, ſimply and unmixed, makes not the leaſt Alteration in them; ſince *Sulphur*, *Camphire*, *Sal Ammoniac*, *Mercury*, diſtilled Waters, and even *Tin*, when ſublimed by Fire alone, provided the Fumes be intercepted by Glaſs, or ſome other ſolid Matter properly placed, to keep them from a total Evaporation, will be converted again into Bodies fully poſſeſſed of all the Properties they originally had before the Operation, but more purified.

THE Atmoſphere then being the common Receptacle of all ſubtle Matters leſs denſe than itſelf, it cannot be diſputed, but that Particles of very different kinds are conſtantly riſing therein in great Abundance. And as acid and alkaline Matters, on meeting, always naturally and evidently begin on each other ſome Degree of Fermentation and Efferveſcence, we cannot be long at a Loſs for the Cauſe of the ordinary, but ſufficiently dreadful Phænomena of Thunder and Lightning. It is therefore more than probable, that the Parts of the Atmoſphere next the Earth may abound with ſpirituous Particles, perhaps of the nitrous kind; and that at certain Times, and on certain Occaſions, other Particles may be exhaled from the Earth, of a ſulphurous, unctuous, or combuſtible Nature, which will act vigorouſly on each other, and take Fire, when they are brought up to a certain Degree of Heat by Fermentation.

THERE may alſo be a thin kind of Vapour, Damps or Steams ariſing from mineral and ſubterraneous Bodies, which being let looſe into the Air, and meeting with the Nitre or other Salts thereof, though neither of theſe may have any ſenſible Degree of Heat in them ſeparately, will ferment and act ſo briſkly on each other, as to produce an actual Flame.

THIS is what has often happened in Mines, and eſpecially if they chance to be kindled, as they ſometimes are, by the Lights the Workmen uſe; though very often they fulminate of themſelves, and then the whole Train of Matter, mixed with the contiguous Air, will immediately take Fire, and, like a Train of Gunpowder, run from one End of the Vapour to the other. And this is done with that Swiftneſs and Violence, that it frequently deſtroys the Miners, blows up their Works, and produces as fatal

fatal Effects as if a Quantity of Gunpowder had been fired in the Mine.

SOMETHING of this kind may be obtained from Experiment, by putting ſome iron Filings into Spirit of Vitriol in a Phial; ſtop them a ſhort Space together, and a Fume will riſe from this Mixture, that will fulminate when apply'd to the Fláme of a Candle. One Part whereof being kindled, 'twill immediately be communicated to the whole, the Fume being denſe, much as all the Parts of a Quantity of pounded Reſin, thrown from the Hand into the Air, near the Flame of a Candle, ſeems to blaze all at once; which is the Manner in which, at the Theatres, Artificial Lightning is made.

NO ſooner ſhall the Mixture juſt above propoſed be made, but 'twill fall immediately into Motion, and quickly become ſenſibly warm to the Hand; and no one that has ſeen the ſudden Ferment, the vigorous Ebullition and Effervescence frequently produced between Bodies of this diſcordant, jarring Nature, but will readily allow, they can only be brought about by the reciprocal and vigorous Action of their Particles upon each other.

THERE are indeed Experiments wherein ſuch Mixtures are found to bring on a Degree of intenſe Cold, ſenſible to the Hand as well as ſhewn by the Thermometer; and by which our artificial Congelations are effected. As the former, by the Activity and Repellency of their Particles, heat and rarefy the compound Fluid; ſo theſe, from a Prevalence of Attraction, perhaps, and from an Aptitude of their Parts to unite, fall into and fill the Interſtices of each other, when the Commotion ceaſes, become thereby condenſed: And 'tis obſervable, that Bodies are generally cold in Proportion to their Denſity. Hence it is that Water is always colder than Air, and Mercury than Water; Plaiſter than Boards, and Marble than Plaiſter.

IT has been ſaid, that a convenient Mixture of Sulphur and Filings of Steel, with a little Water ſtirred briſkly together, will not only produce a great Efferveſcence, but will ſometimes break out into an actual Flame. From ſomething of a like Cauſe probably proceeds the extraordinary Heat found in the *Bath* Waters, and other hot Springs; wherein two Waters, of themſelves actually cold, flowing through Veins of chalybiate and ſulphurous Matter, within the Earth, on mixing together may produce this Effect.

IN the ſame Manner alſo we account for the Conflagrations of *Ætna* in *Sicily*, *Veſuvius* in *Naples*, and all other Volcano's or burning Mountains. Theſe were kindled at firſt, no doubt, by the Diſcordancy of a fit Mixture of Sulphur and Particles of iron Matter in the Bowels of the Earth, which, when the Ferment was become ſufficiently ſtrong, broke out into a Flame, that has burnt for many Ages, and which will continue to burn ſo long as Matter ſhall be found for a Supply in thoſe Places. The great and ſudden Eruptions they ſometimes make, are probably occaſioned by the Influx and Acceſſion of new Matter, that, in the Courſe of the Conflagration, gets vent in the Chaſm. And from a like Cauſe, as has been already hinted, the Earthquakes, uſual in theſe Places, ſufficiently dangerous, are juſtly thought to proceed.

THE Effects of Thunder and Lightning are ſo like thoſe of fired Gunpowder, that they be reaſonably judged to proceed from the ſame, or nearly a like Cauſe. The principal Ingredients of that miſchievous Compoſition are *Nitre*, *Sulphur*, and *Charcoal* pounded together; which laſt being by Nature light and apt to take Fire, is added only to keep the Parts of the other Ingredients at a due Diſtance, that they may be ſuddenly kindled, and to increaſe the Blaſt. Whenever then proportionable Quantities of nitrous and ſulphurous Vapour chance to be admitted into the Air, and thoſe by any Accident there take Fire, their Exploſion muſt be attended with both the Flame and Noiſe obſerv'd in fired Gunpowder; which being once enkindled, the Train may be well expected to run from Place to Place, as the Vapour leads, and with the like Effects. And it may be obſerved, that for this Reaſon, the Flaſhes of Lightning ſeem one while to dart right forward, at other Times to vibrate hither and thither, according to the Courſe of the inflammable Matter, and as it ſucceſſively takes Fire.

LIGHTNING is more or leſs dangerous, according as the enkindled Vapours happen to be more or leſs denſe. If from its Rarity it aſcends pretty high in Air, it there flaſhes without doing any great Harm: If it be denſe, and hangs about the Earth, it whizzes about our Ears, ſweeps along the Ground, deſtroys, or at leaſt drives away the Air wherever the Torrent comes, kills Men and Cattle, and does a deal of Miſchief.

THAT kind of Lightning which makes the greateſt Havock, is obſerved moſt frequently to take Fire in the upper Regions of the Air, whence it uſually comes ſlanting downwards towards the Earth, and often directs its Force, being perhaps thereby drawn in a manner to a focal Point, againſt a Tree or Tower, or ſome eminent Object, on which it often produces ſurpriſing Effects, by piercing and dividing the moſt intimate Parts of hard Bodies, and writhing, rending, and contorting thoſe that are tough in a ſtrange and very violent manner. Theſe more noxious Blaſts probably proceed from the gradual Riſe of Clouds of Matter, proper for Fulmination, from the Earth, in theſe ſtormy Seaſons; the upper Parts of which meeting with fit Matter, either found in, or produced by the Air, come to be firſt fermented, and then taking Fire, purſue the Track of the riſing Vapour to the very End, where perhaps a great Part of the Force of the whole Blaſt may be made to concenter, ſomething like the Rays

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of Light refracted into the focal Point of a Burning-glaſs, with ſuch a reſtleſs and impetuous Force, as may diſſolve one hard Body, calcine another, perforate a third, entirely change the conſtitutional Parts of a fourth, by giving them another Direction, and ſo on. At the ſame time, it has been frequently obſerved, that this impetuous Flame which menaces Mortals thus magiſterially, and rives and reduces to Atoms the hardeſt Things, will often pervade Bodies of a looſer Texture without Harm: For it has ſometimes not ſinged the Purſe wherein it has melted the Money; and at other times diſſolved the Sword, without damaging the Scabbard.

WHAT we call Thunder, is produced merely by the ſudden and violent Motion of the Air contiguous to the Flaſh, in endeavouring immediately to thruſt itſelf into the Vacuity thereby made. This frequently ſhakes the whole nervous Syſtem of Animals, and always affects the Ear in the ſame Manner as does the Exploſion of Fire-arms, or the Burſting of a Bladder, when the Air is drawn from under it by the Air-pump: This Experiment is mentioned, *Page* 172. Now it is impoſſible that the rending of a Bladder, which tears like a Piece of brown Paper, ſhould produce any ſuch Effect. But as the whole Body of the adjacent Air moves on that Occaſion, to make good and fill the Vacuity made, this is what affects the Organ of the Ear, in the manner ſpoken of: And 'tis thence reaſonable to conclude, that all the Vacuities made therein, whether produced by actual Flame, or otherwise, will always be attended with the like Effect.

FROM the continued Length of a Clap of Thunder, and from its various Degrees of Loudness, it may be concluded, that the Lightning really is a Track of running Fire; which though it may seem to be instantaneous, and to fill as it were the Hemisphere with Flame at the same Time; yet is it propagated successively, and from different Distances, as will appear by the gradual coming of the Clap thereby produced, to the Ear, and with a different Degree of Force.

HOW far off, or how near we are to the Danger attending this War of Elements, may in general be estimated by the Length of the Interval between our Seeing the Flash, and Hearing the Clap of Thunder. For though they are instantaneous, and both produced in the same Moment, yet Light moving by many Degrees faster than Sound, they come to our Senses, and affect our Nerves successively. The Motion of Light is discovered, by the Eclipses of *Jupiter's* Satellites, to move progressively at the Rate of about ten Millions of Miles in a Minute; so that we may very well take the Time of our seeing the Flash, coming from a Cloud often within less than a Mile of the Earth, for the very Instant of the Explosion: Whereas Sound, by good Experiments, is found to move but at about the Rate of one thousand, one hundred and fifty Feet in a Second. We may therefore, in round Numbers, reckon that ſo many Seconds as paſs between the Lightning and Thunder, ſo many thouſand Feet at leaſt is the Miſchief from us. And if theſe happen to be conſiderably great, and immediately ſucceed one another, they may rightly be judged to be very near at hand.

CHEMISTRY will furniſh us with ſeveral Subjects, peaceable and quiet in themſelves, but which will, the Moment they are mixed, ſtart into an actual Flame. Of this ſort are moſt of our diſtill'd Oils, thoſe from Vegetables eſpecially, which are full of Salts, as appears by their ſinking in Water; and moſt of the acid Liquors immediately fermenting with them, ſhew them alſo to be of the alkaline kind. If, for Example, we take a few Drops of Oil of Cloves, or Oil of *Guaiacum*, and pour a ſmall Quantity of double *Aqua fortis*, or rather *Glauber*'s compound Spirit of *Nitre*, on them, diſtilled from *Salt-Petre* and Oil of *Vitriol*, a very ſtrong Ferment, accompanied with Flame, and if the ſaid Spirit of *Nitre* be new, ſtrong, and very pure, an Exploſion will alſo follow. The Manner of which is repreſented *Fig.* 11. *Plate* 9. To this may be added a ſmall Quantity of Gunpowder, to be fired on the Effervefcence of the other Ingredients, for no other Purpoſe than purely to augment the Inflammation.

IT muſt not be expected, however, that from hence we ſhould preciſely determine the

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particular Species of Effluvia which compoſe the Mixture, that floating in the Air will ferment, kindle, and flaſhing like Gunpowder, occaſion thoſe Exploſions and rapid Streams of Fire ordinarily called Thunder and Lightning. But that there is in Lightning, very probably, a Mixture of ſulphurous Vapour, appears in great meaſure from the ſulphurous Smell that commonly attends it. Sultry Heats, a heavy-loaded kind of Air, are uſually the Forerunners of it. And the frequent Conſternation of the Inhabitants of the Kingdom of *Naples*, where Sulphur greatly abounds, on Account of Earthquakes, and this kind of Storm, both proceeding, as has been ſaid, from nearly a like Cauſe, is an Intimation that Sulphur may very reaſonably be admitted as one principal Ingredient therein.

AND that Lightning has in it a nitrous Vapour, or ſome other Salt of equal Virtue and Strength, is at leaſt probable for ſeveral Reaſons. One is, from the very great Advantage Rain and melted Snow, both which cannot but be well impregnated with Air and all its Salts, have over other Water in the Way of Vegetation; to the former of which it ſeems ſo very material and neceſſary, that even the Weeds at the Bottom of Rivers are not obſerved to grow or ſhoot but in wet and ſhowery Weather.

A ſecond Reaſon may be deduced from the Difference of Colour obſervable between the venal Blood, which is blackiſh, and the arterial Blood,

Blood, which is of a florid red. The laſt of theſe having newly circulated thro' the Lungs, and therein been mixed with, or at leaſt cool'd and refreſhed by the Air inſpired, immediately becomes of a brighter Colour: Whereas the former, having received that Benefit but ſometime before, ſeems to want that Advantage. Beſides, the Blood iſſuing from the Veins is obſerved to become immediately florid, if a Piece of Saltpetre or ſome other Salt be put into the Baſon, and the *Serum* or wheyiſh Part of it grows thereupon pellucid as Water. It may alſo be farther obſerved, that however black the Blood may appear when the Vein is firſt opened, it ſoon grows more florid when it has ſtood a little in the Air.

AND thirdly, Saltpetre, or Nitre itſelf, generates Air in Plenty, as is evident by putting a Piece of it into a ſtrong bright Aſh-lye, which is uſually ſo replete with other Salts, that have ſo well filled up the Interſtices of that Fluid as to have diſpoſſeſſed it entirely of the Air; and from which alone *in Vacuo* therefore no Air will ſeem to riſe; but from the Saltpetre at Bottom it may be obſerv'd then to iſſue very faſt.

TILL the Air can be perfectly analized, 'twill be impoſſible to ſpeak of its conſtituent Parts with the deſired Certainty. And tho' it muſt be allowed that there are other Methods known of rendring Water vegetative, and of making the Blood florid, without the Help of Nitre; and tho' Dr. HALES has put the Admiſſion of

Air

Air into the Compoſition of almoſt every Thing as well as Nitre, paſt all Doubt; yet as there is nothing, we are inform'd of, capable of ſo ſudden or ſo violent a Degree of Exploſion as Nitre is; therefore the Philoſophers chuſe to offer that as a neceſſary and probable Ingredient of the Phænomenon under Conſideration.

SOME Corruſcations or Flaſhings there are, which in ſerene Weather ſeem to glide from the Zenith, or upper Region, often towards the Horizon, without Symptoms of Noiſe or Violence, called flying Dragons or ſhooting Stars. Theſe doubtleſs proceed from much the ſame Cauſe as the Lightning. Certain Vapours exhaled from the Earth by the Heat of the Sun to ſuch a Part of the Atmoſphere as may afford them Matter fit for Ignition, being lighted as above at one End, and being of no great Breadth, the Flame runs ſteadily forward; juſt as a ſmall and even Train of Gunpowder fired in the Air would appear to do.

THERE are other Kinds of Flaſhings ſometimes ſeen in the Air, ſuch is the *Aurora Borealis*, thoſe Glades or Gleams of Light that have of a long time appeared Northward, and of late have frequently been obſerved in our own and ſtill more ſouthern Climates in ſerene Weather. Theſe ſeem to bear ſome Affinity to the Lights juſt mentioned, and are probably produced from ſomething of a like Cauſe.

WE know from Experiment that there are

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ſome Steams, ſuch as inflammable ſulphurous ones, which are capable of ſo great a Degree of Expanſion, that they become ſpecifically lighter than the Air they float in, even tho' rendered as rare as well it can be by Art (which, as was before obſerved, Page 154, is within one ſixtieth Part of Perfection) For they will riſe to the Top of an exhauſted Receiver, and there adhere: Thoſe of Gunpowder fired *in Vacuo* in particular will do this, and ſo will all ſuch whoſe Particles have ſo great a natural Repellency in them, as to produce this Effect.

STEAMS or Exhalations therefore of this kind riſing from the Earth out of Mines, Volcano's, *&c.* muſt neceſſarily be buoy'd up towards the Top of the Atmoſphere (and that they are ſo, appears from their being viſible in many Countries at the ſame Time: As was that famous one in *March* 1716, ſeen from the Weſt of *England* to the Eaſt of *Poland*, over thirty Degrees of Longitude, and perhaps a great way farther) or that riſe at leaſt till they come into a Region where the Air is expanded as much as by the Air-pump can be done.

THESE Effluvia, according to the ingenious Mr. ROWNING, in his late Treatiſe on theſe Subjects, being thus generally raiſed to the Top of the Atmoſphere, or near it, and floating there, will, as he ſuppoſes, be neceſſarily carried towards the polar Parts of the Earth. Firſt, becauſe the ſuperior Current of the Air to a great Diſtance from the Equator, is, from the general

ral Rarefaction by the Sun's Heat there made, constantly presumed to be that Way. And, Secondly, because from Experience we know, that whatever swims upon a Fluid which revolves upon an Axis, as the Atmosphere does, is by such Rotation carried toward that Axis. This probably may be the Case of these Effluvia, and therefore their Appearance is generally made near the polar Parts of the Earth; when, being there collected, of an inflammable Nature in themselves, and meeting with other heterogeneous Particles in those Regions, proper to produce such an Effect, they appear to emit Streams of Light, become successively conspicuous, seem to glimmer as they rise, and being very thin, are soon consumed and disappear, without making the least Noise, or doing any Mischief.

As to the Objection commonly made to this and the like Hypotheses; Where were these supposed Effluvia when the *Lumen Boreale* was scarce ever, or according to History very rarely seen? It may be answered; First, that the Vapours of which Clouds are formed, never rise so high as the Region in which the Matter of this Light is from late Observations known to float: It is therefore not inconsistent with the Theory, if it be often intercepted from our Sight by the Interposition of Clouds below. Secondly, that the Rise of the Emanations spoken of, is purely accidental, and may depend on several concurrent Circumstances. It may reasonably be presumed, for Instance, that the Air, or or Earth, or both, may be ſometimes, tho' but ſeldom, and perhaps with very great Intervals, diſpoſed to produce this Phænomenon; juſt as ſome Seaſons and ſome Years are found to be incommoded with Thunder and Lightning; whereas in others little or nothing of that Sort appears.

As to the *Ignes fatui*, the Will-o'-Wiſps, and ſuch Appearances as are ſeen by Night, near the Earth, about Pools and watery Places, they are of the ſame Claſs and Tribe: But being a more heavy kind of Vapour, and one that hangs about thoſe Places, they burn more ſlowly, and like a lambent Flame, having wavered a while too and fro, they commonly die much about the Place where they had their Birth.

FLAME is a moſt elaſtic Fluid, and 'tis generated by the vigorous Activity of the minuter Parts of Matter one upon another. Thus Flame may be produced by the violent Rubbing of two Boards together; nor is Flame any other than an enkindled Smoke: For Bodies do not flame without emitting a copious Fume; and the Parts neareſt the fuming Body, or the hotteſt, are what form the Flame. Smoke paſſing thro' Flame, cannot but grow red-hot; and red-hot Smoke can have no other Appearance but that of Flame.

ALL inflammable Bodies, as Oil, Tallow, Wax, Wood, Pit-coal, Pitch, Sulphur, Gums,
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and the like, by flaming, waſte and vaniſh into burning Smoke. If the Flame be extinguiſhed, they ſmell very ſtrongly, and the Smoke is then very thick and viſible: Whereas by the Flame more of the combuſtible, unctuous Parts are conſumed and loſt, and then the Smoke is not ſo copious, nor the Smell ſo ſtrong.

IN diſtilling hot and ardent Liquors, if the Head of the Still be removed, the Vapour will all take Fire at the Flame of a Candle; the Fume will in that Caſe be all turned into Flame, and from the Suddenneſs of it 'twill acquire a miſchievous Force, like that of fired Gunpowder; the Spring whereof we experimentally ſee is able to overcome the Tenacity and Coheſion of any Bodies: Twill lift and rend even Rocks and Baſtions, provided it be thoroughly confin'd, and the Abutments good. This is the Caſe of Mines that are ſprung with any Succeſs, and of the Bullets and Bombs projected from the Chambers of Ordnance and the Barrels of Fire-arms: If any of theſe get Vent, the Project certainly miſcarries.

NOW there is no Flame to be raiſed from any Subſtances, beſides that of Gun-powder, that will bear to be compreſs'd without being extinguiſhed; but the Intenſity of this is ſuch, that being once raiſed, it cannot be put out. In all Exploſions made thereby, it muſt be allowed, that a few Corns of it can only take Fire at firſt; and that the Flame ſpreads and increaſes, till the Spring thereof becomes not only

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an Equilibrium, but alſo often greatly overpowers and ſurprizingly projects the Weight to be removed. Hence a Quantity of Powder, confin'd in the Barrel of a Piece, will lift a much greater Weight than a like Quantity fired beneath it in the open Air; and for the ſame Reaſon, a Charge of Powder, with a Wad upon it, will do greater Execution than an equal Quantity thrown looſely into the Piece and ſo fired.

THAT all the Powder is ſeldom burnt before the Exploſion, and therefore the Spring of an ordinary Charge of Powder is never brought to the higheſt Pitch it might be, appears from the Trail of Powder obſerved commonly to lie ſcattered on the Snow near the Muzzle of the Piece in Fowling: And if a Charge of Powder be fired pretty near againſt a Mark ſmeared over with Wax or Tallow, 'tis odds but many Grains of unburnt Powder will be found ſticking thereon.

THE riffled-barrel'd Piſtols therefore, that is, ſuch as by the Narrowneſs of their Bore keep the Powder longer confined before the Exploſion of the Ball, are found to do greater Execution than thoſe of equal Dimenſions without ſuch an Advantage. And in general it may be obſerved, that thoſe Fuſils which have their Touch-holes ſo diſpoſed, as moſt readily to communicate the Flame to the greateſt Part of the Charge, and to light it more equally before the going off of the Piece, will always kill at fartheſt Diſtance.

And for the ſame Reaſon it is, that the longeſt Guns with equal Charges of Powder, are alſo generally found to have this Effect.

GUNPOWDER fired *in Vacuo,* and when the Reſiſtance of the Air is removed, makes no Exploſion at all; but goes off Corn by Corn, as if they were ſingly lighted. This Experiment is repreſented *Plate* 9. *Fig.* 10. *A* is a Receiver, with a Reſervatory for Gunpowder at Top. *B* is a red-hot Iron put in before Exhauſtion at Bottom. If when it is exhauſted, a ſmall Quantity of Powder be let down from *A* by a Contrivance paſſing thro' a Collar of Leathers, which will allow of the ſliding of a Wire without admitting any Air, the forementioned Experiment may eaſily be made. But if it be ſeveral times repeated, the Exhauſtion ought to be continued to prevent Miſchief; becauſe the firing of the Powder generates Air, as may be obſerved from the ſinking of the Mercury during the Operation in the Gage-tube.

On the Riſe of VAPOURS, *their Formation into a* CLOUD, *and their Reſolution into* RAIN, *&c.*

IT cannot be denied, but that the Air is at all times more or leſs full of humid Particles, as appears by their falling in an exhauſting Receiver, producing the Halo, and the other Experiments of the ſame Sort mentioned *Page* 235, 235, and the following. It is no leſs certain, that more Moiſture will be taken up and imbibed by Air in Motion, than Air at Reſt; as is evident from the Drying of Linen and other things that are wet, much ſooner when there is a Gale of Wind, than in calm Weather. Beſides, Dr. HALLEY's Experiments related in the *Philoſophical Tranſactions*, put this Matter paſt all Doubt.

THIS Gentleman, in order to account for the Circulation of Vapours, cauſed an Experiment to be accurately made by the Operator to the *Royal Society* at *Greſham College*, whereby the Quantity of Water raiſed and carried off in Vapour from the Surface of ſtagnant Water, in a Place as free from Sun and Wind as might be, was determined to be exactly eight Inches deep or perpendicular in a Year. This fell very much ſhort of the Quantity of Rain found by the *French* Academicks to fall in a Year at *Paris*, viz. full nineteen Inches perpendicular: And ſhorter ſtill of the Obſervations of Mr. TOWNLEY; who, at the Foot of the *Lancaſhire* Hills, lying in the Neighbourhood of the *Iriſh* Sea, found there fell in a Year above forty Inches of Water perpendicular. So remarkable a Difference makes it evident, that the Sun and Winds are the principal Cauſes of the Evaporation of Fluids; the one to raiſe the Vapour, and the other to carry it off and diſperſe it.

THE Doctor, in the ſame Courſe of Obſervations, takes Notice of the Vapour, ſeeming at ſometimes to adhere or hang about the Surface of the Fluids whence they riſe, cloathing them as it were with a Fleece of vapouriſh Air; at which Times the Evaporation appeared to be very little, by the ſmall Quantity of Water then loſt in twenty-four Hours: And as this was obſerved to happen commonly when there was very little Wind ſtirring, had theſe Experiments been made in a Place fully expoſed to Wind and Sun, the Expence of riſing Vapour would have been found to compenſate at leaſt the ordinary Return of Rain for a Supply, as later Experiments have ſufficiently evinced.

AND here it may be obſerved, that in ſtill Weather, when this Fleece of vapouriſh Air happens to be lodged in greater Quantities near the Surface of the Water, both it and all Objects thereon ſeem to be conſiderably raiſed, and even to lie in a Level above the Land. This can proceed only from the Refraction or Bending of the Rays of Light, coming out of a Medium of one Degree of Denſity into one of another; as may be exemplify'd at any time by pouring a Quantity of fair Water into a Baſon, which will then ſhew a Piece of Money, lying at the Bottom, to an Obſerver, from whom it was before ſcreened by the Brims of the Veſſel: By this Experiment it will, to Appearance, be raiſed about one third of the Water's Depth.

AND for a like Reaſon it is apprehended that the Cattle grazing on the *Iſle of Dogs*, are ſometimes to be ſeen from *Greenwich* at the

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Time of High-water; and not when the Water is low. This ſome have endeavoured to account for, by ſuppoſing the *Iſle of Dogs* to be raiſed by the Tide. But 'tis far more reaſonable to conjecture, that in ſtill Weather, when this Appearance is moſt remarkable, that the Vapours iſſuing from the Surface of the River are raiſed along with it in the Tides, and ſo exhibit an Appearance, which, were they immediately removed by the Winds, would not happen.

IN ſtill and ſultry Weather, when the Sunbeams ſeem to act with a great, a general, and an equal Force, on both the Land and Water, the Riſe of Vapours is then obſerved to be more dull and languid. When they gleam as it were from behind, or thro' a Cloud, and there is ſomething of a Motion in the Air, or a Wind abroad, they riſe in greater Plenty. And in very hot Climates, as Dr. HALLEY informs us, they mount in ſuch Abundance, that in *St. Helena*, lying in Latitude ſixteen Degrees South, his Glaſſes for Obſervation were very often and very ſoon covered with Water. And even in hot Weather, in our own Climate, the Dews, which are no other than Vapour condenſed, are found ſufficiently copious. Morning and Evening, in that Seaſon of the Year when the Sun is not far above the Horizon, the riſing of Miſts from Rivers, Pools and moiſt Places is frequently very viſible, and is generally the Forerunner of a ſultry Day. As the Sun gains a greater Height, the continued Riſe of the

Vapour is indeed not ſo apparent; but as the Cauſe of their Riſe, *viz.* the Heat, increaſes, there is no Room to ſuſpect, but that the Effect is ſtill proportionable to it.

IT has been Matter of Diſpute among Naturaliſts, how the Waters which form the Clouds, and which deſcending, often deluge over vaſt Tracks of Land, come to be exhaled from the Earth and ſuſpended in a Fluid ſo much lighter than Water, as is the Air. Some have imagined, that Particles of Fire, ſeparated from the Sun-beams, adhering to thoſe of Water, make together little Maſſes of Matter lighter than Air, and which therefore riſe therein till they come to ſuch a Part of the Atmoſphere as is ſpecifically, or Bulk for Bulk of the ſame Weight with themſelves; there forming a thin Cloud. And they ſuppoſe that Rain is produced by the Separation of thoſe Particles of Fire, on Occaſions, from them; whereupon they coaleſce, and then deſcend according to their own Gravity, in Drops of Rain or Dews.

THIS Hypotheſis, as Dr. DESAGULIERS juſtly obſerves in the *Philoſophical Tranſactions*, is not without Objections. As Firſt, Fire has never yet been proved to be a diſtinct Element, or a particular Subſtance; and the Change of Weight of Bodies in chemical Preparations heretofore preſumed to riſe from the Adheſion of Particles of Fire, is proved by Dr. HALES, in his *Vegetable Staticks*, to proceed from the Adheſion of Particles of Air, which

which he has there ſhewed to be abſorb'd by ſome Bodies in good Quantities, while it has been generated as faſt by others; and that it may even be abſorb'd and generated ſucceſſively by the ſame Body under different Circumſtances. Secondly, Should the above-mentioned Suppoſition be allowed, the fiery Particles joined with the watery muſt be of ſome conſiderable Bigneſs, and a Perſon paſſing thro' a Cloud, in aſcending a Hill, muſt be ſenſible of an extraordinary Degree of Warmth, which does not happen; for the Vapour is there found to be really colder than Rain itſelf, falling at the Foot of the Hill. Beſides, the Manner in which theſe Particles of Fire might be ſeparated from thoſe of the Water, is to be conceived from no Phænomena yet obſerved: This Theory therefore ſeems to be without Foundation.

THE ſecond Opinion concerning the Riſe and Suſpenſion of Vapours is, that tho' Water be ſpecifically many times heavier than Air, yet if the Surface of it be increaſed by greatly diminiſhing the Bulk of its Particles, it cannot eaſily fall; ſince the Weight of each Particle is known to diminiſh in Proportion to the Cube of its Diameter; whereas the Surface to which the Air reſiſts, decreaſes only as its Square: And this is ſufficiently evident from the floating of Duſt, Motes, and other light Bodies, for a Time therein, according as they are more or leſs minute.

THIS, however, will not explain the Matter before us to Satisfaction; becauſe, tho' the Increaſe of Surface, the Weight continuing the ſame, may in great meaſure hinder or retard the Deſcent of very ſmall Bodies in the Air, on account of its Reſiſtance to a Surface, ſo much in Proportion larger than their Bulk, as aforeſaid, it will for the ſame Reaſon alſo impede their Aſcent therein. And 'tis known that the riſing of Duſt, *&c.* in the Air, is owing always to ſome outward Force or Motion apply'd; whereas Vapours continue to riſe as well in calm as windy Weather, tho' not in an equal Degree; neither do they always fall to the Ground, or ſubſide therein, when the Wind ceaſes.

THE third and moſt received Opinion concerning this Matter is, that by the Action of the Sun on the Surface of the Water, the aqueous Particles become formed into Spherules or Bubbles, filled with an *Aura*, a much finer Air, or one highly rarefied, which thus becoming ſpecifically lighter than common Air, muſt therefore riſe therein by hydroſtatick Laws, till ſuch time as they meet with ſuch an Air as is Bulk for Bulk of their own Weight.

THIS ſeems indeed to be the more probable Suppoſition of the three; but to ſupport it the following Queries muſt be anſwered. How comes the *Aura* or ſubtle Air within the Bubbles to be at all ſpecifically lighter than that without them; ſince the Sun's Rays muſt be admit-

admitted to heat the one equally with the other, and to beat with equal Strength on every Part of the Surface? Was it poſſible, that a rarer could be thus ſeparated from the ambient Fluid, what ſhould hinder the cold Air, which they needs muſt meet with in their Aſcent, from reducing theſe Bubbles by contracting their Contents; juſt as Bubbles of ſoaped Water commonly are, notwithſtanding their Tenacity is much greater than that of common Water, when blown up by warm Air from the Lungs? And again, Was it reaſonable to admit the reſt of the Suppoſition, a conſiderable Difficulty will yet remain, *viz.* if Clouds were thus conſtituted of Shells of Water filled with Air, in its own Nature elaſtic, Why ſhould they not always expand, when the circumjacent Air is rarefied; and why not be condenſed, when the Weight of the Atmoſphere is there increaſed? This muſt be the natural Conſequence of this Hypotheſis, and the Clouds would ſink and riſe in the Atmoſphere on every Alteration of Weight therein, without affording us any Rain at all.

THE Doctor then plauſibly propoſes another, whereby he endeavours to account for the Riſe and Suſpenſion of the Vapours in the Atmoſphere, from the Elaſticity and Repellency obſerved in the Steam of boiling Liquors, capable of extruding either Air or Water from any Veſſel; and ſuppoſes the Repellency of the Particles of Vapour to be always in Proportion to their Degree of Heat. Hence he

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calculates the Force of the Vapours raiſed, taking, with Sir ISAAC NEWTON, the Heat of boiling Water at 34 (when the Thermometer will ſhew our Heat in the Summer to be 5, in Winter 2, and in Spring and Autumn 3 of thoſe Parts) and computes the Height to which they accordingly muſt riſe, comparing their Elaſticity with that of the Air; on which Heat has a much leſs Effect; ſince that Degree of Heat which will expand Water fourteen thouſand times in boiling, will rarefy Air only two thirds. He next conſiders the Effects the Cold found near and above the Earth muſt have in condenſing thoſe Vapours, and forming the Clouds; and thinks that the Diſtance they are obſerved to float at from the Earth, in the various Seaſons of the Year, correſponds with this Theory.

BUT neither does this ſeem to be abſolutely free from Objections. For in Diſtillations, the Liquor boiling in the Still, over a briſk Fire, raiſes a great Quantity of Steam into the Head, which endeavours to make its Way immediately down the ſpiral Pipe or Worm, uſually ſet in a Tub of Water, which, being cold when the Still begins to work, condenſes the riſing Vapour very faſt. As the Water next the Worm comes to be heated by the continued riſing of the burning Steam, it condenſes it indeed ſomething ſlower; but yet when this Water is become ſo hot, that a Man can ſcarce bear his Hand in it, it will nevertheleſs continue to condenſe them into a groſſer Fluid apace.

Now

Now as the Mitigation of the Heat of Vapour, and the lowering it from that of boiling Water is generally attended with this Effect, and as very little Vapour is raised in the Still before the Liquor actually boils; it may be presumed, that the Repellency of the Particles of Steam, under the Degree of a boiling Heat, can be but inconsiderable in promoting the Rise of Vapours to any great Height in the Atmosphere, or of producing the Thing proposed.

BESIDES, Steam of any Heat whatever, if it be not some how confined, and caught as it were by some Object near at hand, but being let into the Air loose, like that rising from a seething Pot or slaking Lime, as far as we can trace it, that is, so long as it continues visible, does not by its Motion shew any great Disposition or Tendency towards rising steadily, briskly or the shortest Way, into such Part of the Atmosphere as may be of equal Gravity therewith: But it rather seems vaguely to fly hither and thither, till it can be absorb'd and received by the Air, thereby warm'd in the same Manner as the Breath from the Lungs and other humid Vapours are, as mentioned *Page* 237. of this Treatise.

IT might be also suspected, that the Repellency which should give the Particles of Water their first Rise into the denser and circumambient Air, would increase in Air more rare, in their Ascent, and defeat, and by their undue

due Separation prevent their being ever condenſed in Rain. Beſides, as the Preſſure of the denſer Air near the Earth is not able to reduce them into ſo cloſe a Contact as to form Drops of Water there, it is not likely that in a rarer Medium this ſhould be done with more Succeſs.

FOR Want therefore of a more perfect Theory of this Part of our Meteorology, we muſt at preſent, in good meaſure, content ourſelves with obſerved Facts. And it being evident, that rare and warm Air, together with what humid Particles, it ſhall at any time imbibe (and which from the conſtant Heat of the Sun muſt neceſſarily conſtantly be done, and that in very great Plenty) will emerge and ſwim in Air that's denſe and cold, to ſuch Part of the Atmoſphere as is of equal ſpecifick Gravity therewith: And that whenever, for want of the ſuperincumbent Preſſure, a Part of its Denſity ſhall be loſt, it will let the watery Particles fall, and they being collected and aſſembled in good Quantity, will at length perhaps form a floating Cloud, and become viſible, merely by the Reflexion of the Rays of Light, which, falling by various Angles thereon, exhibits various Colourings, and a Multiplicity of Forms, to the Eye of an Obſerver: Or if its Denſity ſhall continue to be ſtill more diminiſh'd, it may be again reſolved into its original Water, and become an immediate Shower of Rain.

THE Sun ſhining with equal Strength on the

the Surface both of the Land and Water, will doubtleſs affect them differently: Becauſe a great Part of his Rays are reflected from the ſolid Earth by the ſame Angle in which they fall thereon, whereby the Air will always be more rarefied over this, than over the Water, which abſorbs moſt of them, and reflects but few: Of conſequence then the light Air will mount, and continue to riſe over the Land, and the denſe and vaporous Air from Sea will croud after it, to make good the Deficiency; as in the Caſe of the Land and Sea-breezes, was before explained, *Page* 251; and hence abundant Matter will probably there be collected towards the Formation of a Cloud.

IF then the Seaſon be inclined to wet, and eſpecially if there be an Eminence upon the Iſland (round which the Air will always be colder, and therefore denſer than over the Campaign, the Sun-beams being thereby diſſipated in a great Variety of Reflexions) the thinner Air charged with Vapour, as before, will ſtream thither from every Quarter, and mounting its Sides, like Smoke up a Chimney, will ſoon envelope, and hood over its Top with a Cloud: And ſhould this Diſpoſition of the Air to Wet continue, the Vapour will continue riſing in this Manner, and condenſing ſo faſt, as till it becomes a heavy Rain in all the Parts adjacent.

AN Appearance of this Sort on the Top of Hills, the *Pike* of *Teneriffe* particularly, is not

un-

uncommon. The Mariners alſo often obſerve a very ſmall Cloud at firſt, which they therefore call the *Bull's-Eye*, gathering over a ſmall Iſland in the Ocean, which frequently increaſes ſo faſt, by the Acceſſion of light and humid Air from the Water, that it fills the whole Hemiſphere very ſoon with Rain, frequently attended with a Tornado of Wind, Lightning and Thunder; and the Storm is doubtleſs more or leſs violent, according as Quantities of Matter happen thereabouts to be amaſſed for the Production of each ſort, as aforeſaid.

AND here it may be remarked, that in a Storm of this kind, the Wind is obſerved to blow all round from the Place where it rages moſt; which is a plain Intimation, that theſe extraordinary Commotions in the Air are really produced by the Exploſions of Matter meeting therein, and diſagreeing in the Manner heretofore propoſed, *Page* 258. whereby a different Direction is given to the Body of Air adjacent, being driven thence all round, as from a Centre.

AN Experiment to prove our Hypotheſis for the general Formation of Clouds over Iſlands, Promontories, Capes and the Sea-coaſts probable, may be thus made. Take a large Diſh, fill it with cold Water; into the middle of this put a Water-plate filled with Water warmed. The firſt will repreſent the Ocean drinking in the Sun-beams falling thereon, the laſt an Iſland reflecting them, and ſo heating the Air above it more. Blow out a Wax-candle, and

and if the Place be ſtill, on applying it ſucceſſively to every Side of the Diſh, the fuliginous Particles of the Smoke being viſible and very light, will be ſeen to make toward the Plate, and riſing over it, will point out the Courſe of the vaporous Air from Sea to Land. Again, if the ambient Water be warmed, and the Plate filled with Water cold, let the ſmoking Wick of the Candle be held over the Center of the Plate, the contrary will happen; and a Demonſtration thereby be alſo given of the Cauſe and Conſequences both of the Land and Sea-breezes before-mentioned.

WAS the Globe of the Earth one plain watery Surface, and had the Sun, as now, his apparent diurnal Motion round it, a certain Quantity of Vapours would then be daily raiſed and retained by the Atmoſphere. Theſe Vapours, when the Air came to be condenſed on Nights, would, 'tis probable, as conſtantly ſubſide and ſink in Dews; as Salts will often precipitate to the Bottom of Liquors overcharged therewith, when they come to cool: Nor in this Caſe could any Diverſity of Weather be expected, other than periodically, and every Year alike.

BUT let this general Ocean be ſuppoſed interſperſed as it is with ſpacious Tracks of Land conſiſting of various Soils, and various in Form, whence Emanations may alſo riſe, not merely of the watery kind, which by their Diverſity, as before explain'd in Caſe of the Winds,

may

may occaſion Variety of Weather: This Land, of different Altitudes, and in particular Places, ribb'd with high Mountains, ſuch as the *Pyrenean*, the *Alps*, the *Apennine*, and *Carpathian* Hills in *Europe*; *Taurus*, *Caucaſus*, *Imaus*, and others of Note in *Aſia*; *Atlas*, and the *Mountains of the Moon*, with other Ridges in *Abyſſinia*, and the leſs known Parts of *Africa*; and in *America*, the *Andes* and *Apalatean* Mountains; all far ſurpaſſing the uſual Height to which the watery Vapours aſcend, will cauſe a conſiderable Difference: For theſe by their Eminence and Situation, either collect humid Particles from the adjacent Seas and Plains, as explained, *Page* 301. or intercept them, being tranſported thither by the Winds, where mounting up the Sides of the Mountains with the Stream of Air, are there frequently daſhed together, or ſo condenſed, that coming within the Reach of each other's Attraction, they run together, and forming larger Drops ſpecifically heavier than the ambient Air, immediately fall in Rains and Dews; or elſe ſettling all round the Eminence, gutter and gleet down the Surface of the Stone, and uniting, often form a Rill; and ſeveral of which collected in a common Channel, make a Brook; Variety of theſe a Stream; and an Aſſemblage of Waters from a Diverſity of theſe, after draining perhaps a vaſt Extent of Land, may become a River, like the *Rhine*, the *Rhone*, the *Thames*, or *Danube*.

IN order to eſtimate the Quantity of Water raiſed

raised in Vapour from the Sea, and to compare it with the Returns made thither by the Rivers which conduct it back, Dr. HALLEY has curiously considered the *Mediterranean* Sea, into which nine very considerable Rivers, *viz.* the *Ebro*, the *Rhone*, the *Tyber*, the *Po*, the *Danube*, the *Neister*, the *Boristhenes*, the *Tanais*, and the *Nile*, are continually emptying themselves, besides the Supply always coming into this Sea from the main Ocean, thro' the Streights of *Gibraltar*, without raising the Waters therein one Jot.

HE judges the Extent of the *Mediterranean* to be about one hundred and sixty square Degrees, forty long and four broad, and thinks that each of the above-mentioned Rivers affording about ten times the Water discharged by the *Thames* in a Day, may be adequate to that brought in by the ten large Inlets of Water before-named, that is, eighteen hundred twenty-seven Millions of Tuns *per Diem.* And from a nice Experiment he made on some Water salted to the same Degree with that of Sea-water, which he evaporated with Care over a gentle Fire, whereby he brought the Heat thereof up to that generally found in the *Mediterranean*, of which he was able to judge by help of a Thermometer, he calculates, that in serene Weather there must be at least five thousand two hundred and fourscore Millions of Tuns exhaled thence in a Day; and in windy and troubled Weather much more. Some Part of this is allowed often to sink therein again in Rains and Dews; but far the greater Part is either tranſported by the Winds, or is inclined to draw toward the adjacent Lands, as has been ſaid, to water the Productions of the Earth; all which may without Difficulty be traced back to their original Water. Of this a good Part indeed remains ſtill in a fluid State, and is therefore capable of being again circulated on Occaſions for the Purpoſes beforeſaid; but a no inconſiderable Part has been thought by modern Philoſophers of principal Note, to become fixed, and abſolutely loſe its Fluidity.

WHAT gave Birth to this Opinion was this: A Quantity of Earth was ſifted, put into an Oven, well dried, and then weighed. This has been afterwards put carefully into a Tub, and a Plant weighing perhaps four Ounces, has been ſet in it, which being well watered, has in due Time grown up to a Tree weighing perhaps a Hundred Pounds. This being taken out of the Mould, the Mould has been again dried and weighed, as at firſt, and the Weight thereof found not in the leaſt diminiſhed. Now as the ſame muſt conſtantly happen to every Thing produced by the Earth, Foſſils as well as Vegetables, the Solids have been thence judged hourly to increaſe upon us, the Fluids to decreaſe, and the Sea-water conſequently to grow more and more diſtaſteful and bitter. So that in a great Length of Time, the Earth is apprehended to be in Danger finally of loſing all her Fluid, and of becoming a ſapleſs Maſs, ſuch as in all Probability is the Moon: Since no viſible Alteration or Change has ever appeared

appeared on her Face view'd from the Earth, whereby ſhe might ſeem in any Part more clouded, as to the lunar Inhabitants, if ſuch there be, muſt frequently have happened with reſpect to the Earth; on which it has frequently rained in different Places for a long Time together.

THO' the Inſtance laſt mentioned be true in Fact; yet it muſt be admitted, that far the greater Part of whatever Bodies are thus produced by the Fixation of our Fluids, does again reſume a fluid State in caſe of a Diſſolution, to which they are ſooner or later all ſubject; and in ſo doing their humid Particles muſt again mingle with the Air, and circulate as before. The Aſhes, for Example, when our before-mentioned Tree comes to be burnt, or the remaining Duſt, when its Parts come to be diſunited by Time, are but inſignificant in point of Quantity: Whereas the fluid, and by far the more conſiderable Parts, riſe again into the Atmoſphere; in the former Caſe, in the Form of humid Smoke; and in the latter, with other Vapours exhal'd from the Earth.

BESIDES, that elementary Water may be changed from a ſolid to a fixed State, is not ſo eaſily proved as ſome have thought. It is certain, that common nutritive Water is a very heterogeneous Subſtance, having in it Air, Salt, Oil and Earth. In Proportion as Water is freed of theſe Ingredients, by Diſtillation or otherwiſe, we learn from Dr. WOODWARD'S

Obſervations, that it becomes leſs fit for the Nutrition of Plants. We learn from the ſame Obſervations, as well as from thoſe of Doctor HALES, what a vaſt Quantity of Water Plants require for their Increaſe and Well-being. How then can we be certain, that the earthy and other fix'd Parts of Vegetables, are not compoſed of ſome of the fixed and earthy Parts of the nutritive Water; the reſt of thoſe Parts flying off along with the true watery Element, in the Courſe of their very copious Perſpiration? So that a Plant may eaſily acquire a great deal of fixed and ſolid Matter, without any ſenſible Diminution of the Earth it ſtands in. Or at leaſt what Part of that Earth or other ſolid Principles may be carried up into, and conſolidated with it, may be again ſupplied by new Earth, depoſited from the Water wherewith it is moiſten'd from time to time. If this be then the Caſe, as it ſeems very likely to be, we need be under no great Apprehenſion of our Earth's loſing all her Fluids, and ſo of becoming unfit for the Habitation of Men and other Animals. Nor ſhall we need the Aſſiſtance of Comets and their Effluvia, to renew from time to time this daily Waſte of fluid Matter, which Sir ISAAC NEWTON thinks neceſſary in his *Principia*. And whether the Motion of the Earth, and other Planets, might not be conſiderably altered by ſuch copious and frequent Acceſſions of foreign Matter, might ſeem, among other things, to be a Point worthy Conſideration.

On

On the ORIGIN *and* SOURCE *of* SPRINGS.

IT has been already hinted, that the Hills are of ſingular Service to Mankind in collecting the Particles which thence deſcend into the lower Lands, and water the Earth. There are in the World numberleſs Inſtances of this kind. *Mercator* ſays, that toward the middle of the Iſland of St. *Thomas*, there is a Mountain well ſtor'd with Wood, which in that hot Climate is always cover'd with thick Clouds, even when the Sun is in the Meridian; whence proceed gentle Streams, ſufficient to water all the Sugars in the Plantations. It may therefore reaſonably be preſumed, that thoſe humid Particles which in theſe Places do neither fall in Rains, or trickle down the Out-ſides of the Hills, are percolated by degrees thro' the Pores of the Earth, and paſs along the Cranies of the Stone, &c. till they find their Way into ſubterranean Reſervoirs; which being thus ſucceſſively ſupplied with Vapour condenſed, may cauſe them to overflow, and thereby feed the Springs that more frequently break out of the Sides of theſe Eminencies, than in any other Place. And thus may the Circulation of Moiſture be imagined to be carried on progreſſively between the higher and the lower Parts of the Earth, in a more reaſonable Manner, than by ſuppoſing, as ſome do, either, Firſt, That Springs are the Reſult of Rain-water only, tho' they flow continually, and often without Diminution in the drieſt Seaſons, and when no Rain has fallen for a long Space of Time; or, Secondly, That they are derived from a Filtration or Percolation of the Sea-water, thro' certain imaginary Tubes or Paſſages within the Earth, in doing whereof they are, with no great Probability, ſaid to loſe their Saltneſs: Which, beſides many others, labours under this Abſurdity, *viz.* That ſome of the greateſt Rivers in the World have their moſt copious Fountains fartheſt from the Sea, and often at ſuch a Diſtance, that it is hardly credible, ſo vaſt Quantities of freſh Water ſhould ſo luckily find a Way thither by the Means propoſed.

It is improbable, for Inſtance, that ſuch a River as the *Nile*, whoſe Source is ſome hundreds of Miles from any Sea, in a high and mountainous Country, and in the middle of the torrid Zone, ſhould at periodical Times roll down firſt a great Quantity of turbid Water, and fill his ſpacious Bed, and this be followed by ſuch a Flood, as lays a flat Country, of ſo large an Extent as *Egypt* is, under Water; from which Advantage it becomes indeed a ſort of Granary to the Eaſt, and without it might probably be as barren as are its neighbouring Deſarts.

The Attraction of Coheſion ordinarily adduced in the Caſe of Springs, bears no Proportion to theſe Effects. If this Cauſe be continual,

tinual, it is doubtleſs uniform. Whence then comes it, that the Inundation here mentioned is periodical? Rain in that Country cannot be the Cauſe: *Egypt* is too well ſurrounded by large Continents to get much Rain. But it is not unreaſonable to believe, that the Source of this famous River lies near the Foot of the Mountains of *Abyſſinia*, which, when the Sun is near the North Tropick, and the Wind conſequently North-eaſterly, collect and condenſe the Vapours directed thither from the vaſt *Indian* Ocean, when the rainy Seaſon in thoſe Latitudes uſually begins; and hence may proceed the Deluge of Rain, which rolls down into the flat Country, and produces the before-mentioned great Effect.

NOR is it utterly improbable, but that thoſe very Mountains, tho' they are ſituated in the torrid Zone, may, like the *Alps* and other like Eminencies more Northward, be covered with Hail and Snow at proper Seaſons, which by the Increaſe of the Heat upon them, and eſpecially when the Sun becomes vertical, may melt pretty ſuddenly, and produce, or at leaſt promote, this periodical Inundation.

AND this ſeems the more likely, ſince People who croſs the *Alps* in *July* and *Auguſt*, are ſenſible of all the Change of Seaſons in the Year, and that often in the Compaſs of ten Miles riding. At the Top, when beyond any great Reflexion of the Sun-beams from the general Surface of the Earth, they ſeem to be in *Greenland*; toward the Middle the Weather grows milder, where they meet a kind of Spring; and at Bottom they ſweat under the Violence of the Heat.

As there are ſundry Places of the Earth where it ſeldom or never rains, ſo there are others where it is almoſt always Dripping. The firſt are extenſive Flats, where there are no Hills to intercept and ſtop the Moiſture floating in the Winds; the other are mountainous Places, that catch all the Humidity that comes in their Way. Hilly Countries therefore never want an over Proportion of Rain, for which they often, indeed, rob their neighbouring Plains.

THE Deſign of the Hills then in general ſeems to be, That they are placed by Providence commonly about the Middle of the ſeveral Continents, that they might ſerve to ſtop, or at leaſt to collect, freſh Water, for the Support of vegetable and animal Life in the adjacent Countries. By their Height they are alſo of ſignal Uſe and Service in giving the proper Deſcent to the Streams thus produced, to the End that they may flow gently, as the Fluids in the Veſſels of the Body do, thro' every Part, in order to render them of more general Uſe and Benefit: And from the extraordinary Preſſure of the ſubterranean, deſcending Waters, probably, proceeds the free and plentiful Riſe of Springs in Wells dug in lower Grounds.

AT the ſame time, however, that we aſcribe the principal Origin of Springs to the general Circulation of Vapours, we cannot but obſerve, that ſome of them are temporary, others perennial. The firſt flow plentifully in moiſt Weather, and then are often long dry; the others iſſuing from the Bowels of no great Eminencies perhaps, yield conſtantly, even in the greateſt Droughts, an equal Quantity of Water. This can only proceed from their being happily furniſhed with a conſtant Vein of that Fluid, thro' ſubterraneous Paſſages leading from the Parts adjacent, and higher ſituated, to the Place of its breaking forth. Nor can it be denied, but that Vapours may, by the Heat of the Earth only, when not expoſed to the Winds, riſe from the Bottom of the Caverns, ſometimes found in the Belly of huge Hills, as in an Alembic, eſpecially if near the Springs, where being ſlowly condenſed above, and gleeting gradually down the Sides, may from time to time repleniſh certain natural ſtone Reſervoirs, often to be found within ſuch Hills (ſomething of which ſort in particular may be obſerved in *Pools-Hole* in *Derbyſhire)* whence they glide on the firſt Bed of Clay or tenacious Earth they meet with, to ſome convenient Aperture, thro' which they make their Way.

On HAIL, SNOW *and* FROST.

HAIL appears to be no other than Drops of Rain congealed by the Cold, always found in the upper Regions of the Air, beyond the Reach of the Reflexion of the Sun-beams from the Earth. Being opened, there appears ſomewhat like Snow, of a looſer Contexture than Ice, in the middle of the Hail-ſtones, and the reſt ſeems to lie one concentric Kernel upon another. They often differ pretty much in Size: The larger Sort, by the Violence of their Fall, ſhew they come from a great Height; and tho' at the firſt Out-ſetting their Bulk might not perhaps exceed the ordinary Size of common Hail, yet in their long Journey, ſuppoſing the humid Medium, thro' which they paſs'd, inclined alike to Congelation, they probably increaſe their Bulk throughout their whole Paſſage. And that they do ſo, by the Acceſſion of freezing Vapours, appears in part by their being commonly of a looſer Texture than Ice.

HAIL is a frequent Attendant on Thunder and Lightning; whence it may be conjectured, that the Salts in the Air, then probably abroad in greater Quantities, contribute in great meaſure to the Congelation thereof. That Nitre, and ſeveral other penetrating Salts, will produce a like Effect on Water, will appear on mixing a Quantity of them, or even common Salt, with

with ſome Snow or Ice pulverized. In this Mixture, diſſolved before the Fire, immerſe a Bolt-head full of common Water, which preſently freezes, even in warm Air. The Experiment is deſcribed *Fig.* 12. *Plate* 9. The Bolt-head *A B* is filled with Water only to *C.* This immers'd in the beforeſaid Solution will, from the ſudden Conſtriction of the Glaſs, firſt meeting with the Cold, immediately riſe in the Stem, perhaps to *D.* Soon after it will gradually deſcend from that Point, condenſing till it comes down, and ſettles perchance at *E*; where for ſome time it will remain at Reſt: But ſoon recovering itſelf, and beginning to expand, it will gradually riſe from *E* to *F*, and thence ſoon after, by one Leap, to *G.* The Water in *A* is hereupon ſeen thick and cloudy, and that Moment ſeems to be converted into Ice. As more of the Water in *A* however becomes congealed, and the Ice hardens, part of the Water will overflow at *B*, in order to give it Room to do ſo. Whence it appears, that all Fluids ſubject to freeze, (except Oil, which alone is more contracted in freezing) become ſpecifically lighter, from Obſervation, about a ninth Part; all inferior Degrees of Cold however will make them ſeem ſpecifically heavier by Contraction: For this Reaſon it is, that Ice not confined always floats on the Surface of Water.

IT may here alſo be remarked, that a Quantity of Water, before and after it has been frozen, is found by Experiment to differ conſiderably in Weight; whence it may be concluded,

cluded, that the Evaporation ceaſes not, either when the Water is freezing, or even when it is in a State of Ice: Which inſeparable Quality of Ice renders it difficult to ſay, whether frigorific Particles, which deprive Bodies of their Heat, if ſuch there be, have any Weight or not.

THE Principle which Authors have gone upon, in order to ſolve the Phænomena of Freezing, are either, Firſt, according to GASSENDUS, that ſome foreign Matter is introduced into the Pores of the Fluid, by Means whereof its Bulk is increaſed, and its Parts become fixed.

AND theſe Gentlemen, to ſolve it, apply to certain nitrous Particles, properly formed to produce this Effect; in regard *Sal Ammoniac*, Saltpetre, Salt of Urine, and many other volatile and alkalizate Salts, mixed with Water, increaſe its Degree of Cold very ſenſibly. And the Manner in which theſe Particles are preſumed to hinder the Fluidity of Water is, that they are conſtituted of rigid pointed *Spiculæ*, eaſily, they ſay, driven into the Globules of Water, which, being variouſly mingled, and as it were intangled together, by Degrees enfeeble, and finally deſtroy the Motion thereof.

SECONDLY, The Followers of DES CARTES aſſert, that ſome Matter, naturally contained in the Fluid, is by an intenſe Degree of Cold expelled, thro' the Abſence of which, the Body becomes fixed. And this they preſume to

be

be brought about by the Receſs of the active, ætherial Matter, to which they aſcribe all Motion of Bodies, out of the Pores of the Water, or at leaſt to a very large Abatement of it. And conſidering the known Phænomena of the Freezing of the natural Fluids (the Attraction and Repulſion of whoſe Parts in a State of Fluidity are pretty near equal, and therefore eaſily moved one among another; as alſo from the Melting of ſuch as are only reduced to a State of Fluidity by Heat, the Parts being put under a Degree of extraordinary Vibration, which by Cold again become rigid, wherein the Attraction of their Parts ſeems greatly to overpower that of their Repulſion; whence proceeds what we call Coheſion, Tenacity, Viſcidity, and the like) we cannot refute either of the Syſtems above-mentioned, ſince neither of them at preſent come under Proof by any Experiment: They are therefore purely hypothetical.

BUT the third Opinion on this Subject, according to a late *French* Author, is, That there is ſome Alteration produced in the Texture or Form either of the fluid Particles, or of ſomething contained in them.

IN Favour of this laſt, it may be obſerved, That a Globule of Water held on the Point of a Needle, in a ſmart Froſt, will, upon freezing, ſhoot itſelf out into a Star, having a certain Number of Points; and Snow, which is a frozen Vapour, ſeems to be no more than a

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Congeries of theſe Stars, united to each other by the Tips of thoſe Points, and by no means adapting themſelves to, or filling the Interſtices between them: It muſt thence follow, that the Dimenſions of a Quantity of Water, reduced thus by Cold from a fluid to a fixed State, will be conſiderably enlarged. Nor are any Pipes or Veſſels ſtrong enough to reſiſt the natural Power of the Congelation, but they generally burſt whenever the Fluid therein confined happens to be frozen: And a Force capable of making a Gun-barrel fly, will be eaſily admitted gently to heave the Earth or Soil in a Froſt, thereby rendering it more light, that ſo the Fibres of Plants may afterwards be able to ſhoot therein with greater Freedom; whence may probably proceed the general Fertility of ſuch Summers, with us, as ſucceed hard Winters; not to inſiſt on the Deſtruction Froſt uſually brings upon the *Ova* of Inſects, and other noxious Animals.

IT may farther be obſerved, in favour of this laſt Opinion, that Ice being never ſo tranſparent as Water, the Rays of Light do not paſs thro' Water congealed and fluid in the ſame Manner: Which ſeems to imply, that the Contexture and Connection of the Parts of this Fluid are changed, and, in theſe Circumſtances, otherwiſe combined; for Snow, wherein this Change of Parts is moſt remarkable, is ſtill far more opake than Ice. At leaſt it is an Evidence, that there is an uneven Mixture of an infinite Number of Air-Bubbles,

and

and thoſe various in Size, with the Particles of congealed Water, which will alſo hinder its Tranſparency.

IF we look warily among the regular and intire Flakes of Snow, as has been ſaid, we always find them conſtituted of Rowels of ſix Points, adhering to each other by the Ends of thoſe Points; ſometimes however they appear in broken Points and Parcels, that ſeem to be only Fragments of the regular ones; and ſome there are that ſeem to be wholly unform'd. This probably proceeds from the Accidents they may have met with in their Deſcent to the Earth; as, by various Winds in their Paſſage, they may be firſt thaw'd and then frozen perhaps again, and ſo occaſion this ſeeming Irregularity.

THO' Snow ſeems to be ſoft, it is truly hard as Ice; and did not the Points melt on the Approach of the Finger, or yield under it, they would appear ſo to the Touch, as when it is cruſhed by the Foot, it really does. It is however very light, on Account of the extream Thinneſs of each Icicle, and of its large Surface in Proportion to its Weight; and Gold, tho' the moſt ponderous of Metals, will eaſily ride on the Air, we know, when beaten into thin Leaves.

SNOW is white, becauſe it conſiſts of Parts that ſingly are tranſparent; but when they are mixed together, they appear white; as do the

Parts

Parts of Glaſs, Froth, and other diaphanous Bodies, whether ſoft or hard.

On SOUNDS.

SOUND is itſelf not a Body, but a Motion, accidentally impreſſed on the Body of the Air, by the Tremors of ſounding Bodies, excited either by Percuſſion or the like. It is a Motion very different from that of the Winds, which conſiſts in the local Motion of the Air, or a Stream of it flowing ſucceſſively, without the leaſt Vibration; whereas Sound is conveyed by ſuch a Motion of this Fluid, as is incapable of produciug any Repetition thereof in the ſame Place; but having once floated along the Medium by the Ear, the Sound ſeems to drop at once, and be thenceforward there wholly loſt, unleſs it be afterward reflected thither.

THE Motion of the Air in the Winds will act vigorouſly on Flame; but it affects not the Ear with Sound, unleſs it meets with ſome fixed Object, the Reſiſtance whereof cauſing a Vibration therein, it then becomes audible. But the Agitation of the Air, in the Caſe of Sounds, gives no Motion at all to Flame: For a lighted Candle put near a great Bell, when made to ſound, will not have its Flame agitated in the leaſt thereby.

SIR ISAAC NEWTON, according to the received Notion of this Truth, alſo demonſtrates, in in the 43*d* Propoſition of the 2*d* Book of his *Principia*, That *Sounds, as they riſe from the tremulous Motion of elaſtic Bodies, are nothing more than the Propagation of a Pulſe in the Air ſhaken thereby*: And this is confirmed by the great Tremors that ſtrong and grave Sounds, as the Report of Cannon, or the Sound of great Bells, excite in Bodies all round them. And he concludes, that Sounds do not conſiſt in the Motion of any Æther, or finer Air, as ſome have aſſerted, but in the Agitation of the whole Body of the groſſer Air contiguous; becauſe by Experiments we find, that the Motion of Sounds, and their Propagation, depends abſolutely upon the Denſity of the whole Air.

To prove this; if we put a ſharp-noted Bell under a Receiver, and ring it, it will be heard to a good Diſtance; exhauſt the Air, and make the Clapper ſtrike againſt the Sides, the Sound will gradually abate; and when the Atmoſphere is quite removed, it will ſcarce be heard at all. Again, if the Air be condenſed in the Receiver, the Sound will grow louder and louder, in juſt Proportion to the Degree of Condenſation, or the Quantity of Air crouded in.

NOR does this happen only in forced Rarefactions and Condenſations; but in ſuch alſo as are natural: As is evident from FREDLICIUS' Account given in VARENIUS' Geography, of his Journey to the Top of the *Carpathian* Mountains in *Hungary*, ſaid to be higher than the *Alps*. Here the Atmoſphere, on account of the Abatement of its Height, with regard to the Sea and lower Parts of the Earth, muſt be very much attenuated; and the Exploſion of a Muſquet there fired, ſeemed to him to ſound but like the Breaking of a little Stick.

IT may alſo here be remark'd, that in miſty Weather, when the Air is loaded with Water, or floating Vapours, Parts of an unelaſtic Fluid, Sounds ſeem to come heavily to the Ear, and much altered from what they ſeem, from the ſame Objects, when the Air is clear.

THE Sound of the Bell, continually ſenſibly increaſing on the gradual Re-admiſſion of the Air into the Receiver, plainly ſhews, that the Quantity of Sound depends on the Degree of the Condenſation. Mr. HAWKESBEE's Experiments on Sounds made in the condenſing Engine, put this Matter alſo beyond all Doubt; and ſuch Perſons as at great Depths of Water, in the Diving-bell, have their Atmoſphere very denſe, and of Conſequence very elaſtic, at the ordinary Pitch of Speaking ſeem to give very high Words; and a Perſon who attempted to blow a Hunting-horn in that Situation, had like to have ſtunn'd both himſelf and Hearers.

THIS can only proceed from the Parts of the elaſtic Fluid, adjacent to the ſounding Body, being thereby put in Motion, which immediately thereupon catch and communicate Motion to thoſe which lie neareſt, theſe to the next,

next, and ſo forward, tho' more and more faintly, till by the Diſtance from the Centre of Sound, or the Inactivity of the Matter, in the Courſe of its Progreſs to be moved, the Reſiſtance will at length be equal to the Impulſe, and the Motion therefore be no farther propagated. Much as a Stone thrown into Water, will therein immediately raiſe a wavy kind of Motion, ſhewn by the concentric Circles, continually floating off, but growing leſs and leſs conſpicuous, till they impinge or ſtrike againſt the Bank if near, or finally diſappear of themſelves, if the Surface thus put in Motion be over-large. It muſt only be obſerved, that the Tremors of the elaſtic Particles beforeſaid will be propagated from the ſounding Body, in all Directions, as from the Centre, to all Parts of a ſurrounding Sphere.

FOR this Reaſon, the Organs of Hearing, that are equally ſenſible and good, are equally affected by the ſame Sound, convey'd to them from equal Diſtances; and at different Diſtances they are by it differently affected, receiving it in a different Manner. For Inſtance, a Perſon, at the Diſtance of two Miles, may hear St. *Paul's* Clock ſtrike without any great Emotion; but at the Diſtance of ten Yards it would give him a good deal of Surpriſe. The Colliſion of the Bell with the circumjacent Air will be there very violent; but farther off the Motion will become moderate and more languid. And

THE Blow on theſe Occaſions given to the *Membrana Tympani* will be ſucceſſively propagated thro' the artful Meandrings of the Ear, till at length the auditory Nerves will be more or leſs ſhaken thereby, and the Senſation of Sound will to the Perception be conveyed, in Proportion to the Degree of the Impulſion given; upon which alone the Variety of Sounds wholly depends.

IT may not here be amiſs juſt to hint, that in the Proceſs of Hearing there is a two-fold Impulſe given to the auditory Nerves, and both propagated from the *Membrana Tympani.* One ſeems to be by the undulating of the Air in the Cavity of the ſubjacent *Concha* or Drum of the Ear, which acts upon the Membrane of the *Foramen rotundum:* And this only influences one of the ſpiral Cavities of the *Cochlea.* The other Impulſe is made with wonderful Contrivance and exquiſite Art: The Tremor of the *Membrana Tympani* being propagated all along the five ſmall Bones of the inner Ear, ſome of which are movable, to the Membrane of the *Foramen ovale,* which opens into the *Veſtibulum* or Porch, whence alone the ſonorous Motion is communicated to the Nerves, which are very artfully diſtributed along the other ſpiral Cavity of the *Cochlea,* and its three ſemicircular Canals.

THE moſt elaſtic Bodies are the moſt ſonorous; therefore Bell-metal, Glaſs, and the like, are remarkably ſo: But nothing more than a well-ſtretch'd String. This being ſtruck, will ſound a conſiderable Time, vibrating this Way and that, croſſing the Line at each Vibration, as a double Pendulum would do. Its Motions in this Caſe are deſcribed *Plate* 9. *Fig.* 13. wherein *A B* is the Direction of the String before it is ſtruck, and *A D B* and *A C B* the Figure it will form after. Theſe Vibrations are greateſt juſt after the Stroke, the greateſt Range being made by the Middle of the String; and from the Counter-action of the two fix'd Points *A* and *B*, and the Reſiſtance of the Air it ſtrikes againſt at each Vibration, the String at length ceaſes to move or ſound.

FATHER MERSENNIUS ſays, he found by certain Experiments, that a String extended till it was of a Concert Pitch with the Note *C faut* in the Middle of the Baſe Cliff, made no leſs than an hundred and four Vibrations in a Second of Time, which conſequently gave as many Impulſions to the ambient Air; but were ſo ſwiftly performed, even here, toward the Bottom of the *Gamut*, where the Vibrations are beyond Compariſon ſlower than they are above, that the Ear was not ſo perfect as in the leaſt to diſtinguiſh the Intervals thereof: But as in whirling a live Coal round pretty faſt, tho' we know it changes its Place ſucceſſively, and every Moment, yet it appears to the Eye to deſcribe one continued Circle of Fire, we are apt to judge that to be a Continuity of Sound, which in Effect is the Conſequence of ſeveral diſtinct Strokes or repeated Impulſes from the ſounding Body. And Sir ISAAC NEWTON ſhews, in the Corollary of his 48th Propoſition, *That* *the Number of Pulſes propagated, is always the ſame with the Number of the Vibrations of the tremulous Body; and that they are not by any Means multiplied in their Progreſs from it.* This alſo plainly appears, by the immediate ceaſing of the Sound, with the ſtopping the Tremor of the ſounding Body, which, in Bells that are ſtruck, is ſufficiently plain to the Touch, and in Strings of a grave Tone it is alſo evident to the Eye.

THE Difference of the Velocity of the Vibrations of Strings ſounding a higher and a lower Note, may be in Part collected from the very great Smartneſs wherewith the ſhorter Strings of a Spinet will throw off a Fragment of Paper, or other light Body, hung looſely thereon; whereas on the longer it will eaſily ride, at equal Diſtances from the Jack, when the Strings are made to ſound.

THE Manner in which a Stroke acts upon a Bell, is ſomething different from one on a String. The Vibrations of this are made directly acroſs the Line of its Tenſion; the only fixed Point of the other is that of its Suſpenſion at the Crown, or in the ſtrongeſt Part of the Bell. The firſt is a ſingle ſtreight Chord; the other is compoſed of an infinite Number of Rings, greater or leſs in Diameter, according to their Diſtances from the fixed Point. As the longeſt String, when ſtretched, vibrates ſloweſt, ſo do the Rings of greateſt Circumference in this Machine: Hence we

find

find that a Bell differs in Tone, according to the Part 'tis ſtruck in. Toward the Top, the Sound will be more ſharp; toward the Baſe, more grave; according to the different Dimenſions of the circular Chord, ſuppoſed to be ſtruck.

A STROKE on a Bell throws that Machine into an elliptical Form: If it be ſtruck without, the Front and Rear are thruſt thereby nearer together, the Sides flie out, and the Endeavour of the elaſtic Matter to reſtore it ſelf to its circular Figure, vibrating to and again, becoming elliptical as it were, firſt one Way and then another, is what gives and continues the Sound: and if the Blow come from within, the contrary muſt happen. This will be evident, from ſtriking a glaſs Bell, faſt ſuſpended in a Frame, by the Crown, having a Screw in one of its Pillars, which may be either eaſily advanced toward the Machine, or withdrawn from it, at Pleaſure. The Jarring of the Machine againſt the Screw, when gently ſtruck in Front or Rear, will ſhew that the Diameter is increaſed at right Angles to the Direction of the Blow; and its not jarring when ſtruck, in like manner toward, or in the Direction of the Screw, will demonſtrate, that the fore and back Side do then flie out, on the firſt Impulſe given.

THE Difference of muſical Tones (which are only ſeven diſtinct, or the Notes of the *Gamut*; and the whole Compaſs of Notes above or below theſe, are no more than a Repetition of the ſame Notes, either in a higher or lower Key) depends on the different Number of Vibrations, communicated to the Air in a given Time, by the Tremors of the ſounding Body. The quicker the Succeſſion of the Vibrations is, the acuter is the Tone; and the contrary.

THERE are various Ways of making Strings expreſs the Notes in Muſick. The ſimpleſt Way of doing this, is to extend them with Weights; and if they be of one Length and Thickneſs, keeping the Series of the ſquare Numbers, *viz.* 1, 4, 9, 16, 25, 36 and 49, will produce this Effect *. If you would have the Weight or the Extenſions all equal, you muſt increaſe the Diameters of the Wires or the cylindrical Strings ſo, that the Areas of their Sections may be in the foregoing Proportion. But the beſt Way of doing this is, by Stretching or Tenſion, and then compounding both thoſe Proportions in a judicious Manner, for the ſake of Convenience; as is done in the Harp, Dulcimer, Spinet, and Inſtruments of that Kind; the Strings whereof are extended above, and one End of them fixed over a Cavity intended to magnify their Sound. This is always covered by the Belly, a dry elaſtic Piece of porous white Fir, left thicker beneath the Treble Strings, and thinner

* The ſame Reaſon obtains alſo in Bells; for if you chuſe ſeven Drinking-glaſſes all of the ſame Note and Tone, and fill them with Water in Proportion to thoſe Numbers, they will expreſs the ſeveral Notes of Muſick tolerably well; but in an inverted Order.

ner under the Baſe, that it may by their ſeveral Vibrations be more or leſs ſhaken, in order, by its Counter-vibration, to moderate the Notes, to mix and meliorate the Sound, and ſo to give what is called the fine Tone of the Inſtrument.

A MUSICAL Chord performs all its Vibrations, whether long or ſhort, in the ſame Space of Time. For if a String be ſtretched between two Pins, and a Force be applied to the middle Point, to draw it out of its rectilineal Situation, if the Diſtance be but ſmall, 'twill be in Proportion to the Force applied; and conſequently the Velocity wherewith it returns, when left to itſelf, will be as the Space it has to move over; and 'twill therefore perform all its Vibrations, from firſt to laſt, in the ſame Time. For which Reaſon the ſame Chord, in what manner ſoever ſtruck, always produces the ſame Note. It is alſo found by Experience, that when Strings of equal Diameter, but of different Lengths, are equally ſtretched, the longer they are, ſo much the leſs Weight will draw them from their rectilineal Situation, to the ſame Diſtance; the Forces therefore by which they return are leſs, the Times of their Vibrations longer, and their Tones are conſequently more grave.

WHEN two Chords perform their Vibrations in equal Times, the Tone produced is termed a *Uniſon*. If one performs one Vibration, while the other is making two; 'tis called an *Octave*. If one makes three, while the other two; 'tis called a *Fifth*. If one three, while the

the other four; 'tis called a *Fourth*. If there be an Interval of two, or if the Vibrations are as 1 to 3; 'tis called a *Third*, &c.

To make an *Unison* Sound, it is not necessary that the Vibrations of the two Strings should actually concur; but only that they should be performed in equal Times, so that they would always concur, if they began at the same Instant. For, as it has been observed, the Ear perceives not the single Vibrations distinctly; but only discovers that Difference, which proceeds from the Intervals of Time which pass between them.

FROM these Principles, we endeavour, with a late ingenious Author, to account for the Trembling excited in all the *Unison* Strings of any Set of Instruments in Tune, when any one of them is made to speak. For the Vibrations of the Air, which correspond to the Tremors of the first, agreeing exactly in point of Time with those which are capable of being given to the others, when they have, by their first Impulse, communicated a small Degree of Motion to them, will by conspiring therewith, as they move backwards and forwards, by the same Means continually increase their Motion, till it becomes sensible. And the contrary happens when Strings are in Discord with each other: For in this Case, should one possibly give Motion to the other, yet their Vibrations not being performed in equal Times, the second will come

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unſeaſonably, and, when the other is moving the contrary Way, will obſtruct its Motion.

IT is farther obſervable, that all the *Octave* Strings of a Harpſicord in Order, will tremble more or leſs when any one of them ſounds. If one of them vibrates twice, while the other once, every ſecond Vibration of the former will ſound a *Uniſon* with every one of the latter. So if one vibrates thrice, while the other once, the Intervals of the laſt will be divided into three Parts, each of which will ſound a *Uniſon* with it, while the two Points between thoſe two Parts will remain at Reſt; or otherwiſe they would interfere, hinder each others Vibration, and not receive from thence Motion ſufficient to produce either a Tremor or a Sound. Theſe Experiments are to be made very well on Glaſſes of Water, rightly toned; becauſe the incloſed Fluid will help to make the Tremors more evident.

THAT Strings thus circumſtanced do actually vibrate, and therefore give a Sound in ſome Degree, will alſo be ſufficiently plain, from obſerving the Motion of a ſmall Piece of Paper or Down put on all the *Uniſon* or *Octave* Strings of all Inſtruments in Tune. And the Thirds and Fifths being more nearly allied to theſe in Point of Tone than any other, ſomething of an inferior Motion may be obſerved in them, when an *Octave* ſounds: Theſe three Notes are therefore called *Perfect Concords.*

Now

Now as a *Unison* String *in Vacuo* cannot this Way have Motion communicated to it, it thence appears, that 'tis the Collision of the sounding String with the Parts of the Medium, put thereby in Motion, which excites a certain Degree of Motion in all those Bodies, that within the Reach of the Sound happen to be in the same Disposition, with regard to Tensity and Tone, to receive that kind of Impulse or Impression from it. For Instance; one kind of Tone shall make the Pewter jar; a second Note will cause the China and the Glasses to sing; a third shall put your Seat in Motion, a fourth shall set your Teeth on Edge; and the like.

HENCE too it is, that some Persons are able to break a Drinking-glass merely by the Tone of their Voice when brought to a *Unison* with it. The Sound of the Glass, being struck, always gives its natural Note; which being increased by Degrees, from a smaller to a larger Degree of Vibration, the Tremor at length becomes too great to be supported by so brittle a Substance.

FROM a Principle like this, with some Probability perhaps, we may, at least in Part, deduce the Cause of the customary lazy Action of Yawning, often appearing to be sympathetick. It must be allowed, that every Part of the Animal System is made up of Fibres, or little Strings: Of these the Muscles of the Flesh are composed; so are the Bones, Tendons and Nerves,

Nerves, all in a various Degree of Tenſion, according to their Texture, Office and Uſe: Theſe are therefore ready to receive Impreſſions from the moving of their *Uniſon* Strings, and to repeat the Notes which they ſhall ſound.

THE Perſon then that leads this Concert, either having his Spirits waſted by a long Watching, or from ſome great Application, or he may perhaps be enervated thro' a too long Indolence, whereby his Nerves and Syſtem of Fibres may be all relaxed: Theſe therefore want bracing up, and being all elaſtic Chords, by ſtretching they recur and naturally contract, after Extenſion, with greater Force and Vigour. Nature by this Means is a while refreſhed, and when ſhe flags again, is again ſtimulated to a Repetition of the ſame Experiment. Now ſuch of the Aſſiſtant-Performers as happen to be in the ſame Circumſtances, and have their Fibres lowered down to the ſame Pitch, immediately take it, and incline like a Set of *Uniſon* Strings, to give the ſame Note; and this it often like a Contagion ſpreads, and goes round the Company.

AND doubtleſs it is from much the ſame Cauſe that good Muſick has ſo great a Command over and ſo viſible an Effect on the Paſſions of Men. The fibrous Syſtem is always tenſer in Age, and more pliant in Youth; ſome of thoſe Fibres will correſpond with, and be affected by Muſick of one Sort; ſome by another. The Young there-

therefore are usually delighted with Airs, which are gay, bounding and lively; the Middle-aged are more pleased with martial Musick, and the Din of War; and the Antient generally prefer the Solemnity of Church-musick to any other. Thus does our Taste of Things often vary with our Years; nor is our Opinion always within our Power. It will be prudent therefore, never, at least not too positively, to condemn, what, from the Changes in our natural Constitution and Frame, we may be in Danger one Day of falling into ourselves; nor, on the other Hand, too eagerly to censure the Levity and little Extravagance of Taste in others, the Sense whereof we have either now out-lived, or what from a different Organization of Body we could not possibly fall into.

WHERE a Multitude or the most of our Fibres are agreeably moved, by the excellent Performance of a fine musical Composition, we are apt to be transported. When mournful Sounds invade our Ears, we are moved to Pity; sprightly Airs inspire Love; martial Fury is to be raised by fitting Sounds, and proper Measures: And thus may the generality of human Passions be influenced by Musick; as Mr. DRYDEN and Mr. POPE have finely described in their several Odes upon St. *Cecilia*'s Day.

WHEREVER we meet with a Collection of harsh, discording, unharmonious Sounds, we are most sensibly tortured; doubtless from the before-mentioned Cause: The Mind seems to

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be thereby unhinged, and great Violence is done to the whole Conſtitution. This made Lord VERULAM, who was a very good Judge of human Nature, think, that an Anti-muſick might be contrived, of ſome Uſe in War, whereby Groans, Screams, and hideous Clamours, might be conveyed to the Ears of the Enemy, and Horror and dreadful Apprehenſions to their Minds. But whether this might not have equally a bad Effect on thoſe who uſed it, is a Queſtion; and perhaps one Reaſon why this Thought has been purſued no farther.

IT muſt, however, be confeſs'd, that the Shouts which our Countrymen frequently make, when they undertake any very hazardous Attempt in War, has its Uſe; chearing themſelves, at the ſame time perhaps that it ſpreads Diſmay among the Enemy; more eſpecially ſince they act together, and in Concert execute the Commands they have received: While the adverſe Party, being unapprehenſive of what is meant or intended, are divided in their Sentiments, unprepared, and therefore leſs reſolute in their Defence, than the other are in making the Attack.

THE Effect Muſick has on Perſons bit by the *Tarantula*, if true, is alſo a conſiderable Proof of the Power of Muſick, in putting the Fibres of the Body in Motion. The *Tarantula* is a large Spider, ſaid to be obnoxious only to the People of *Apulia*, a Part of *Calabria*, in the Southermoſt Part of *Italy*. The Patient

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after the Accident loſes both Senſe and Motion, and dies if deſtitute of Help. The moſt effectual Remedy is Muſick. The Muſician tries Variety of Airs, till he hits upon one that affects the Patient, who upon that begins to move by Degrees, and keeps Time with his Fingers, Arms and Legs, afterwards with his whole Body. He then raiſes himſelf up, begins to dance, increaſing in Activity every Moment, till after five or ſix Hours ſmart Exerciſe in this Way, being much fatigued, he is put to Bed, to recover Strength. The next Day the ſame Air brings him out of Bed for a new Dance, and no other Perſuaſion whatever will incline him to ſtir. This Exerciſe being thus continued, the Diſtemper is abated in the ſpace of four or five Days, the Effects of the Poiſon being then in ſome Meaſure carried off by Sweat, and the Patient begins to recover his Strength and Senſes by Degrees.

I HAVE ſeen a Perſon that was born deaf, and probably ſo will always continue, when he held the End of a Violin between his Teeth, on which another played, rejoice very much, as being made that Way ſenſible of the Muſick. This could only be communicated to his Perception by the Vibration of the ſolid Parts, the Bones of his Head, communicated thereto by thoſe of the Inſtrument.

AND this Experiment any one may make, by ſtopping his Ears with his Fingers ſo cloſe, that he cannot hear an Inſtrument that ſhall

be

be played on; let him then lean his Head, either againſt the Inſtrument itſelf, or apply it to the End of a long Stick that bears againſt the Inſtrument, and he will diſtinctly perceive every Note that is played.

THIS is one Way, and a very certain one it is, which the Mariners take to diſcover whereabout the Leak in a Ship is, when not eaſily to be found, *viz.* They take a Staff, and holding one End of it tight to the Ear, they apply the other ſucceſſively to the ſeveral Parts of its Sides, till they diſtinctly hear where it is the Water ruſhes in, tho' the Noiſe be too inconſiderable, and not poſſible to be found by the Ear alone. And every one knows how difficult 'twould be to remove all the Ballaſt and Stowage of this bulky Machine, in order to diſcover it any other way.

IT is a common Experiment, for a Perſon liſtening at one End of an extended Cable, or a Stick of Timber of any Length, to hear a Scratch made with a Pencil, or a ſmall Fillip with the Finger, at the other, purely by the Elaſticity of the Parts of thoſe Bodies. The Centinels of the advanced Guard, in Time of War, are ordered to lie on their Bellies, with their Ear to the Ground, that the earlieſt Notice of any Motion of the Enemy may ſo be had, and prevent a Surprize; the Sound being communicated a long Way by means of the Earth. And jealous Princes have ſometimes had Pipes laid from the Council to the Cabinet, whereby they have become Maſters of the Conferences there carried on, being conveyed by means of the elaſtic Fluid encloſed therein.

As the Effect of String-muſick is produced by the Tremor or Vibrations of a ſounding String, excited by a Blow or ſome external Force applied; ſo is Wind-muſick produced by thoſe of the ſounding Pipe, by means of the Influx of Air condenſed. The Organ in particular has a very long Trough, air-tight, with which the Pipes of the whole Inſtrument communicate, and into which all the Bellows are made to blow, in order to furniſh a conſtant Supply of Wind. The Keys, by lifting little Springs from time to time, let a Part of this Air out of the common Magazine, which immediately ruſhes into its peculiar Pipe, the nether End whereof is formed ſomething like the Mouth-piece of a Flute; where meeting with a ſharp Edge, exactly oppoſite to the Channel of Induction, the Stream of Air is thereby divided into two Parts; one whereof paſſes without the Pipe, and runs waſte; the other puſhes in with a Force ſufficient to put the Parts of the elaſtick Matter, of which it is compoſed, into ſuch a Tremor, as is proper to ſound the intended Note, to which the Dimenſions of the Pipe and other Circumſtances alſo contribute. The Metal Pipes are cylindrical; the Wooden ones uſually ſquare.

It may be obſerved of the Flute, Hautboy, and ſuch Inſtruments whereon the Notes of

Muſick

Musick are struck by the Help of Ventages or Holes made in the Trunk of the Tube, that they are not bored cylindrical, but conically; not only that the Tube may be kept of a due and manageable Length, but also to save a great Expence of Breath.

WAS the Tube of the same Bigness throughout, the Quantity of Wind requisite to sound the highest Note distinctly, would necessarily be attenuated in its Passage down it, gradually mingling with Air of the common Degree of Density found therein. This would require, let us suppose, the Aperture fit to sound the second Note to be placed an Inch below the first. The same Cause still increasing, let us suppose the third Note put at the Distance of two Inches, the fourth at three, the fifth at four, the sixth at five, the seventh at six, and the Octave at seven Inches. The Sum total of all these, with the Intervals proper to be left between the Extremities of the Flute and the Holes, would make the Tube of an inconvenient Length, and bring the Ventages not within the Reach of an ordinary Set of Fingers. It would also require an uncommon Stream of Air to replenish a Tube thus circumstanced; whereas, by the gradual Contraction of the Channel, as 'tis bored taper, the Wind will be rather condensed in its Passage, and to very good Purpose. To this Artifice the Workmen generally add another, which is, to make the Holes of a greater or less Diameter, according as the Note requires the Sound to be more or leſs ſharp.

AND here we may not improperly mention the Organs of Speech, the Voice being modulated or governed by the Contraction, Extenſion and Management of the Muſcles of the *Larinx*, which is made up of five Cartilages, different in Shape and Size, and diſtinct from thoſe ſemicircular cartilaginous Rings which conſtitute the Windpipe; but are very nicely contrived and adjuſted to one another for modulating the Ingreſs and Egreſs of the Air in Reſpiration, Speaking, Singing, *&c.* The Muſcles that move the Tongue, alſo contribute very much to the Production, Formation and Articulation of the Voice; ſo does the apt Diſpoſition and Organization of the other Parts of the Mouth, the Palate, Lips and Teeth. A juſt Arrangement of theſe greatly conduces to the Propriety and Harmony of Speech: And when thoſe Parts are happily formed for the Purpoſe of Singing, the judicious Performer is now a days found to be in Poſſeſſion of a very lucrative, as well as entertaining Qualification.

IT is alſo from a Difference of the Organization in the Throat and Mouth of other Animals, that to expreſs the ſame Paſſion of the Mind, one growls, another hiſſes, and another roars; in the ſame Manner that equal Blaſts from the ſame Lungs produces one Tone on the Trumpet, another on the French-horn, a third on the Baſſoon, and the like.

On

On the SPEAKING-TRUMPET, *and* AURICULAR-TUBE.

THE Speaking-trumpet was invented by Sir SAMUEL MORLAND, for the Benefit of making People hear at a Diſtance; as at Sea, in a Siege, *&c.* It is a conical Tube, made of thin Braſs, Tin, or other elaſtic Matter, from two to ſix Foot long.

THE Reaſon why the Voice is magnified by this Machine is, becauſe it is made of a Subſtance eaſily ſhaken, by the Vibrations whereof the circnmjacent Air is put into greater Motion. Theſe being ſucceſſively propagated thro' the Tube, are continually reverberated or reflected from the Sides into its Axis, by that Means being prevented from ſpreading, till they get out of it. The gradual Increaſe of the Cavity of the Tube puts all Parts of the Metal into a proportionable Degree of Motion; ſo that what Tremors might be confined within the Compaſs of an Inch in Diameter at firſt, will be afterwards diffuſed ſo as to fill a Circle, perhaps twelve or fifteen Inches in Diameter, before it leaves the Inſtrument, which then generally becomes the Centre of Sound. It muſt, however, be obſerved, that the more ſonorous and audible the Voice is made by this Means, the leſs articulate or diſtinct it is: Juſt as Light, to which Sound bears in many Things a pretty near Reſemblance, the more it is diffuſed, the leſs will it diſtinguiſh the Objects whereon it falls; and the more it is condenſed, the brighter and more diſtinct will the Objects it is thrown on always appear.

FOR a contrary Reaſon the Auricular Tube, the Figure of which is repreſented *Fig.* 14. *Plate* 9. aſſiſts ſuch as are hard of Hearing, when not occaſioned by the Humours becoming inſpiſſated by Cold, *&c.* and the Obſtructions conſequent thereon. In which Caſe this Machine can be of little Service; waſhing out the Wax does much better: But when the Organ itſelf is by Age enfeebled and decayed, that is, when the acouſtic as well as other Nerves have loſt their Delicacy, this Tube may be of real Uſe and Service, in rendering Sounds more diſtinct and audible.

THIS Machine then ſeems to be juſt the Reverſe of the Stentorophonic Tube, or the Speaking-trumpet juſt mentioned: As the Uſe of that is to diſſipate, this is intended to collect the Rays of Sound. With regard to the Structure of it, the Baſe is beſt made in Form of the parabolic Curve, finiſhing at Top with a ſmall bent Tube, that it may more conveniently be applied to the Ear. It does thus in ſome Meaſure reſemble the auditory Duct, or the inner Ear itſelf, which is alſo ſomething conical, having the Baſe outward, and the *Apex* next the Head; that ſo a larger Quantity of the moved Air may be collected, received, and thereby tranſmitted to the Point

of

of the auditory Nerve, which muſt be ſhaken to produce Hearing and give Perception. So that this Contrivance is in Effect no more than the Baſe of the Ear enlarged, and therefore capable of intercepting more of the Rays of Sound than the Ear alone; and that in Proportion to its Baſe. And theſe being gradually contracted into the ſmaller End, are thence thrown upon the *Tympanum*, and affect the inner Ear according to the Force and Quantity of the Impreſſion received.

THE Smoothneſs of theſe Machines is no ſmall Advantage to the Conveyance of Sounds thro' them; for by Experiment we know, that theſe always glide with moſt Eaſe, and move the fartheſt, over ſmooth Surfaces, where there is nothing to obſtruct and divert their Progreſs, or to occaſion a Rebound.

On Places of HEARING.

IT might ſeem incredible, that the Voice of a Man might be diſtinctly heard at the Diſtance of ten or twelve Miles: But a Gentleman of great Veracity, who had lived ſome Years at *Gibraltar*, affirms to me, that he has at *Old Gibraltar* heard the Watch-word of the Night, *v z. All's well*, given by the Centinels to the P. trole, paſſing along the Ramparts of *New Gibraltar*, in a ſtill ſerene Night, when the Water was perfectly ſmooth, and that, he thinks, as plain and diſtinctly as thoſe who walked the Round, or himſelf (had he been upon the Rampart) could have done. The Bay between the two Places he judges to be about three *Spaniſh* Leagues over. This is a ſufficient Proof of the Service it is to Places of Hearing, that their Surfaces ſhould be as ſmooth as poſſible. Carpets, Hangings, and the like, are great Impediments to Hearing. Such Furniture having nothing elaſtic in it, the Voice is damped thereby. Snow lying on the Ground will do the ſame thing, and even alter the Tone of Bells very much.

FOR this Reaſon the Surfaces of Whiſpering-places are commonly made very ſmooth. They are beſides this, commonly diſpoſed and built in a circular, or at leaſt a curvilineal Form, capable of catching and tranſmitting all the Reflexions of Sound that come within their Compaſs. That of the greateſt Note in *London*, is in the grand Gallery of St. *Paul's* Cupola. Juſt above the Gallery is a ſtrong ſmooth blank Wall painted, being the Baſis of the Dome. It is circular, and being the Zone of an Ellipſe, it is not quite ſo wide at Top as at Bottom. Let a Perſon here ſpeak with his Cheek to the Wall, in Whiſper, he will be audibly heard quite croſs the Gallery; the Reaſon of which comes next under Conſideration.

LET *ABC*, &c. *Fig.* 15. *Plate* 9. repreſent the Line or Part of the blank Wall, againſt which the Speaker whiſpers. The Air put into to Motion thereby, impinging firſt at *A*, according to the Angle in which he directs his Voice towards the Wall, will be thence reflected to *B*, thence to *C*, to *D*, to *E*, and ſo on to *F* and *G*, where the Reflexions, brought by the collateral and contiguous Lines, will alſo nearly meet, and by their Union, there cauſe a much ſtronger Sound than in any other Part of the Circle whatſoever; much greater than at *A*, the Point from whence the Sound originally came. It will be very well heard at *G*, if there happens to be a Pier, or ſomewhat projecting, to ſtop and reflect it thence at once: But if there be no ſuch thing, nor any Ear to receive it applied, it will probably proceed quite round the Dome, and come again to the Speaker himſelf, tho' much diminiſhed, at *A*, on account of the more frequent Reflexions it muſt have ſuffered in paſſing over twice the Space. Nor is this the only Cauſe of this Phænomenon; for the Air thus agitated by the Voice, and paſſing round the Zone as before-mentioned, is very much augmented by ſomething of a like Courſe it alſo takes, from the Lips of the Speaker, quite croſs the upper Part of the Dome; which being elliptical, is from its Form and Structure, of good Advantage to the eaſy Reflexion of the bounding Voice, in its Paſſage from one Side of the Figure to the other; the Rays of which there concentring as it were, and meeting, make their general Effort diametrically on the oppoſite Side.

AN Ear placed at the *Vertex* or Top of a Dome, or indeed any other vaulted or arched Place, would find any Sound made within reach very much magnified, on account of the many Reflexions made from Side to Side thro' every Part of the Hemiſphere: But it will be alſo confuſed and very indiſtinct, not being placed in or near the focal Point of the Figure: And hence proceeds the Bomb that generally attends Voices uttered, and Noiſes made, in cavernous and vaulted Places.

IN Auditories, ſuch as Churches, Theatres, Courts of Judicature, *&c.* where the Hearing diſtinctly and well may be of Uſe, the Form of the Building ſhould be a little conſidered. We know, that if a lighted Candle be placed in one of the *Foci*, or the Centres, from whence an Ellipſe is deſcribed, as at *A*, *Fig.* 16. *Plate* 9. the Rays of Light, ſuppoſing the Hoop to be made of bright Tin-plate, or other poliſhed Matter, will be generally reflected into the other of them, as to *B*, which will then be the Point moſt enlightened. And there being a great Similarity between the Progreſſion of Light, and that of Sounds, as was before hinted, it will thence follow, that whatever Sounds, proceeding from one of theſe Points, ſhall be caught by the Walls of an Edifice of this Figure, will be reflected thence, with great Advantage, toward and indeed into the other, following the Direction of the Lines *AC*, *CB*; *AD*, *DB*; *AE*, *EB*; *AF*, *FB*; and *vice verſa*. If one of theſe central Points be ap-

pointed

pointed for the Evidence, and the Criminal, the Judge, and Jury, might be very well poſted in the other, as it is the moſt commodious Point for Hearing that can be contrived.

AND in general it may be obſerved, that all the Auditors will by the Reflexion of the Voice from ſome one or more Parts of a Room that has its Area of the above-mentioned Form, hear the Speaker much better in every Part, than in one that happens to be incumbered, or of a leſs advantageous Figure for the Purpoſe. The good Effect of ſuch a Diſpoſition is, by Experience, well known to the Inhabitants of St. *Anne's*, *Weſtminſter*; for the Reader is certainly much better heard, in all the remoter Parts of the Church, from the Communion-table, placed in an Alcove of that Figure, than from the Reading-deſk, tho' it be a great deal nearer. The Theater in *Oxford*, wherein this Matter was very rightly conſidered by its great Architect Sir CHRISTOPHER WREN, is, regarding its Dimenſions, an excellent Room for Hearing.

On the ECHO.

THE Antients, being wholly unacquainted with the Cauſe of the Echo, aſcribed it to ſeveral Cauſes ſufficiently whimſical. The Poets, who were not the worſt of their Philoſophers, imagined it to be a Perſon of that Name metamorphoſed, and that ſhe affected

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to take up her Abode in particular Places; for they found by Experience, that ſhe was not to be met with in all.

WE are very well ſatisfied, that the Echo is produced by the Reverberation or Reflexion of Sound from certain fixed Objects to the Ear, placed in a proper Situation to receive the Impreſſions returned thither by the Recoil of the Air. From this Cauſe the Sound is always weaker in the Return, than in its direct Progreſs forward.

THERE are ſeveral Places fit for the Echo; Experience eaſily points them out to us. For Inſtance: *F* is an old Building, having a blank Wall. *C* is the Stand of the Speaker, about two hundred Paces diſtant. The Ground from *C* to *F* lies on a Declivity. Here placing yourſelf directly fronting the Wall, and pronouncing any Number of Letters currently and clearly, the laſt eight of them will be perhaps diſtinctly repeated, and with the ſelf-ſame Intervals wherewith they were uttered. If you pronounce the ſame at *D*, you hear perhaps only the three or four laſt; and if at *E*, you perceive no Repetition at all. The Reaſon is, becauſe at *E* the Stroke ariſing from the Vibration of the Air is reflected to the Ear the very Moment it is made; whereas at a proper Diſtance, the Sound reverberated from *F*, at fitting Intervals returns firſt one Syllable, and then another, till eight, and often more, according to the Situation and Diſtance of the Place, as was ſaid, are diſtinctly and ſucceſſively heard.

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THE Diſtance of the Object returning the Echo, may be pretty well known by the Number of Syllables which it repeats. No one Syllable or ſingle Note will be returned clearly under the Diſtance of twenty four Paces or an hundred and twenty Feet, and ſo on in a direct Proportion: The Echo then returning eight Syllables, muſt come from an Object diſtant at leaſt an hundred and ninety two of the former, and nine hundred and ſixty of the latter.

DR. PLOT, in his *Natural Hiſtory of Oxfordſhire*, informs us of an Echo in *Woodſtock Park*, which in the Day, when little Wind was ſtirring, returned in his Time ſeventeen diſtinct Syllables, and in the Night, twenty. The probable Reaſon why it repeated more Syllables by Night, than it did by Day, is, becauſe the Air being then colder, was conſequently denſer, whence the Return of the Vibrations became ſlower, which gave Time for the audible Repetition of more Syllables.

THE Cauſe why ſome Echo's return more, and ſome fewer Syllables, lies, without all Doubt, in the different Diſtances of the Objects returning the Voice to the Ear. In a Wood of lofty Trees, the barking of a ſingle Dog may be ſo ſoon and ſo often repeated, that it ſhall reſemble the Opening of a whole Pack; and for a like Reaſon the Fret-work pendent from the Roof of *Gothic* Choirs, at *King's College* Chapel in *Cambridge*, for

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Inſtance, and many other Places, procures a conſiderable Lengthening of the Sounds, from their frequent Repetition by the Means beforeſaid, which is eſteemed an Advantage to the Muſick. Theſe are called Tautological Echo's; ſome of which will return a Clap with the Hands, or a Stamp with the Foot, eight, nine or ten times diſtinctly; the Noiſe dying as it were away, and melting by Degrees, becomes conſtantly weaker and weaker. There are alſo, as the Lord VERULAM obſerves, Echo's upon Echo's, which he calls Back-echo's: Theſe may promote the harmonious Dying away of the Notes in the forementioned Places, but are otherwiſe inconſiderable.

IT may be obſerved, that all Echo's have ſome one Place, whither they may be returned, ſo as to be heard by a Man's ſelf more ſtrongly and diſtinctly than any other; and that is always that lying at Right-angles with the returning Object: For if a Man ſtands obliquely to it, the Voice will be better returned, and more diſtinctly heard by another Perſon at ſome other Place. The Angle of Incidence is always equal to the Angle of Reflexion; the Note or Sound thrown directly on any Object, will therefore be returned nearly in the ſame Line: Whereas that which is thrown thereon obliquely, will be thence reflected in the ſame Manner, and will reach another Place with greater Advantage. For Inſtance: Let the Speaker at *C*, directly front

front the Building at *F*, *Fig.* 17. *Plate* 9. he will plainly hear his own Words, by reflex Sound. Let him remove to *G*, the Echo will be moſt audible at *H*; and if the Voice be uttered at *I*, the Reflexion will beſt be made at *K*.

THIS being all material, that occurs at preſent, on the Subject of the Air, and its Dependencies, let us conclude this Treatiſe with ſome Account of the Tides.

On the TIDES.

THE Tides could no way be accounted for, till Sir ISAAC NEWTON diſcovered the Principle and Properties of univerſal Gravitation; that is, the Force whereby not only every Particle of Matter in each Planet tends to the Centre of that Planet, but alſo that whereby the Planets reciprocally tend to one another, and the whole Chorus of them in general to the Sun, being by far the greateſt Body: As alſo that the Force of the Attraction exerted by thoſe Bodies at different Diſtances, is reciprocally as the Squares of thoſe Diſtances.

IT is one Conſequence of theſe Principles, that the Earth, Sea, and the celeſtial Bodies, acquired at firſt, and ſtill preſerve, their ſpherical Figure: And tho' the Tenacity and Firmneſs of the ſolid Parts may in ſome Places

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ſupport the Inequalities of the Land above the ordinary Level; yet do the Fluids preſſing equally, and eaſily yielding, ſoon reſume their Equilibrium, whenever it is diſturbed, and more exactly maintain the Figure of the Globe.

ANOTHER Conſequence of them is, that tho' heavy Bodies on the Surface do gravitate and tend toward the reſpective Centres of the Sun, Moon and Planets, yet is the Force exerted by the gravitating Body, in its Deſcent towards the Centre, in all Places not alike; but is ſtill leſs and leſs, as the Diſtances from that Centre increaſes: That is, both the Weight of Bodies and the Force of their Fall is leſſened in Parts more removed from the Centre, in the Proportion of the Squares of the Diſtance. For Example: A hundred Weight on the Surface of the Earth being removed one Semidiameter from the Centre more, or raiſed to the Height of four thouſand Miles above the Earth, would weigh but a Quarter of a Hundred, and removed ſtill four thouſand Miles farther, no more than a Quarter of that, or ſeven Pounds; and conſequently, the Body that ſhould weigh three thouſand ſix hundred Pounds in the Centre of the Earth, at the Diſtance of the Moon would weigh no more than a Pound, by the ſame Rule. And in the ſame Proportion does the Velocities of the Fall of Bodies decreaſe. For as on the Surface of the Earth, all things not impeded by the Medium, fall about ſixteen Foot in a Second; at one Semidiameter above it, would fall but four Foot in the

the ſame Time; at four Semidiameters from the Centre, no more than one Foot in a Second; and at the Diſtance of the Moon, 'twill fall no farther in a Minute than it does near the Earth's Surface in one Second of Time.

FROM theſe Principles, not only the Theory of the ſeveral Appearances in the Syſtem of the Moon and Planets is diſcovered, and accounted for, but alſo the general Cauſe of the Tides may thence be deduced, and ſufficiently explained.

THE Moon revolves, as it were, round the Earth, to which it is a Satellite or an Attendant Planet, in twenty ſeven Days, ſeven Hours, and forty three Minutes, at the Diſtance of two hundred and forty thouſand Miles from its Centre, having but about a fortieth Part of the Matter contained in the Earth. The Earth, at the Diſtance of about eighty one Millions of Miles, revolves round the Sun in a ſyderial Year, *viz.* in three hundred ſixty five Days, ſix Hours, and about three Minutes and a quarter. His Quantity of Matter is one hundred ſixty nine thouſand two hundred and eighty two times that of the Earth, according to Sir ISAAC NEWTON's laſt Calculation.

THE Earth then attracts the Moon in a ſuperior Degree, and confines it from flying off in a Tangent Line to its Orbit, which would happen, were it not for this Attraction. The Moon, in its turn, re-attracts the Earth to a certain Degree; the ſolid Parts whereof being rigid, ſeem not to be affected by it: But the Fluids yielding thereto, riſe, ſwell, and thereby ſeem to confeſs its Power. The Sun, in like manner, attracts the Earth, ſo as to preſerve and keep it in its annual Orbit; in ſome ſort alſo it affects her Fluids; but, by reaſon of his very great Diſtance, ſeemingly in a much leſs Degree than does the Attraction of the Moon.

IT being demonſtrable then, that the Earth is within the Sphere of the Attractions of both Sun and Moon; it follows, that the Equality of the Preſſure of the Gravity of Matter, or its general Tendency toward the Centre of the Earth, will be thereby occaſionally diſturbed. Was the Earth intirely free from the Actions of the Sun and Moon, the Ocean, being equally attracted on all Sides by the Force of Gravity, would continue in a perfect Stagnation, and neither ebb or flow: But as the Caſe is otherwiſe, it muſt needs riſe higher in thoſe Places, where the Actions of the Sun or Moon ſhall occaſionally diminiſh its Gravity.

THE Action of theſe upon the whole Maſs of the ſolid and coherent Earth, is the ſame as if all its Matter were accumulated and contracted, and the whole Weight of it were brought and depoſited in its Centre. For the Parts about *Z* are juſt ſo much more attracted by the Moon at *L*, *Fig*. 18. *Plate* 9. by how much the Parts about *N* are attracted leſs than is the Centre *T*, and *vice verſa*. And ſince one compenſates for the other, it follows, that the whole Body of the Earth at *ZOHN* is equally attracted by the Moon at *L*, as if all its Parts were reduced into and fixed in the Centre *T*. We may therefore ſpeak of the ſolid Parts of the Earth, excluſive of the Water ſurrounding it, as of that Point.

THIS premiſed, let us next conſider the Globe of the Earth as covered with a deep Sea: It will then follow, that by the yielding hereof, the Earth will put on the Figure of a Spheriod, whoſe longeſt Diameter, if produced, would paſs thro' the Moon: That is, wherever the Moon is vertical, ſhe will not only raiſe Tides immediately under her, in the Zenith at *Z*; but alſo, at the ſame time, in the Nadir, or the oppoſite Point of the Earth at *N*. She raiſes the Water in the former, becauſe the Fluid there is near four thouſand Miles nearer to her attractive Power, than is the Centre of the Earth at *T*, it therefore gravitates leſs, and becomes lighter, than that in the Parts about *H* and *O*, lying in the ſame Line with *T*, and, in order to preſerve the general Equilibrium, preſſes of courſe toward *Z*, and cauſes an Accumulation, or a Swell of the Fluid there.

THIS then is the Cauſe of the Tides in the Zenith. But to account for thoſe in the Nadir, we muſt obſerve, That as the Water in *Z* is attracted more by the Moon at *L*, than is the Earth at *T*; so is the Earth at *T* thereby more attracted than will the Water at *N*, lying near four thousand Miles still farther distant from such her attractive Power. The Water therefore at *N* tending less toward the Moon at *L*, than the Earth at *T*, will be less attracted by the Difference of Gravitation toward the Moon severally in *T* and *N*; which, as has been said, is according to the Squares of their respective Distances reciprocally.

THIS rightly understood, it will plainly follow, That the Ocean must on these Occasions necessarily put on a spheroidic Figure, whose longest Diameter will be where the Moon is vertical, and shortest where she appears in the Horizon: And that the Moon, apparently shifting her Position, as she seems to turn round the Earth once a Day, from East to West, (produced however by the Rotation of the Earth, from West to East, upon her own Axis) thereby occasions the Floods and Ebbs, observable every twenty four Hours four fifths, which happens to make the mean Length of a lunar Day.

IT may not be amiss to endeavour to explain this Difference of the Moon's Attraction between the Parts in the Zenith, Centre, and Nadir of the Earth, by a familiar Example. Let us suppose, a four-oar'd Boat a-head, a Wherry with a pair of Oars in the middle, and a third Vessel with a pair of Sculls behind, all of the same Bulk and Weight, and floating at

equal

equal Diſtances from each other, down the Stream, without Rowing: Being all impelled with the ſame Force, or carried by the ſame Stream, they will all move equally, and keep, in general, the ſame Diſtances they had when firſt they ſet forward. In this Circumſtance they will repreſent the three forementioned Parts of the Earth moving regularly in the Expanſe, and barely proceeding in its Orbit round the Sun. Let then the Rowers, according to their ſeveral Power and Force, begin at once to work, the four-oar'd Boat will ſoon gain Ground upon the other two, and the two-oar'd Boat will leave the Sculls behind, in Proportion to the ſeveral Forces wherewith they ſhall be wrought. The advancing of the foremoſt Boat will eaſily denote the ready Riſing of the Water toward the Moon, when in the Meridian; the coming forward of the central Parts of the Earth will be ſignified by the getting on of the middle Boat; and the Swelling of the Water in the oppoſite Point, will be repreſented by the lying behind of the Sculler.

OR again; Suppoſe a String faſtned to a concave Sphere, ſay of Wire, which has a Bullet in it looſe; as ſoon as the Sphere ſhall be whirl'd about, at the End of the String, the Bullet will recede from it as far as may be; and it will be found always diametrically oppoſite to the String, and endeavouring to fly off, will, by its centrifugal Force, draw the Sphere, not being perfectly rigid, into the Form of a Spheroid.

OR once more; Suppose the String fastned to the Bullet within the Sphere, now left at Liberty, and being together whirl'd about as before, the Bullet will remain in the Place where it is confined by the String; but the Sphere, not being perfectly rigid, will, from its own Weight, be drawn out, as before, into a Spheroid.

TO apply this; Imagine the great Ocean, which we before supposed to cover the Earth, to be analogous to the Sphere; the Earth to the Bullet, and the Gravity between the Moon, Earth and Water, to the String, whereby they are retained in their Orbit, and the Gravity or Attraction between the Earth and Water, to the Rigidity of the Sphere: Suppose then the Water to gravitate towards the Moon, and the Earth not; of consequence the whole Mass of Waters will get into the Zenith, and the Earth will seem rather to endeavour to recede from the Water, as the Bullet inclines to do. But the natural Attraction between the Water and Earth answering, as was said, to the Rigidity of the Sphere, will not suffer it wholly to fly off, whence the Earth will remain in the Point the most distant from the Moon, that is, in the Nadir: And this is fitly represented by the String's being fastned to the Sphere.

AGAIN; Suppose the Earth to gravitate toward the Moon, and the Waters not, the Earth will

will then be in the Zenith, and the Waters will take their place in the Nadir; which again would quit the Earth, but for the Attraction between the Earth and Waters: And this is correspondent to the whirled Bullet's being faſtned to the String, leaving the Sphere at Liberty.

LASTLY; Suppoſe both the Earth and Water to gravitate towards the Moon, as they really do, 'twill follow, that the Parts of the Water nearer the Moon than the Earth, will be more attracted thereby, and riſe into the Zenith: Whereas thoſe Parts of Water which are farther from the Moon than the Earth, will be leſs attracted on the whole, and ſo flow into the Nadir. By which means Tides will be raiſed both in the Zenith and the Nadir, at the ſame Time: And this may ſuffice to give an Idea of the general Cauſe of the Tides. Let us now conſider their Phænomena in particular Places.

1. THE Tides flow according to the lunar and not the ſolar Day, tho' the Action of the Sun on the whole Body of the Earth, be to that of the Moon as three hundred to one hundred ſixty nine; the Quantity of his Matter before-mention'd, more than compenſating for the Greatneſs of his Diſtance. In conſidering this Matter, however, we are to diſtinguiſh between the abſolute and relative Attraction of theſe two Luminaries. Abſolute Attraction is that which acts upon all Parts of the Body with a Force nearly equal; but relative Attraction is that

which is exerted upon ſome Parts of a Body more intenſely than others. Hence 'twill appear, that the Tides muſt be the Conſequence of a relative or partial Attraction; and the relative Attraction of the Moon being greater than that of the Sun in particular Places, thence it is that the Tides will generally follow the Moon, and not the Sun, as by Experience we ſee they do. Now the relative Attraction of the Moon exceeds that of the Sun, becauſe a Semidiameter of the Earth bears a very ſenſible Proportion to the Diſtance of the Moon, it being about one ſixtieth Part thereof; but a much leſs to that of the Sun, of which it is ſcarce the twenty thouſand two hundred and fiftieth Part.

2. THE Tides happening about fifty Minutes later each Day, is the Conſequence of their following the lunar Day. Thus, if 'tis High-water to Day at twelve o'Clock, it will be High-water to-morrow at twelve Hours fifty Minutes, that is, twenty four Hours fifty Minutes after Twelve to-day. The lunar Day is ſo much longer than the ſolar; becauſe while the Earth turns from Weſt to Eaſt, toward and from the Sun, in twenty-four Hours (at the ſame time getting forward, at a certain Rate, in her own Orbit) the Moon alſo proceeds from Weſt to Eaſt, one twenty-ſeventh Part of her Orbit, in ſome meaſure keeping Pace, tho' not an equal Pace, with the Earth.

3. THE Tides being greateſt, *cæteris paribus*,

bus, when theſe Luminaries are in *Perigæo*, or at the leaſt Diſtances from the Earth, is conſonant to the Laws of Gravitation, which, as has been ſaid, are more or leſs powerfully exerted, *viz.* in Proportion to the Squares of the Diſtances of the Bodies under Conſideration reciprocally.

4. THE Tides are, *cæteris paribus*, greateſt when the Sun and Moon are either in Conjunction at the New Moon, or in Oppoſition at the Full. In the firſt Caſe, the Moon is one Semidiameter of her Orbit nearer the Sun than is the Earth; in the ſecond, ſhe is a Semidiameter of her Orbit more diſtant than the Earth from the Sun. In either of theſe Caſes, the Actions of both Luminaries will concur to raiſe the Tides. In Conjunction they both conſpire to elevate the Waters in the Zenith, and by conſequence, at the ſame time, in the Nadir: In Oppoſition, while one makes High-water in the Zenith and Nadir, the other endeavours to do the ſame in the Nadir and Zenith, as already explained: And this is the natural Cauſe of the *Spring-tides* produced at thoſe Times. In the Quadrature or Quarters, the Actions of the Sun and Moon interfere, and in part obſtruct each other; *viz.* the Water raiſed by the Sun is depreſſed by the Moon, and the contrary: Hence it is, that the Tides are leſs at thoſe Times, and are diſtinguiſhed by the Denomination of *Neap-tides*.

5. IN Places not under the Equator, the Tides

Tides are not equal, but are alternately greater and leſs. The Reaſon of which will be better underſtood by regarding *Fig.* 19. *Plate* 9. Let *APEP* be the Body of the Earth covered with deep Water, *C* the Centre, *P P* the Poles, *E A* the Equator, *Ff*, *D d*, Parallels of Latitude, *H h* the Axis of the watery Spheroid, *L* the Moon's Place, *K k* the Circle wherein the Moon appears horizontal; the Lines *B F*, *B D*, *B f*, *B d*, ſhall denote the Height of the Sea at the Places *F f*, *D d*, in each of which it is High-water, but higheſt at *F*, becauſe the Moon is neareſt its Zenith; and ſo at *D*, becauſe that is the *Antipodes* of *F*, or the Point diametrically oppoſite, conſidering the daily Rotation of the Earth is upon the Axis *P P*; by which Means too the Point *F* will in twelve Hours Time be transferred to *f*, and the Point *D* to *d*; now whereas the Lines *B f*, *B d*, are evidently ſhorter than the Lines *B F*, *B D* (that is, the Water is lower in thoſe Places) it follows, that the Points *F* and *d*, muſt, in the Space of twelve Hours, paſs thro' low and high Water alternately, whilſt the equatorial Parts *A* and *E* paſs thro' Tides equally elevated, ſince *C A* and *C E* always continue equal.

6. THE Tides, *cæteris paribus*, are obſerved to be greater when the Luminaries are in or near the Equator, than when at their greateſt Declination from it. This ariſes from the two oppoſite Protuberances, which at that Time are in the Equator, and which of conſequence deſcribe

deſcribe there the greateſt Circle of the Earth; whence by the diurnal Rotation, they will move ſwifter, deſcribing the greateſt Circle of the Earth, in the ſame Time that they uſed to deſcribe the leſſer ones, parallel to it; and conſequently, being thrown upon the Shores with greater Force, they riſe higher there. For it is plain, that if the Moon were fixed in the Pole, that the watery Spheroid would tend thither, producing always high Water there, and low Water every where under the Equinoctial; and therefore the nearer the Moon approaches the Poles, the leſs is the circumvolutary Agitation of the Ocean in particular Latitudes, which of conſequence muſt be the greateſt when ſhe is in the Equinoctial, or the fartheſt removed from the Poles.

7. THE Time of high Water happens not preciſely at the Time of the Moon's Appulſe to the Meridian; but about three Hours afterwards, or when ſhe is toward South-weſt. This is, becauſe the Moon acts with ſome Force, after ſhe is paſt the Meridian, thereby adding to that Libration, which ſhe had put the Waters into, during her coming to, and whilſt ſhe was in the Meridian: Not unlike the Time of the greateſt Heat in Summer happening about two or three Hours after Noon; or juſt as a ſmaller Force apply'd to a riſing Ball, will raiſe it ſtill conſiderably higher.

8. THE Tides are obſerved to ſucceed each other quicker in the Tranſits or Paſſing of the

Lumi-

Luminaries from their Conjunction and Opposition, commonly called their Syzygies to their Quadratures, than from the Quadratures to the Syzygies. In the latter Case, the Tides grow continually larger, and the larger they are, the longer they are in riſing and falling; as the more Length a Pendulum has, the longer it is in making its Vibrations: and of conſequence they ought to ſucceed quicker in the Tranſit from the Syzygies to the Quadratures; becauſe, by a Parity of Reaſon, they then grow leſs and leſs.

9. THE Tides often fall out greater in *February* and *October*, than at other Times. The Reaſon of this, not happening preciſely at the two Equinoxes, as they ought to do, but ſomething before the vernal, and after the autumnal Equinox, is, becauſe the Sun (as the Planets move round him in elliptic Orbits) is neareſt the Earth in the Winter Months (for the Earth's Motion is then certainly ſwifteſt, as appears by the Winter's being always eight Days ſhorter than the Summer) conſequently the Sun comes then to have a greater Influence in producing the Tides, than uſual, and cauſes the Alterations ſpoken of. But it does not happen every Year ſo; becauſe ſome Variations may ariſe from the Declination or Situation of the Moon's Orbit at that Time, and the Diſtance of the Syzygies from the Equinox.

10. THE Morning and Evening Tides are remarked to be often different in Height. This

is owing to the Moon's being nearer or more diſtant from the Zenith or the Nadir. While the Sun is in the northern Signs, the greater of the two diurnal Tides, in our Climates, is that ariſing from the Moon's being above the Horizon; when the Sun is in the ſouthern Signs, the greater is that ariſing from the Moon's being below the Horizon; that is, according as their Influences act together, or oppoſe each other.

AND ſuch probably would the Tides regularly be, if the whole Earth were covered with Water, very deep: But by reaſon of the Shoalneſs of ſome Places, and the Narrowneſs of the Streights in others, thro' which the Tides are to paſs, there ariſes great Diverſity in the Effects, which are not to be accounted for without a perfect Knowledge of all the Circumſtances of the Situation of the Land, the Breadth and Depth of the Channels, *&c.* For a ſlow and almoſt imperceptible Motion of the whole Body of Water, where, for Example, it is two Miles deep, might ſuffice to raiſe its Surface ten or twelve Feet in a Tide's time very well; whereas, was the ſame Quantity of Water to be conveyed thro' a Channel but forty Fathom deep, it would run like a Sluice to effect it, as it does in the narrow Parts of the *Britiſh* Channel on ſome Occaſions. This alſo may be one Reaſon why high Water in many Places happens not nearer the Time of the Moon's being in the Meridian.

IT

IT may here be remarked, that the Motions hitherto mentioned muſt be ſomewhat altered by the Libration of the Water, which, in forming the Tides, acts ſomething like the Vibrations of a Pendulum, whereby the Flux and Reflux of the Sea would for ſome time continue, tho' the Luminaries ſhould be at once annihilated, and their Actions intirely ceaſe: This Conſervation of the impreſſed Motion diminiſhes the Differences that would otherwiſe be between two conſequent Tides; and is the Reaſon why the higheſt Spring-tides are not preciſely on the new and full Moons, or the Neap-tides on the Quarters, but generally about the third Tide after them, and ſometimes later.

To anſwer all the Phænomena of the Flux and Reflux of the Water in particular Places, would be endleſs; but all things duly conſidered, they are fully ſoluble by the Doctrines and Theory before laid down. As the moſt notable Inſtance of this kind, let us take notice of the Tide that comes into the Port of *Tunquin* in *China*. Here it ebbs and flows but once in twenty four Hours; and twice in every Month, that is, When the Moon is near the Equinoctial, there is no Tide at all, but the Water is entirely ſtagnant: With the Moon's Declination, however, there begins a Tide, which is always greateſt when ſhe is in the tropical Signs; with this Difference only, that when ſhe is northward of the Equator, it flows when ſhe is above the Horizon, and ebbs when we is below it, ſo as to make high Water at Moon-

Moon-ſetting, and low Water at Moon-riſing: Whereas, on the contrary, the Moon's being to the ſouthward of the Line, makes it high Water at her Riſing, and low Water at her Setting; and it ebbs all the time ſhe is above the Horizon.

THE Cauſe of this odd Appearance is propoſed by Sir ISAAC NEWTON, in his *Principia*, as ariſing from the Concurrence of two Tides; the one propagated in ſix Hours, out of the great *South-Sea*, along the Coaſt of *China*; the other out of the *Indian Sea*, from between the Iſlands, in twelve Hours, along the Coaſt of *Malacca* and *Camboya*. One of theſe Tides being produced in North Latitude is, as has been ſaid, greater when the Moon, being to the North of the Equator, is above the Earth, and leſs when ſhe is beneath it. The other of them, promoted from the *Indian* Ocean, being raiſed in South Latitude, is greater when the Moon, declining to the South, is above the Earth, and leſs when ſhe is under it. So that of theſe Tides, alternately greater and leſs, there comes always ſucceſſively two of the greater, and two of the leſs every Day; and the high Water falls always between the Arrival of the two greater Floods, and the low Water between the Arrival of the two leſſer. The Moon coming to the Equinoctial, makes the alternate Floods equal, the Tides then ceaſe, and the Water ſeems to ſtagnate: But ſhe being paſſed the Equator, thoſe Floods, which in the former Order were the leaſt, now become the greateſt; the Times of high and low

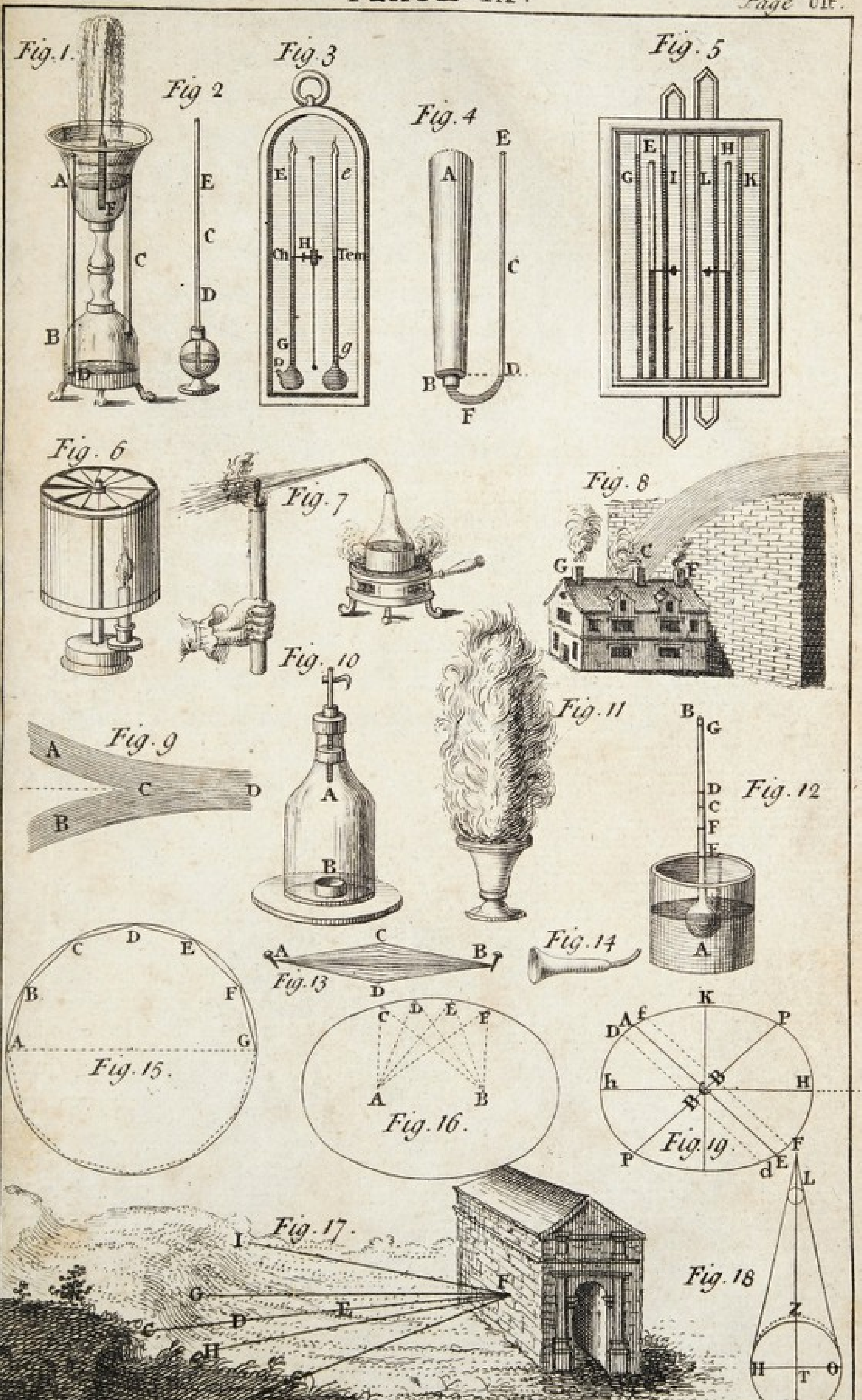
low Water are then inverted, and the whole Appearance of theſe ſtrange Tides is naturally and with Eaſe to be ſolved from the Theory thus laid down.

THE Seas nearly environed with Land, ſuch as the *Mediterranean*, *Red-Sea* and *Baltick*, have no apparent Tides; becauſe the Streights whereby they communicate with the Ocean, are Inlets ſo ſmall, and the Seas themſelves ſuch large Bodies of Water, that Water ſufficient cannot, in the Compaſs of a few Hours, be received into, or ſent out of them, to cauſe their Waters to riſe or ſink conſiderably on ſo large a Surface.

THE *Caſpian* Sea is no more than a very large Lake, having no Communication with the Ocean at all. This, as well as all other Lakes, is too ſmall to be ſenſibly affected by the Attraction of the Moon, even where ſhe is vertical: For ſhe needs muſt attract all Parts of theſe Waters alike, rendering them in every Place equally light; ſo that no Part of them can be raiſed perceptibly higher than another. Or, in other Words, they are generally ſo ſmall, as not to be capable of any relative Attraction from the Moon.

IT may here be remarked, that the Swell of the ſuperior Air, or thoſe aerial Tides before hinted at, probably occaſioned by the Moon's Attraction when ſhe happens to be vertical, or even near the Meridian of any Place, as well

PLATE IX.



J. Cole sculp.

as are conſtantly thoſe of the Waters, where no evident Cauſe of Obſtruction appears, is not however obſerved to produce any perceivable Variations on the Height of the barometric Mercury: Whereas it might be expected, that from the Acceſſion of new Matter on thoſe Occaſions, the Gravity of the Air might by that curious Machine appear to be increaſed; which, was not the Air's Gravity, thus augmented adequately ſtill, and in a juſt Proportion diminiſhed by the Power of the Attraction beforeſaid, muſt unavoidably happen.

AND for the ſame Reaſon neither is there ever any Variation on the Weather-glaſs obſerv'd, when the Moon is in or near the Horizon of thoſe Places: Since the Gravity in one Caſe will reaſonably be admitted conſtantly to counterbalance the Attraction ſpoken of in the other.

THE
GLOSSARY;
OR, A
Short EXPLANATION of ſuch uncommon Words as could not without Affectation be omitted in this Treatiſe.

A

Abdomen, the lower Belly.
Abſorb, to drink in; to ſwallow.
Acid, ſour; Matter fermenting with an *Alkali*.
Accelerated, haſtened, or hurried forward.
Acouſtic, ſee *Auditory*.
Adequate, equal thereto.
Adheſion, the ſticking of Parts together.
Æther, an imaginary Fluid, fine and ſubtle.
Aliments, Food to nouriſh.
Alkali, fixed Salt of Subſtances fermenting with Acids.
Alternate, firſt this, then that; by turns.
Ambient, ſurrounding.
Analogy, Proportion, Compariſon.
Analogous, bearing, &c.
Aorta, the great Artery leading from the Heart.
Apex, the Point or Summit of a Cone or Pyramid.
Apparatus, Inſtruments for Operation or Experiment.
Appendix, Supplement; ſomething added.
Appulſe, the Arrival of a Planet at a certain Point.
Articulate, to joint.
Aſſimilate, to make like.
Atmoſphere, the Fluid Maſs of Air, &c. ſurrounding the Earth, to about ſixty Miles high.
Attenuate, to thin, or make a thing weaker.
Attraction, a drawing towards; producing a Tendency.
Aura, a finer kind of Air.

Audi-

Auditory, belonging to Hearing.
Auricular, belonging to, or received by the Ear.
Axis, an Axle on which any thing turns.

B

Bronchia, the Branchings of the Wind-pipe continued throughout the Lungs.

C

Capillary, ſmall as an Hair.
Cæteris paribus, in other Circumſtances the ſame.
Centrifugal, a Direction given a Body different from that inclining to the Centre.
Centripetal, tending toward the Centre.
Chaſm, a Gap, or Opening.
Chimera, a groundleſs Fancy.
Circulate, to come round.
Coaleſce, to grow together, or unite.
Coheſion, a clinging, or ſticking together.
Collateral, lying ſide by ſide.
Colliſion, a Striking, or Daſhing againſt.
Compages, a Collection.
Compreſs, to ſqueeze cloſe together.
Concave, ſpherically hollow.
Condenſe, to bring the Parts of Matter cloſer together.
Cone, a round Pyramid, or Spire.
Connect, to knit together, or join.
Conſiſtent, fixed, *i. e.* not fluid.
Conſonant, correſpondent to.
Contact, a touching each other.
Contiguous, Parts which touch.
Contort, twiſt; wind about.
Contorted, twiſted round.
Convex, protuberant; ſwelling ſpherically outwards.
Convulſion, an involuntary Motion of the Muſcles; a Twitching.
Corroborate, to ſtrengthen or confirm.
Corrugation, a Contraction by wrinkling up.
Cylinder, a ſolid Body, in Form of a Rolling-ſtone.
Cylindric, reſembling this in Figure

D

Denſity, Compactneſs; Cloſeneſs of Parts.
Deterſive, fit to cleanſe or ſcower.
Diaphanous, tranſparent.
Diaphragm, the Midriff, dividing the Trunk of the Body into two Cavities, the *Thorax* and the *Abdomen*.
Diaſtole, the Dilatation of the Heart.
Digeſtion, the Converſion of the Aliments into Fluids.

E

Ebullition, a Bubling, like boiling Water.
Efflux, the flowing forth of a Fluid.
Elaſtic, having a Spring.
Efferveſcence, a waxing hot.
Elaſticity, endowed with the Property of a Spring.
Ellipſis, an oval Line or Surface.
Elliptical, oval, or like an Egg.
Excretory Ducts, very ſmall Canals for ſeparating the animal Juices.
Expanſe, Space extended.
Expiration, breathing forth.
Extravaſated, being out of the proper Veſſels.

F

Fibre, a ſmall String.
Fibril, one ſmaller ſtill.
Filament, a ſmall Thread.
Flaccid, lax, looſe or flabby.
Fluid, eaſily flowing or ſeparable.
Flux, the Act of flowing
Foſſils, things ſolid, dug out of the Earth.
Fulcrum, a Prop or Point of Support.
Fuliginous, ſooty, or reſembling Soot.
Frigorific, chill, or cauſing Cold.

G

Gland, a Bundle of connected Fibres to ſtrain the Fluids, and ſeparate finer Parts from them.
Gravity, Weight; the Tendency one Body has to another.
Groove, a ſmall Channel cut.
Gyration, a whirling round..

H

Hemiſphere, half a Globe.
Hermetically ſeal'd, Tube cloſed with melted Glaſs.
Hexangular, ſix angled or ſided.
Horizon, the Limit of the Sight at Sea or on a Plane.
Hypothetical, ſuppoſitious.
Hydroſtaticks, Doctrine and Laws of the groſſer Fluids, as Water, *&c.*
Hydraulick, for the Purpoſe of raiſing Water.

Igni-

I

Ignition, a taking Fire.
Immerse, to dip, or plunge into.
Impinge, to ſtrike upon, or againſt.
Incompreſſible, not to be reduced into leſs Compaſs.
Incidence, a falling, or lighting on.
Incumbent, lying upon.
Indefinite, undetermined, unlimited.
Ingenite, inborn, or produced with.
Inſertion, a grafting in, or joining.
Inſpiration, the drawing in the Breath.
Inſpiſſate, to thicken or render viſcid.
Interſtice, Interval, or intermediate Space.
Inverſe, when the Antecedents are turned into Conſequents.

L

Lacteals, ſmall Ducts in Animals, conveying a milky kind of Liquor.
Lambent, licking; unſteady.
Lateral, ſidewiſe.
Libration, a balancing Motion.
Lobe, the Diviſion of the Lungs and Liver.
Longitudinal, length-wiſe.

M

Meatus auditorius, the Paſſage into the Ear.
Membrana Tympani, the Membrane covering the Drum of the Ear.
Microſcope, Glaſſes for examining minute Bodies.
Miniature, contracted; drawn in little.
Monſoon, a Change, or Variation in the Direction of the Trade-winds ſettled between the Tropicks.
Morbid, ſickly; diſeaſed.
Mucus, ſlimy Matter.

N

Nadir, the Point juſt beneath us, on the oppoſite Part of the Globe.
Nerve, a Bundle of Fibres, ariſing from the Brain, whither it conveys Perception from every Part of the Body, and voluntary Motion back to particular Parts.
Nutrition, the Nouriſhment of an Animal.

O

Origin, Source, Riſe or Beginning.

P

Percolated, ſtrain'd thro' an incompact Body.
Percuſſion, ſtriking, or the Effects of a Stroke.
Perennial, conſtant; the Year about.
Perforate to bore through, or pierce.
Pericardium, the Heart-bag.
Phænomenon, an Appearance in Nature.
Piſton, a moveable Plug juſt fitting a Pipe.
Pleura, the Membrane lining the Cheſt.
Pneumaticks, the Doctrine and Laws of the ſubtile Fluid the Air.
Polygon, a Figure containing more Angles than four.
Pores, ſmall Paſſages in the Scarf-skin for the Sweat, *&c.*
Preponderate, to deſcend, being heavier.
Projectile, a Body in a Motion, caſt or thrown.
Protrude, thruſt away.
Protuberance, a ſwelling out.

Q

Quadratures, the quartering Points of an Orbit.

R

Rarefy, to thin, to lower, or weaken denſe Matter.
Reflexion, a bending back, or returning a Body.
Reflux, the Return, or flowing back of a Fluid.
Reciprocal, mutual, or relative.
Refract, to bend or break.
Relaxed, leſs extended, looſened.
Reſervoir, a Ciſtern or Head for a Reſerve of Water.
Reverberate, to beat back, or reflect.
Rotation, a turning about; like a Wheel on an Axle.

S

Salubrity, Wholeſomeneſs.
Sanguification, the making Blood by Digeſtion, *&c.*
Secern, *Secrete*, to ſeparate.
Senſorium, the Seat of Perception in the Brain.
Seroſity, *Serum*, the wheyiſh Part of the Blood.
Species, Sort or Kind.
Specifick, peculiar, or appropriate.
Spicula, little Spikes.
Spiral, like a Rope coil'd round.
Spiſſitude, Thickneſs, Viſcidity.

Sternum, the Breaſt-bone.
Stimulate, to provoke or incite.
Subterraneous, within the Earth.
Suction, the Faculty of Sucking.
Syphon, a bent Tube or Crane.
Syſtem, Compoſition, general Structure.
Syſtole, the Contraction of the Heart.
Syzygies, the Oppoſition and Conjunction of a Planet with reſpect to the Sun and Earth.

T

Tangent, a ſtreight Line, drawn from the Circumference of a Circle, touching it but in one Point.
Teguments, Coverings, as in the Body, Skin and Fat.
Tenacity, the clinging of the Parts of Fluids together.
Tendon, the Extremity of a Muſcle.
Thorax, the Cheſt or Breaſt.
Tranſit, a paſſing of a Planet croſs another in Courſe.
Tranſverſe, croſs-wiſe.
Tropicks, imaginary parallel Lines to the Equator, at the Diſtance of 23° 29′ from it, being the Limits of the Declination of the Sun towards the North or South.
Tube, a Pipe.
Turbid, troubled, muddy, foul.
Turgid, ſwell'd.
Tympanum, the Drum of the Ear.

U

Vague, uncertain, wandering.
Valves, membranous Subſtances, acting like Trap-doors to prevent the Return of the Fluids.
Vapid, dead, taſteleſs.
Vena cava, the large Vein conveying the Blood back to the Heart
Ventricle, a ſmall Cavity.
Vertebræ, the Chain of Bones, twenty four in Number, reaching down the Back from the Head.
Vertex, the Top of any thing.
Vibrate, to ſwing as a Pendulum; to come and go as a Spring.
Viſcid, *Viſcous*, clammy, coheſive, as Bird-lime.
Undulating, a wavy Motion.
Volatile, ſubject to evaporate or fly away.

Z

Zenith, the Point above us in the Heavens; or with reſpect to the Centre of a Sphere, any Point on the Surface.
Zone, a Portion of a Sphere ſurrounding it like a Girdle.

AN
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Pointing out in what Page of this Treatise the following Particulars may be found.

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