

PHILOSOPHICAL TRANSACTIONS.

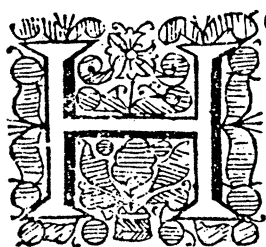
Munday, August 6. 1666.

The Contents.

An Essay of Dr. John Wallis, exhibiting his Hypothesis about the Flux and Reflux of the Sea, taken from the Consideration of the Common Center of Gravity of the Earth and Moon; together with an Appendix of the same, containing an Answer to some Objections, made by severall Persons against that Hypothesis. Some Animadversions of the same Author upon Master Hobs's late Book, De Principiis & Ratiocinatione Geometricarum.

An Essay

Of Dr. John Wallis, exhibiting his Hypothesis about the Flux and Reflux of the Sea.



Now abstruse a subject in Philosophy, the *Flux and Reflux of the Sea* hath proved hitherto, and how much the same hath in all Ages perplexed the Minds even of the best of *Naturalists*, when they have attempted to render an Account of the Cause thereof, is needless here to represent. It may perhaps be to more purpose, to take notice, that all the deficiencies, found in the *Theories* or *Hypotheses*, formerly invented for that End, have not been able to deterre the Ingenious of *this* Age from making farther search into that Matter: Among whom that Eminent Mathematician Dr. *John Wallis*, following his happy *Genius* for advancing reall Philosophy, hath made it a part of his later Inquiries and Studies, to contrive and deduce a certain Hypothesis concerning that *Phenomenon*, taken

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from the Consideration of the *Common Center of Gravity of the Earth and Moon*, This being by several Learned Men lookt upon, as a very rational Notion, it was thought fit to offer it by the Press to the Publick, that other Intelligent Persons also might the more conveniently and at their leisure examine the *Conjecture* (the Author, such is his Modesty, presenting it no otherwise) and thereupon give in their sense, and what Difficulties may occur to them about it, that so it may be either confirm'd or laid aside accordingly; As the *Proposer* himself expressly desires in the Discourse, we now, without any more *Preamble*, are going to subjoyn, as it was by him addressed, by way of Letter, from *Oxford* to Mr. *Boyle* April 25. 1666. and afterwards communicated to the *R. Society*, as follows:

YOU were earnest with me, when you last went from hence, that I would put in writing somewhat of that, which at divers times, these three or four years last past, I have been discoursing with your self and others concerning the *Common Center of Gravity of the Earth and Moon*, in order to salving the *Phænomena* as well of the *Seas Ebbing and Flowing*; as of some perplexities in *Astronomical Observations* of the *Places* of the *Celestial Bodies*.

How much the *World*, and the great *Bodies* therein, are manag'd according to the *Laws of Motion*, and *Statick Principles*, and with how much more of clearness and satisfaction, many of the more abstruse *Phænomena* have been salved on such Principles, within this last Century of years, than formerly they had been; I need not discourse to you, who are well versed in it. For, since that *Galilæo*, and (after him) *Torricellio*, and others, have applied *Mechanick Principles* to the salving of *Philosophical Difficulties*; *Natural Philosophy* is well known to have been rendered more intelligible, and to have made a much greater progress in less than an hundred years, than before for many ages.

The *Seas Ebbing and Flowing*, hath so great a connexion with the *Moons* motion, that in a manner all Philosophers (whatever other Causes they have joyned with it) have attributed much of its cause to the *Moon*; which either by some *occult quality*,

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or *particular influence*, which it hath on moyst Bodies, or by some *Magnetick vertue*, drawing the water towards it, (which should therefore make the Water there *highest*, where the Moon is *vertical*) or by its gravity and pressure downwards upon the Ter-
 raqueous Globe (which should make it *lowest*, where the Moon is *vertical*) or by whatever other means (according to the several Conjectures of inquisitive persons,) hath so great an influence on, or at least a connexion with, the Sea's Flux and Reflux, that it would seem very unreasonable, to seclude the consideration of the Moons motion from that of the Sea: The *Periods of Tides* (to say nothing of the greatness of them near the New-moon and Full-moon) so constantly waiting on the Moon's motion, that it may be well presumed, that either the one is governed by the other, or at least both from some common cause.

But the first that I know of, who took in the consideration of the *Earth's* motion, (*Diurnal* and *Annual*) was *Galilæo*; who in his *Systeme of the World*, hath a particular discourse on this subject: Which, from the first time that I ever read it, seemed to me so very rational, that I could never be of other opinion, but that the true Account of this great *Phænomenon* was to be referred to the Earths motion, as the *Principal* cause of it: Yet that of the Moon (for the reasons above mentioned) not to be excluded, as to the determining the *Periods of Tides*, and other circumstances concerning them. And though it be manifest enough, that *Galilæo*, as to some particulars, was mistaken in the account which there he gives of it; yet that may be very well allowed, without any blemish to so deserving a person, or prejudice to the *main Hypothesis*: For that Discourse is to be looked upon onely as an *Essay* of the *general Hypothesis*; which as to *particulars* was to be afterwards adjusted, from a good *General History of Tides*; which it's manifest enough that he had not; and which is in a great measure yet wanting. For were the matter of Fact well agreed on, it is not likely, that several Hypotheses should so far differ, as that one should make the Water *then* and *there* at the Highest, *where* and *when* the other makes it at the Lowest: as when the Moon is Vertical to the place.

And what I say of *Galileo*, I must in like manner desire to be understood of what I am now ready to say to you. For I do not profess to be so well skilled in the History of Tides, as that I will undertake presently to accommodate my *general Hypothesis* to the *particular cases*; or that I will indeed undertake for the certainty of it, but onely as an *Essay* propose it to further consideration; to stand or fall, as it shall be found to answer matter of Fact. And truly had not your importunity (which is to me a great Command) required me to do it; I should not so easily have drawn up any thing about it, till I had first satisfied my selfe, how well the Hypothesis would answer Observation: Having for divers years neglected to do it, waiting a time when I might be at leisure throughly to prosecute this design.

But there be two reasons, by which you have prevailed with me, at least to do something. *First*, because it is the common Fate of the *English*, that out of a modesty, they forbear to publish their Discoveries, till prosecuted to some good degree of certainty and perfection; yet are not so wary, but that they discourse of them freely enough to one another, and even to Strangers upon occasion; whereby others, who are more hasty and venturous, comming to hear of the notion, presently publish something of it, and would be reputed thereupon, to be the first Inventers thereof: though even that little, which they can then say of it, be perhaps much less, and more imperfect, than what the true Authors could have published long before, and what they had really made known (publicly enough, though not in print) to many others. As is well known amongst us as to the business of the *Lymphatick Vessels* in *Anatomy*: the *Injection of Liquors into the veines of Living animals*; the *Exhibiting of a straight line equal to a crooked*; the *Spot in Jupiter*, whence his motion about his own Axis may be demonstrated; and many other the like considerable Inventions.

The *other Reason* (which, with me, is more really of weight, though even the former be not contemptible) is, because, as I have been already for at least three or four years last past diverted from prosecuting the inquiry or perfecting the Hypothesis, as I had thoughts to do; so I do not know, but like Emergencies may divert me longer; and whether I shall ever so
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do it, as to bring it to perfection, I cannot determine. And therefore, if as to my self any thing should *humanitus accidere*; yet possibly the notion may prove worth the preserving to be prosecuted by others, if I do it not. And therefore I shall, at least to your self, give some general account of my present imperfect and undigested thoughts.

I consider therefore, that in the Tides, or the Flux and Reflux of the Sea, besides extraordinary Extravagancies, or Irregularities, whence great Inundations or strangely high Tides do follow, (which yet perhaps may prove not to be so merely accidental as they have been thought to be, but might from the regular Laws of Motion, if well considered, be both well accounted for, and even foretold;) There are these *three* notorious Observations made of the Reciprocation of Tides. *First*, the *Diurnal* Reciprocation; whereby twice in somewhat more than 24. hours, we have a Floud and an Ebbe; or a High-water and Low-water. *Secondly*, the *Mensual*; whereby in one *Synodical* period of the Moon, suppose from Full-moon to Full-moon, the Time of those Diurnal Vicissitudes doth move round through the whole compass of the *Νυχθημερον*, or Natural day of twenty four hours: As for instance, if at the Full-moon the full Sea be at such or such a place just at Noon, it shall be the next day (at the same place) somewhat before One of the clock; the day following, between One and Two; and so onward, till at the New-moon it shall be at midnight; (the other Tide, which in the Full-moon was at midnight, now at the New-moon coming to be at noon;) And so forward till at the next Full-moon, the Full-sea shall (at the same place) come to be at Noon again: Again, That of the Spring-tides and Neap-tides (as they are called;) about the Full-moon and New-moon the Tides are at the Highest, at the Quadratures the Tides are at the Lowest: And at the times intermediate, proportionably. *Thirdly*, the *Annual*; whereby it is observed, that at sometimes of the year, the Spring-tides are yet much higher than the Spring-tides at other times of the year: Which Times are usually taken to be at the Spring and Autumn; or the two *Æquinoxes*; but I have reason to believe (as well from my own Observations, for many years, as of others who have been

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much concerned to heed it, whereof more will be said by and by;) that we should rather assign the beginnings of *February* and *November*, than the two *Æquinexes*.

Now in order to the giving account of these three Periods, according to the *Laws of Motion* and *Mechanick Principles*; We shall first take for granted, what is now adays pretty commonly entertained by those, who treat of such matters; *That a Body in motion is apt to continue its motion, and that in the same degree of celerity, unless hindered by some contrary Impediment*; (like as a Body at rest, to continue so, unless by some sufficient mover, put into motion:) And accordingly (which daily experience testifies) if on a Board or Table, some loose incumbent weight, be for some time moved, & have thereby contracted an *Impetus* to motion at such a rate; if that Board or Table chance by some external obstacle, or otherwise, to be stopped or considerably retarded in its motion, the incumbent loose Body will shoot forward upon it: And contrarywise, in case that Board or Table chance to be accelerated or put forward with a considerably greater speed than before, the loose incumbent Body, (not having yet obtained an equal *Impetus* with it) will be left behind, or seem to fly backward upon it. Or, (which is *Galileo's* instance,) if a broad Vessel of Water, for some time evenly carried forward with the water in it, chance to meet with a stop, or to slack its motion, the Water will dash forward and rise higher at the fore part of the Vessel: And, contrarywise, if the Vessel be suddenly put forward faster than before; the Water will dash backwards, and rise at the hinder part of the Vessel. So that an Acceleration or Retardation of the Vessel, which carries it, will cause a rising of the Water in one part, and a falling in another: (which yet, by its own weight, will again be reduced to a Level as it was before.) And consequently, supposing the Sea to be but as a loose Body, carried about with the Earth, but not so united to it, as necessarily to receive the same degree of *Impetus* with it, as its fixed parts do; The acceleration or retardation in the motion of this or that part of the Earth, will cause (more or less, according to the proportion of it) such a dashing of the Water, or rising at one part, with a Falling at another, as is that, which we call the Flux and Reflux of the Sea.

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Now this premised, We are *next*, with him, to suppose the Earth carried about with a double motion; The one *Annual*, as (Fig. 1.) in B E C the great Orb, in which the Center of the Earth B, is supposed to move about the Sun A.

The other *Diurnal*, whereby the whole moves upon its own *Axis*, and each point in its surface describes a Circle, as D E F G.

It is then manifest, that if we suppose, that the Earth moved but by any one of these motions, and that regularly, (with an equal swiftness;) the Water, having once attained an equal *Impetus* thereunto, would still hold equal pace with it; there being no occasion, from the Quickening or Slackening of the Earths motion, (in that part where the Water lyeth) for the Water thereon either to be cast Forward or fall Backward, and thereby to accumulate on the other parts of the Water: But the true motion of each part of the Earths surface being compounded of those two motions; the *Annual* and *Diurnal*; (the *Annual* in B E C being, as *Galileo* there supposeth, about three times as fast as a *diurnal* motion in a great Circle, as D E F;) while a Point in the Earths surface moves about its Center B, from G. to D. and E, and at the same time, its Center B. be carried forwards to C; the true motion of that Point forwards, is made up of both those motions; to wit, of B to C, and of G to E; but while G moves by D to E, E moves backward by F to G, contrary to the motion of B to C; so that the true motion of E, is but the difference of B C, and E G: (for, beside the motion of B, ^{ALONG} the Center; G is also put forward as much as from G to E; and E put backward as much as from E to G:) so that the *Diurnal* motion, in that part of the Earth, which is next the Sun, as E F G, doth abate the progress of the *Annual*, (and most of all at F;) and in the other part, which is from the Sun, as G D E, it doth increase it, (and most of all at D.) that is, in the day time there is abated, in the night time is added to the *Annual* motion, about as much as is G E, the Earths *Diameter*. Which would afford us a Cause of two Tides in twenty four hours; the One upon the greatest Acceleration of motion, the Other upon its greatest Retardation.

And thus far *Galileo's* Discourse holds well enough; But then

in this it comes short; that as it gives an Account of two Tides; so those two Tides are always to be at F and D; that is, at *Noon* and *Midnight*; whereas Experience tells us, that the Time of Tides, moves in a *months space* through all the 24. hours. Of which he gives us no account. For though he do take notice of a Menstrual Period; yet he doth it onely as to the *Quantity* of the Tides; greater or less; not as to the *Time* of the *Tides*, sooner or later.

* *Vid. Riccioli Almagest. novum*, Tom. 1. lib. 4. cap. 10. n. III. pag. 216 2.

To help this, there is one (*Vid. * Jo. Baptista Balianus*) who makes the *Earth* to be but a *secondary Planet*; and to move, not directly about the *Sun*, but about the *Moon*, the *Moon* meanwhile moving about the *Sun*; in like manner as we suppose the *Earth* to move about the *Sun*, and the *Moon* about it.

But this, though it might furnish us with the foundation of a *Menstrual Period* of Accelerations and Retardations in the compound motion of several parts of the *Earths surface*; yet I am not at all inclined to admit this as a *true Hypothesis*, for divers Reasons, which if not demonstrative, are yet so consonant to the general Systeme of the *World*, as that we have no good ground to disbelieve them. For 1. The *Earth* being undeniably the greater Body of the two (whereof there is no doubt to be made) it cannot be thought probable, that this should be carried about by the *Moon*, lesser than it self: The contrary being seen, not onely in the *Sun*, which is bigger than any of the *Planets*, which it carries about; but in *Jupiter*, bigger than any of his *Satellites*; and *Saturne*, bigger than his. 2. As the *Sun* by it's motion about it's own *Axis*, is with good reason judged to be the *Physical cause* of the *Primary Planets* moving about it; So there is the like reason to believe, that *Jupiter* and *Saturne* moving about their *Axes*, are the *Physical cause* of their *Satellites* moving about them, which motion of *Jupiter* hath been of late discover'd, by the help of a *fixed Spot* discern'd in him; and we have reason to believe the like of *Saturne*. Whether *Venus* and *Mercury* (about whom no *Satellites* have been yet observed) be likewise so moved; we have not yet the like ground to determine: But we have of *Mars*; from
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the Observations of Mr. *Hook* made in *February* and *March* last, and by him communicated to the *Royal Society*, and since Printed in the *Transactions*, published *Apr. 2. 1666.* consonant to the like observations of *Jupiter*, made by him in *May. 1664.* and since communicated to the same *Society*; and then published in the *Transactions*, of *March. 6.* then next following. Now that the Earth hath such a motion about its own Axis (whereby it might be fitted to carry about the Moon) is evident by its *Diurnal* motion. And it seems as evident that the Moon hath not; because of the same side of the Moon alwaies turned towards us; which could not be, if the Moon carried the Earth about: Unlesse we should say, that it carries about the Earth in just the same Period, in which it turnes upon its own Axis: Which is contrary to that of the Sun carrying about the Planets: the shortest of whose Periods, is yet longer than that of the Sun moving about its own Axis. And the like of *Jupiter*, shorter than the Period of any of his *Satellites*; if at least the Period of his conversion about his Axis, lately said to be observed, prove true. (Of *Saturn* we have not yet any Period assigned; but it's likely to be shorter, than that of his *Satelles.*) And therefore we have reason to believe, not that by the Moons motion about its Axis the Earth should be carried by a contemporary Period (whereby the same face of the Moon should be ever towards us;) but that by the Earths revolution abouts its Axis in 24. hours, the Moon should be carried about it in about 29. dayes, without any motion on its own Axis: And accordingly, that the *Secondary Planets* about *Jupiter* and *Saturn*, are not (like their *Principals*) turned about their own Axis. And therefore I am not at all inclined to believe, that the *Menstrual* Period of the Tides with us, is to be salved by such an Hypothesis.

In. stead of this, that *Surmise* of mine, (for I dare not yet, with confidence give it any better name,) of what I have spoken to you heretofore, (and which hath occasioned this present account which I am now giving you,) is to this purpose.

The Earth and Moon being known to be Bodies of so great connexion, (whether by any Magnetick, or what other Tye, I will not determine; nor need I, as to this purpose;) as that

the motion of the one follows that of the other; (The Moon observing the Earth as the Center of its *periodick* motion:) may well enough be looked upon as *one Body*, or rather *one Aggregate of Bodies*, which have *one common center of Gravity*; which Center (according to the known Laws of *Statics*) is in a straight Line connecting their respective Centers, so divided as that its parts be in reciprocal proportion to the Gravities of the two Bodies. As for Example Suppose the Magnitude (and therefore probably, the Gravity) of the Moon to be about an *One and fourtieth part* of that of the Earth; (and thereabouts *Hewelius* in his *Selenography* page 203. doth out of *Tycho*, estimate the proportion; and an exact certainty is not necessary to our present business.) And the distance of the Moons Center from the Center of the Earth, to be about *fifty six semidiameters* of the Earth, (as thereabouts he doth there estimate it, in its middle distance; and we need not be now very accurate in determining the numbers; wherein Astronomers are not yet very well agreed.) The distance of the Common Center of Gravity of the two Bodies, will be from that of the Earth, about a two and fourtieth part of fifty six Semidiameters; that is, about $\frac{1}{42}$ or $\frac{1}{43}$ of a Semidiameter; that is about $\frac{1}{3}$ of a Semidiameter of the Earth, above its surface, in the Air, directly between the Earth and Moon.

Now supposing the Earth and Moon, joyntly as one Body, carried about by the Sun in the great Orb of the *Annual* motion; this motion is to be estimated, (according to the Laws of *Statics*, in other cases,) by the motion of the common Center of Gravity of both Bodies. For we use in *Statics*, to estimate a Body, or Aggregate of Bodies, to be moved upwards, downwards, or otherwise, so much as its Common Center of Gravity is so moved, howsoever the parts may change places amongst themselves.

And accordingly, the Line of the *Annual* motion, (whether *Circular* or *Elliptical*; of which I am not here to dispute,) will be described, not by the Center of the Earth (as we commonly estimate it, making the Earth a *Primary* and the Moon a *Secondary Planet*), nor by the Center of the Moon, (as they would do, who make the Moon the *Primary* and the Earth a *Secondary*

Secondary Planet, against which we were before disputing:) But by the *Common Center of Gravity of the Bodies, Earth and Moon*, as one Aggregate.

Now supposing A B C D E to be a part of the great Orb of the *Annual* motion, described by the Common Center of Gravity, in so long time as from a *Full-Moon* at A to the next *New-Moon* at E; (which, though an Arch of a *Circle* or *Ellipse*, whose Center we suppose at a due distance below it; yet being but about $\frac{1}{3}$ of the whole, may well enough be here represented by a straight Line:) the Center of the Earth at T, and that of the Moon at L, must each of them (supposing their common Center of Gravity to keep the Line A E) be supposed to describe a *Periphery* about that Common Center, as the Moon describes her Line of *Menstrual* motion. (Of which I have (in the *Scheme*) onely drawn that of the *Earth*; as being sufficient to our present purpose; parallel to which, if need be, we may suppose one described by the Moon; whose distance is also to be supposed much greater from T than in the *figure* is expressed, or was necessary to expresse.) And in like manner E F G H I, from that *New-moon* at E, to the next *Full-moon* at I.

From A to E (from Full-moon to New-moon,) T moves (in its own *Epicycle*) upwards from the Sun: And from E to I, (from New-moon to Full-moon) it moves downwards, toward the Sun. Again, from C to G, (from last quarter to the following first quarter,) it moves *forwards* according to the *Annual* motion; But from G forward to C, (from the first Quarter to the ensuing last Quarter,) it moves *contrary* to the *Annual* motion.

It is manifest therefore, according to this Hypothesis, that from Last quarter to First quarter (from C to G, while T is above the Line of the *Annual* motion) its *Menstrual* motion in its *Epicycle* adds somewhat of Acceleration to the *Annual* motion; and most of all at E, the New-moon: And from the first to the last quarter (from G forward to C, while T is below the Line of the *Annual* motion,) it abates of the *Annual* motion; and most of all at I, or A the Full-moon.

So that in pursuance of *Galilæo's* Notion, the *Menstrual* add-

ing to or detracting from the *Annual* motion, should either leave behinde, or cast forward, the loose waters incumbent on the Earth, (and thereby cause a Tide, or accumulation of Waters ;) and most of all at the Full-moon and New-moon, where those Accelerations or Retardations are greatest.

Now this *Menstrual* motion, if nothing else were superadded to the *Annual*, would give us two Tides in a moneth, and no more ; (the one upon the Acceleration, the other on the Retardation ;) at New moon and Full-moon ; and two Ebbs, at the two Quarters ; and in the Intervals, Rising and Falling water.

But the *Diurnal* motion superadded, doth the same to this *Menstrual*, which *Galilao* supposeth is to do to that *Annual* ; that is, doth *Add* to, or *Substract* from, the *Menstrual* Acceleration or Retardation ; and so gives us Tide upon Tide.

See Fig. 4. For in whatsoever part of its Epicycle, we suppose T to be ; yet because, while by its *Menstrual* motion the Center moves in the Circle L T N ; each point in its surface, by its diurnal motion moves in the Circle L M N : whatever effect (accelerative or tardative) the *Menstrual* would give, that effect by the *Diurnal* is increased in the parts L M N (or rather I M n. the Semicircle) and most of all at M : but diminished in the parts N O L (or rather n O l) and most of all at O. So that at M, and O, (that is when the Moon is in the *Meridian* below or above the *Horizon*,) we are to have the *Diurnal* Tide or High-water, occasioned by the greatest Acceleration or Retardation, which the *Diurnal* Arch gives to that of the *Menstrual* : which seems to be the true cause of the *Daily Tides*. And withall gives an account, not onely why it should be *every day* ; but likewise, why at *such a time* of the day ; and, why this time should in a moneth run through the whole 24. hours ; *viz.* because the Moons coming to the *Meridian* above and below the *Horizon*, (or as the Seamen call it, the *Moons Southing*, and *Northing*,) doth so : As likewise of the *Spring-tides* and *Neap-tides*. For, when it so happens, that the *Menstrual* and *Diurnal* Accelerations or Retardations, be coincident, (as at New moons and Full-moons they are.) the effect must needs be the greater. And although (which is not to be dissembled) this happen
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but to one of the two Tides ; that is, the Night-tide at the New-moon (when both motions do most of all Accelerate,) and the Day-tide at Full-moon (when both do most Retard the *Annual* motion ;) Yet, this tide being thus raised by two concurrent causes ; though the next Tide have not the same cause also, the *Impetus* contracted will have influence upon the next Tide ; Upon a like reason, as a *Pendulum* let fall from a higher Arch, will (though there be no new cause to occasion it) make the Vibration on the other side (beyond the Perpendicular) to be also greater : Or, of water in a broad Vessel, if it be so joggled, as to be cast forward to a good height above its Levell, will upon its recoyling, by its own gravity, (without any additional cause) mount so much the higher on the hinder part.

But here also we are to take notice, that though all parts of the Earth by its *Diurnal* motion do turn about its Axis, and describe *parallel* Circles ; yet not *equal* Circles ; but *greater* near the *Æquinoctial*, and *lesser* near the *Poles*, which may be a cause why the Tides in some parts may be much greater than in others. But this belongs to the *particular* considerations, (of which we are not now giving an Account :) not to the *general* Hypothesis.

Having thus endeavoured to give an account of the *Diurnal* and *Menstrual* Periods of Tides ; It remains that I endeavour the like as to the *Annual*. Of which there is, at least, thus much agreed ; That, at some times of the year, the Tides are noted to be much higher, than at other times.

But here I have a double task ; *First*, to rectify the Observation ; and *then*, to give an account of it.

As to the *First* ; It having been observed (grossly) that those high Tides have used to happen about the *Spring* and *Autumn* ; it hath been generally taken for granted (without any more nice observation) that the *two Æquinoxes* are the proper times, to which these *Annual high Tides* are to be referred ; And such causes sought for, as might best suite with such a Supposition.

But it is now, the best part of twenty years, since I have had frequent occasions to converse with some Inhabitants of *Rumney-marsh* in *Kent* ; where the Sea being kept out with great Earthen walls, that it do not at high water overflow the Levell ;

and

and the Inhabitants livelyhood depending most on grazing, or feeding Sheep; they are (as you may believe they have reason to be) very vigilant and observant, at what times they are most in danger of having their Lands drowned. And I find them generally agreed, by their constant Observations, (and Experience dearly bought) that their times of danger are about the beginning of *February* and of *November*: that is, at those Spring Tides which happen near those times; to which they give the names of *Candlemas-stream* and *Allhallond-stream*: And if they scape those Spring-tides, they apprehend themselves out of Danger for the rest of the year. And as for *March* and *September* (the two *Æquinoxes*) they are as little solicitous of them, as of any other part of the year.

This, I confess, I much wondred at, when I first heard it; and suspected it to be but a mistake of him, that first told me, though he were indeed a person not likely so to be mistaken, in a thing wherein he was so much concerned: But I soon found, that it was not onely his, but a general observation of others too; both there, and elsewhere along the Sea coast. And though they did not pretend to know any reason of it, (nor so much as to enquire after it;) Yet none made doubt of it; but would rather laugh at any that should talk of *March* and *September*, as being the dangerous times. And since that time, I have my self very frequently observed (both at *London* and elsewhere, as I have had occasion) that in those months of *February* and *November*, (especially *November*) the Tides have run much higher, than at other times: Though I confess, I have not been so diligent to set down those Observations, as I should have done. Yet this I do particularly very well remember, that in *November 1660*. (the same year that his Majesty returned) having occasion to go by Coach from the *Strand* to *Westminster*, I found the Water so high in the middle of *King-street*, that it came up, not onely to the Boots, but into the Body of the Coach; and the *Pallace-yard* (all save a little place near the *West-End*) overflow'd; as likewise the Market-place; and many other places; and their Cellars generally filled up with Water. And in *November* last, 1665. it may yet be very well remembred, what very high Tides there were, not onely on the Coasts of *England*, (where much hurt was done

done by it) but much more in *Holland*, where by reason of those Inundations, many Villages and Towns were overflow'd. And though I cannot so particularly name other years, yet I can very safely say, that I very often observed Tides strangely high about those times of the year.

This Observation did for divers years cause me much to wonder, not only because it is so contrary to the received opinion of the two *Æquinoxes*; but because I could not think of any thing signal at those times of the year: as being neither the two *Æquinoxes*, nor the two *Solstices*, nor the Sun's *Apogæum* and *Perigæum*; (or Earths *Aphelium* and *Perihelium*;) nor indeed, at contrary times of the year, which at least, would seem to be expected. From *Alhollandtide* to *Candlemas* being but three months; and from thence to *Alhollandtide* again nine months.

At length it came into my mind, about four years since, that though there do not about these times happen any *single* signal Accident, which might cast it on these times, yet there is a *compound of two* that may do it: Which is the *Inequality* of the *Natural day* (I mean that of 24. hours, from noon to noon) arising at least from a double cause; either of which singly would cast it upon other times, but both joyntly on those.

It's commonly thought, how unequal soever the length be of the *Artificial* dayes as contradicting to nights, yet that the *Natural Day*, reckoning from noon to noon, are all *equal*: But *Astronomers* know well, that even these dayes are *unequal*.

For, this *Natural Day* is measured *not onely* by one intire conversion of the *Æquinoctial*, or 24. *Æquinoctial* hours, (which is indeed taken to be performed in equal times,) *but* increases by so much, as answers to that part of the *Sun's* (or *Earth's*,) Annual motion as is performed in that time. For, when that part of the *Æquinoctial*, which (with the *Sun*) was at the *Meridian* yesterday at noon, is come thither again to day, it is not yet *Noon* (because the *Sun* is not now at the place where yesterday he was, but is gone forward about one degree, more or less) but we must stay till that place, where the *Sun* now is, comes to the *Meridian* before it be now *Noon*.

Now this Additament (above the 24 *Æquinoctial* hours, or intire conversion of the *Æquinoctial*) is upon a double account unequal;

qual. *First*, because the Sun, by reason of its *Apogæum* and *Perigæum*, doth not at all times of the year dispatch in one day an equal Arch of the *Ecliptick*; but greater Arches near the *Perigæum*, which is about the middle of *December*; and lesser near the *Apogæum*, which is about the middle of *June*: As will appear sufficiently by the *Tables* of the Sun's Annual motion. *Secondly*, though the Sun should in the *Ecliptick* move alwaies at the same rate; yet equal Arches of the *Ecliptick* do not in all parts of the *Zodiack* answer to equal Arches of the *Æquinoctial*, by which we are to estimate time: Because some parts of it, as about the two *Solstitial* Points, lie nearer to a *parallel* position to the *Æquinoctial*, than others, as those about the two *Æquinoctial* points, where the *Ecliptick* and *Æquinoctial* do intersect; whereupon an Arch of the *Ecliptick*, near the *Solstitial* points answers to a greater Arch of the *Æquinoctial*, than an Arch equal thereunto near the *Æquinoctial* points: As doth sufficiently appear by the *Tables* of the *Sun'sright Ascension*.

According to the *first* of these causes, we should have the longest *natural* daies in *December*, and the shortest in *June*, which if it did operate alone, would give us at those times two *Annual High-waters*.

According to the *second* cause, if operating singly, we should have the longest daies at the two *Solstices* in *June* and *December*, and the two shortest at the *Æquinoxes* in *March* and *September*; which would at those times give occasion of four *Annual High-waters*.

But the true *Inequality* of the *Natural Days*, arising from a *Complication* of those two causes, sometimes crossing, and sometimes promoting each other: though we should find some increases or decreases of the *Natural* daies at all those seasons answerable to the respective causes (and perhaps of *Tides* proportionably thereunto:) yet the longest and shortest *natural daies* absolutely of the whole year (arising from this complication of Causes) are about those times of *Allhallontide* and *Candlemas*; (or not far from them) about which those *Annual High-tides* are found to be: As will appear by the *Tables of Equation of Natural daies*. And therefore I think, we may with very good reason cast this *Annual Period* upon that cause, or rather complication

plication of causes. For (as we before shewed in the *Menstrual* and *Diurnal*) there will, by this inequality of Natural daies, arise a *Physical* Acceleration and Retardation of the Earths *Mean* motion, and accordingly a casting of the Waters backward or forward ; either of which, will cause an Accumulation or High-water.

'Tis true, that these longest and shortest daies, do (according to the *Tables*, some at least) fall rather before, than after *Alballontide* and *Candlemas* (to wit the ends of *October* and *January*;) but so do also (sometimes) those high Tydes: And it is not yet so well agreed amongst *Astronomers*, what are all the Causes (and in what degrees) of the Inequality of Natural daies ; but that there be diversities among them, about the true time : And whether the introducing of this New Motion of the Earth in its *Epiycle* about this Common Center of *Gravity*, ought not therein also to be accounted for, I will not now determine: Having already said enough, if not too much, for the explaining of this general Hypothesis, leaving the particularities of it to be adjusted according to the true measures of the motions ; if the General Hypothesis be found fit to be admitted.

Yet this I must add, (that I be not mistaken) that whereas I cast the time of the daily Tydes to be at all places, when the Moon is there in the *Meridian* ; it must be understood of *open* Seas, where the water hath such free scope for its motions, as if the whole Globe of Earth were equally covered with water : Well knowing, that in *Bays* and *In-land-Channels*, the position of the Banks and other like causes must needs make the times to be much different from what we suppose in the open Seas : And likewise, that even in the Open Seas, *Islands*, and *Currents*, *Gulfs* and *Shallows*, may have some influence, though not comparable to that of *Bays* and *Channels*. And moreover, though I think, that Seamen do commonly reckon the time of High-water in the *Open* Seas, to be then, when the Moon is there in the *Meridian* (as this Hypothesis would cast it :) Yet I do not take my self to be so well furnished with a *History of Tides*, as to assure my self of it ; much less to accommodate it to particular places and cases.

Having thus dispatched the main of what I had to say concerning

cerning the Seas Ebbing and Flowing: Had I not been already too tedious, I should now proceed to give a further reason, why I do introduce this consideration of the *Common Center of Gravity* in reference to *Astronomical Accounts*. For indeed, that which may possibly seem at first to be an Objection *against* it, is with me one reason *for* it.

It may be thought perhaps, that if the Earth should thus describe an *Epicyle* about the Common Center of Gravity, it would (by this its change of place) disturb the *Celestial* motions; and make the *apparent* places of the Planets, especially some of them, different from what they would otherwise be. For though so small a removal of the Earth, as the *Epicyle* would cause (especially if its *semidiameter* should not be above $1\frac{1}{3}$ of the Earths *Semidiameter*) would scarce be sensible (if at all) to the remoter Planets; yet as to the nearer it might.

Now though what *Galilæo* answers to a like Objection in his *Hypothesis*; (that its possible there may be some small difference, which *Astronomers* have not yet been so accurate, as to observe) might here perhaps serve the turn; Yet my answer is much otherwise; to wit, that such difference hath been observed, and hath very much puzzled *Astronomers* to give an account of. About which you will find Mr, *Horrocks* (in some of his Letters, whereof I did formerly, upon the Command of the *Royal Society*, make an *Extract*) was very much perplexed; and was fain, for want of other relief, to have recourse to somewhat like *Keplers* amicable *Fibres*, which did according to the several positions of the Moon, accelerate or retard the Moon's motion; which *amicable Fibres* he had no affection to at all (as there appears) if he could any other waies give account of those little inequalities; and would much rather (I doubt not) have embraced this Notion of the Common Center of Gravity, to salve the *Phænomenon*, had it come to his mind, or been suggested to him. And you find, that other *Astronomers* have been seen to bring in (some upon one supposition, some upon another) some kind of *Menstrual Equation*, to solve the inequalities of the Moon's motion, according to her *Synodical* Revolution, or different *Aspects* (of New-moon, Full Moon, &c.) beside what concerns her own *Periodical* motion.

For

For which, this consideration of the *Common Center of Gravity of the Earth and Moon*, is so proper a remedy (especially if it shall be found precisely to answer those *Phænomena*, which I have not Examined, but am very apt to believe) that it is so far from being, with me, an Objection against it, that it is one of the reasons, which make me inclinable to introduce it.

I must before I leave this, add one Consideration more, That if we shall upon these Considerations think it reasonable, thus to consider the *Common Center of Gravity of the Earth and Moon*; it may as well be thought reasonable, that the like Consideration should be had of *Jupiter* and his four *Satellites*, which according to the Complication of their several motions, will somewhat change the position of *Jupiter*, as to that *Common center of Gravity* of all these Bodies; which yet, because of their smallness, may chance to be so little, as that, at this distance, the change of this apparent place may not be discernable. And what is said of *Jupiter*, is in the like manner to be understood of *Saturne* and his *Satelles*, discovered by *Hugenius*: For all these *Satellites* are to their *Principals*, as so many Moons to the Earth. And I do very well remember, in the Letters forecited, Mr. *Horrocks* expresseth some such little inequalities in *Saturnes* motion, of which he could not imagine what account to give, as if (to use his Expression) this crabbed *Old Saturn* had despised his *Youth*. Which, for ought I know, might well enough have been accounted for, if at that time the *Satelles* of *Saturn* had been discovered, and that Mr. *Horrocks* had thought of such a motion as the *Common Center of Gravity* of *Saturn* and his *Companion*, to be considerable, as to the guiding of his motion.

You have now, in obedience to your Commands, an Account of my thoughts, as to this matter, though yet immature and unpolished: What use you will please to make of them, I shall leave to your prudence, &c.

An APPENDIX, written by way of Letter to the Publisher; Being an Answer to some Objections, made by several Persons, to the precedent Discourse.

I Received yours; and am very well contented, that objections be made against my *Hypothesis* concerning *Tydes*: being

