

PREFACE TO THE READER

Since the ancients had made Mechanics to be of the greatest use in the investigation of natural things (and Pappus is the authority), and in more recent times, with substantial forms and occult qualities passed over [these are veiled references to Descartes' Vortex theory of describing planetary motion], natural phenomena shall be recalled to be undertaken according to the laws of mathematics : It is seen in this Treatise that Mathematics is to be developed as far as that may be considered according to Philosophy. Indeed the ancients established Mechanics in a twofold manner: Theoretical Mechanics which proceeded from careful demonstrations, and Practical Mechanics. To practical mechanics may be considered all the manual arts and the uses arising ; from which indeed the name Mechanics has been borrowed. But since craftsmen may not be accustomed to labour accurately enough, it comes about that all Mechanics thus may be distinguished from Geometry, so that anything perfect shall refer to Geometry, anything less accurate to Mechanics. But yet the errors are not of the Art but of the Artisan. He who labours with less care is the more imperfect Mechanic, and if anyone may be able to work with the greatest care, here there may be the most perfect Mechanic of all. For the descriptions of both right lines and circles upon which Geometry is established relate to Mechanics. Geometry does not instruct how to describe these lines but requires them to be drawn. It demands that the beginner should have learned first how to describe the same with accuracy as he stands on the threshold of Geometry; then, it may teach how problems may be solved by these operations. To describe right lines and circles are problems, but not geometrical ones. The solution of these is postulated by Mechanics, in Geometry the uses of the solution [of this problem] is taught. And Geometry glorifies because by so few principles desired from elsewhere so much more may be established. Therefore Geometry is founded in the practice of Mechanics, and it is nothing other than that part of general Mechanics which proposes and demonstrates the art of measuring accurately. But since the manual arts may be applied particularly to moving bodies, it comes about that Geometry be applied to the magnitude, while Mechanics refers to the motion generally. In which sense rational Mechanics will be the Science of Motion which results from any forces, and of the forces which are required according to any motion accurately proposed and demonstrated. This part of Mechanics had been developed into five Forces [or Powers] by the ancients according to the manual arts considered, who scarcely considered weight (since it was not a manual force) other than as in heavy objects required to be moved by these other forces. We are not looking to the manual arts but to philosophy, and concerning which not writing about manual but natural forces, we examine these especially which are concerned with weight, levitation, the elastic force,

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the resistance of fluids and forces of such a kind either attractive or repulsive : And from that we propose these as our Mathematical principles of [Natural] Philosophy. Indeed a difficulty of all Philosophy on being engaged in that [study] may be seen, as from the phenomena of motions we may investigate the forces of nature, then from these forces we may investigate the remaining phenomena. And the general propositions which we have worked upon in the first and second book consider these. But in the third book we have proposed an example of this theory through an explanation of the System of the World. For there, from celestial phenomena, through the propositions demonstrated from mathematical derivations in the previous books, the forces of gravity are derived, by which bodies tend towards the sun and individual planets. Then from these forces also through propositions, the motion of planets, comets, the moon, and of the sea is deduced mathematically. If only the rest of natural phenomena were allowed to be derived from the principles of mechanics by the same general arguments. For many things move me so that I may suspect somewhat all these are possible to depend on forces of some kind, by which the small particles of bodies by causes not yet known either are forced towards each other mutually and cohere following regular figures, or reciprocally they are forced away and depart; for which unknown forces, so far philosophers have tested nature in vain. But I hope that the principles put in place here will provide a little light either for this method of conducting philosophy, or for some truer one.

In publishing these, Edmund Halley, the most intelligent of men and in all kinds of literature the most learned, has done the work with zeal, not only has he corrected faults of the typesetting and looked after the inscribed diagrams, but also he was the influence that I might undertake this edition. Certainly since he had obtained from me a figure of the celestial orbits, he had not stopped asking that I might share the same with the Royal Society, which then he effected to begin under their encouraging and kindly auspices, so that I might begin to consider sending out the same to the light of day. But after I had attacked the inequalities of the motions of the moon, then also I attempted others I might grasp according to the laws and measures of gravity and of other forces, according to the figures required to be described by bodies following some other laws of attraction, and likewise to consider the motion of several bodies among themselves, and the motion of bodies in resisting mediums, according to the forces, densities and the motion of the medium, to the orbits of comets, which I had thought to be in another publication at another time, so that I might probe the rest and I might give in a single publication. [Those corollaries] which consider lunar motions, (imperfect as they shall be), I have included likewise in the Corollaries of Proposition LXVI, lest I should be held to put in place corollaries by a single method with greater prolixity than the derivation warrants, and attempt to demonstrate [those corollaries] one by one and to interrupt the series of the remaining propositions. Several late discoveries I have preferred to insert in less suitable places, as the number of propositions and citations [otherwise] change. So that everything may be gathered together clearly and not be held back by such difficulties, I earnestly ask that defects in the material as they may be investigated, may be remedied kindly by the fresh endeavors of readers.

Cambridge, Trin. Coll.

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May 8. 1686.

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AUTHOR'S PREFACE TO THE SECOND EDITION

In this second edition of the *Principia* much scattered material is corrected and some has been added. In Book I, Section II, the discover of the forces, by which bodies shall be able to revolve in given orbits, is returned easier and more fully. In Section VII of Book II, the theory of fluid resistance is investigated with more care, and confirmed by new experiments. In the third Book the theory of the moon and the precession of the equinoxes are deduced more fully from their principles, and the theory of comets is confirmed from many examples, and more careful computations of the orbits.

London,
Mar. 2nd. 1713.

IS. NEWTON.

THE EDITOR'S PREFACE OF THE SECOND EDITION.

[Prof. Roger Cotes (1682-1716).]

We present to you, gentle reader, the long awaited new edition of Newtonian Philosophy, now much corrected and enlarged. You can find out from the added index what things chiefly are contained in this most celebrated work: the author's preface will almost teach you what either may be added or changed. The remainder [added here] is concerned with several things that may be added concerning the method of this philosophy.

Any who undertake to discuss natural philosophy [*i.e.* physics] can be placed into three classes roughly. Indeed those have stood out, who attributed specific and hidden qualities to individual kinds of things; upon which the operations of individual bodies wished to depend on, for some unknown reason. All scholastic doctrines derived from this principle had been put in place by Aristotle and the followers of his school: certainly they affirm that an individual effect arises from the nature of the individual bodies; but they do not teach the nature of these bodies; and thus nothing is taught. And the whole matter shall be in the names of things, not in the things themselves; and though they have arrived at agreeing about a certain philosophical manner of speaking, they cannot be agreed to be discussing philosophy.

[A brief whimsical account of Aristotle's physics can be found in Bertrand Russel's *History of Western Philosophy.*]

Others, following with more diligence, expected praise from the trifles of useless designations rejected. And thus they established all matter to be homogeneous, truly all variation of the forms which are discerned in bodies, to arise and to be understood most easily, from the influences of certain of the most simple compositions of particles. And indeed progress is established rightly from the more simple to the more composite, if they are not given other ways apart from these primary influences, which nature itself attributes. Truly where they [*i.e.* natural philosophers] take upon themselves the liberty, of putting whatever unknown figures and magnitudes and uncertain positions and motions of the parts, as it pleases; and why a certain hidden fluid needs to be devised, which may permeate the pores of bodies freely, provided with an all powerful subtly, and driven by hidden motions. Now they have slipped into dreams, by ignoring the true constitution of things: which certainly has been sought in vain from fallacious

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conjectures, since also scarcely may it be possible to be investigated from sure observations. Those who chose the foundations from the hypotheses of their own speculations; even if then they may advance most carefully following the rules of mechanics, may be said to have prepared but a story, indeed perhaps an elegant and attractive story.

Hence the third kind is left, of course who profess experimental philosophy. Indeed these wish the causes of all things to be derived from the most simple principles possible: but they assume nothing in place of a principle, which were not yet proven from phenomena. They do not fabricate hypotheses [*i.e.* in the sense of stating falsely], nor do they admit these into physics, unless as questions, regarding the truth of which there may be a dispute. And thus they advance by a twofold method, both analytic and synthetic. Natural forces and the simpler laws of forces are deduced from certain selected phenomena by analysis, from which the constitution of the remainder are then treated by synthesis. [*i.e.* experimental phenomena are analyzed, laws deduced, which can then predict other phenomena that can be verified by further experiment.] This is by far the best method of conducting a philosophical enquiry, which our most illustrious author agreed to embrace with merit before the rest. Certainly this alone he judged worthy, that he might apply to cultivate and adorn his work. Therefore he has given a most illustrious example of this, truly an explanation deduced most happily from the theory of gravitation of the system of the world. Others have suspected or imagined the strength of gravitation present for all bodies : he the first and only person was able to demonstrate this from external signs, and from the most excellent observations to put in place the most firm foundations.

Indeed I know also several men of great name, more patiently occupied with certain prejudices, who have been scarcely able to give assent to this new principle, and with certainty have repeatedly preferred uncertainties. I have not in mind to criticize the reputations of these unfairly: rather to you, benevolent reader, it may please to expound a little on these, on which you may pass a fair judgement.

Therefore so that the arguments are taken at the start from the most simple and nearest to us; we may consider for a short while what kind of gravity there shall be on the earth, so that then without further risk we may progress to where the celestial bodies, remote from our situations by far, may be come upon. Now it is agreed among all philosophers, all bodies around the earth are attracted to the earth. That no bodies are given truly to levitate, will be confirmed by manifold experience immediately. what is called relative levitation is not true levitation, but only apparent, and arises from the extra weight of contiguous bodies.

Again, as all bodies may gravitate to the earth, thus the earth in turn equally may gravitate to the bodies ; that the action of gravity is mutual and equal on both sides, is shown thus. The whole mass of the earth may be separated into any two parts, either equal or unequal to each other: now if the weights of the parts may not be equal to each other; the lesser weight concedes to the greater, and the parts together precede directly to infinity, in the direction towards which the greater weight tends: entirely against experience. And thus it will be required to be said, the weights of the parts are to be set

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up in equilibrium: that is, the action of gravity to be mutual and equal on each side [of the partition].

The weights of bodies, equally distant from the centre of the earth, are as the quantities of material in the bodies. This certainly is deduced from the equal acceleration of all bodies, from a state of rest by the forces of the falling weights: for forces by which unequal bodies may be accelerated equally, must be proportional to the quantities of matter to be moved. Now truly all falling bodies are to accelerate equally, from which it is apparent because in the vacuum as produced by Boyle, in equal times equal distances are described in falling, without doubt with the air resistance removed : but with more care it can be demonstrated by experiments with pendulums.

The attractive forces of bodies, at equal distances, are as the quantities of matter in the bodies. For since bodies acting on the earth and in turn the earth acting on bodies gravitate with equal amounts ; the weight of the earth on some body, or the force by which the body attracts the earth, will be equal to the weight of the same body on the earth. But this weight will be as the quantity of matter in the body : and thus the force by which some body is attracted to the earth, of if the absolute force of the body, will be as the same quantity of matter.

Therefore the attractive force of whole bodies arises and is composed from the attractive forces of the parts : if indeed with the mass of the body either increased or decreased, it has been shown to be increased or decreased proportionally the strength of this force. And thus it will be agreed that the action of the earth is to be put together from the actions of the parts ; and therefore it is required that all terrestrial bodies mutually attract each other by absolute forces, which shall be in the ratio of the attracting matter. This is the nature of gravity on the earth: we may consider now what sort it shall be in the heavens.

Every body persists either in its state of rest or of moving uniformly straight forwards, unless as far as by impressed forces it is trying to change that state; a law of nature that has been received by all philosophers. Thence truly it follows that bodies which are moving in curves, and thus their orbits continually depart from right line tangents, are held in curvilinear paths by some force acting continually. Therefore with the planets revolving in their curved orbits by necessity some force will be near, by the actions of which they are deflected repeatedly from the tangents.

Now that has been agreed upon equally, because it is deduced from mathematical reasoning and most certainly may be demonstrated : all bodies obviously, which are moving in some curved line described in a plane, and each with a radius drawn to a point, either at rest or moving somehow, describe areas around that point proportional to the times, are pressed on by forces which are attracted to the same point. Therefore since it shall be an acknowledged fact with astronomers, both the primary planets around the sun, and the secondary around their own primaries, describe areas proportional to the times ; a consequence is so that that force, by which perpetually they may be turned from rectilinear tangents and forced to revolve in curvilinear orbits, shall be directed towards bodies which shall be in the centres of the orbits. This force thus aptly can be called centripetal, indeed with regard to the revolving body; but attractive with regard to the central body; from whatever cause at last it may be imagined to arise.

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And indeed these also are to be conceded, and demonstrated mathematically: If several bodies are revolving in concentric circles, and the squares of the periodic times shall be as the cubes of the distances from the common centre ; the centripetal forces of revolution to be reciprocally as the squares of the distances. Or, these bodies may be revolving in orbits which are nearly circular, and the apses of the orbits remain at rest, the centripetal forces of revolution of circles to be reciprocally as the squares of the distances. The astronomers are in complete agreement for the planets to maintain either case. And thus the centripetal forces of all the planets are reciprocally as the squares of the distances from the centres of the orbits. If anyone may object that the apses of the planets, and especially of the moon, are not completely at rest ; but by a certain motion are to be carried slowly in consequence: it can be answered, even if we may concede this exceedingly small motion to be brought about because the centripetal force differs a very small amount from the square, that aberration can be found by mathematical computation and evidently it is of little concern. Indeed the account of the centripetal force of the moon itself, which of all must be disturbed especially, it must become indeed a little over the duplicate ; truly it will approach nearly sixty times nearer to that than to the triple. But it will be a truer answer, if we say that the progression of the apses to originate not from an aberration from the duplicate proportion [*i.e.* the inverse square law], but to originate completely from other causes, just as is pointed out uncommonly well in this philosophy. Therefore it remains that the centripetal forces, by which the planets are attracted towards the sun and the secondaries towards their primaries, shall be accurately as the reciprocal of the squares of the distances.

From these things which have been said up to now, it is agreed that the planets are to be retained in their orbits by some force perpetually acting on themselves: it is agreed that force always to be directed towards the centre of the orbits: it is agreed the effectiveness of that force is to be increased in moving towards the centre, to be diminished on receding from the same : and to be increased indeed in the same proportion in which the square of the distance is diminished, and to be diminished in the same proportion in which the square of the distance is increased. Now we may consider, with a comparison put in place between the centripetal forces of the planets and the force of gravity, can it be perhaps they shall be of the same origin. Truly they are of the same origin, if hence they may be taken, and thence [we find] the same laws and the same influences. And thus in the first place we may consider the centripetal force of the moon, which is nearest to us.

The rectilinear distances, which are described by bodies dropped from rest under the initial motion itself, where they are acted on by some force, are proportional to the forces themselves : this certainly follows from mathematical reasoning. Therefore the centripetal force of the moon revolving in its own orbit will be, to the force of gravity on the surface of the earth, as the distance which in a time which may be described as minimal, the moon by descending by the centripetal force towards the earth, if it may be imagined deprived of all circular motion, to the distance which in the same minimal time, a heavy body will describe in the vicinity of the earth, by falling by its own force of gravity. Of these distances the first is equal to the arc of the versed sine described by the moon in the same time, clearly which measures the translation of the moon from the

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tangent, made by the centripetal force ; and thus then can be computed from the given periodic time of the moon, as well as from the distance of this from the centre of the earth. The latter distances may be found from experiments with pendulums, just as taught by *Huygens*. And thus entering into the calculation, the first distance to the second distance, or the centripetal force of the moon in its own orbit of revolution to the force of gravity on the surface of the earth, will be as the square of the radius [half-diameter in the original] of the earth to the square of the radius of the orbit. They have the same ratio, by those which we have shown above, the centripetal force of the moon in its orbit of revolution to the force of the centripetal force of the moon near the surface of the earth. And thus the centripetal force near the surface of the earth is equal to the force of gravity. Therefore the forces are not different, but one and the same: for if they should be different, bodies with the forces taken jointly fall to the earth with twice as fast as from the force of gravity alone. Therefore it is agreed that the centripetal force, by which the moon is either always drawn from the tangent or is being impelled and is retained in orbit, is itself the force of terrestrial gravity reaching as far as the moon. And indeed on that account it has been agreed that strength may extend itself to huge distances, since there is not permitted to observe a perceptible change of this, even from the highest tops of mountains. And thus the moon gravitates to the earth: indeed with a mutual action, the earth in turn gravitates to the moon equally: that which indeed is confirmed abundantly in this philosophy, where [this force] has acted by the agitation of the sea and from the precession of the equinoxes, arising both from the action of the moon and the sun on the earth. And hence finally we are taught well that, from that law without doubt the force of gravity may decrease with greater distances from the earth. For since the force of gravity shall not differ from the centripetal force of the moon, truly this shall be reciprocally proportional to the square of the distance ; and it may diminish in the same ratio.

We may now progress to the remaining planets. Because the revolutions of the primary planets around the sun and of the secondaries around Jupiter and Saturn are phenomena of the same kind and from the revolution of the moon around the earth, because again it has been shown the centripetal forces of the primaries to be directed towards the centre of the sun, of the secondaries towards the centres of Jupiter and of Saturn, [note that the word 'moon' in Latin is reserved for our moon ; other moons were distinguished otherwise as secondary planets], just as the centripetal force of the moon is directed towards the earth; according to this, because all these forces are reciprocally as the square of the distances from the centres, just as the force of the moon is as the square of the distance from the earth: it will have to be concluded the same to be the nature of the universe. And thus so that the moon gravitates towards the earth, and the earth in turn towards to moon ; thus also all the secondaries will gravitate towards their primaries, and the primaries in turn towards the secondaries ; and thus all the primaries towards the sun, and the sun in turn towards the primaries.

Therefore the sun gravitates towards all the planets, and the sun towards all the planets. For the secondaries as well as their primaries they accompany, are revolving meanwhile around the sun with the primaries. And thus by the same argument, the planets of each kind gravitate towards the sun, and the sun towards them. Truly the secondary planets to be gravitating towards the sun in addition is agreed abundantly from

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the lunar inequalities ; the most precise theory of which, made apparent with wonderful sagacity, we have explained in the third book of this work.

The attractive strength of the sun is propagated to huge distances in all directions, and to have spread itself to all the surrounding parts of space it is possible to gather itself most widely into : from the motion of comets ; which have departed from the most immense intervals are carried to the vicinity of the sun, and sometimes thus approach nearly to the globe of this, in turning themselves around the sun, yet may be seen not to touch together. The theory of these was sought in vain previously by astronomers, finally in our age we are indebted to our most excellent author who happily found and explained these most carefully from observations. Therefore it appears comets move in conic sections with foci at the centre of the sun, and with radii drawn to the sun describe areas proportional to the times. Truly it is evident from these phenomena and it is proven mathematically, these forces, by which comets are retained in their orbits, are taken considering the sun and to be reciprocally as the square of the distances from the centre of this. And thus comets gravitate around the sun : and as the attractive of the sun not only to the bodies of planets at their given distances and gathered almost in the same plane, but also pertain to comets placed in the most diverse regions of the heavens. This therefore is the nature of gravitating bodies, so that they put forth forces at all distances to all gravitating bodies. Thence in truth it follows, the planets and comets everywhere attract each other, and gravitate between themselves : which also is confirmed from the perturbation of Jupiter and Saturn, not unknown to astronomers, and arising from the actions of these planets in turn between themselves; indeed from the that slowest motion of the apsides, which has been mentioned above, and which proceeds from a similar cause.

Finally from that we arrive at that which shall be required to be said, both the earth and the sun and all the celestial bodies, which accompany the sun, mutually attract each other. Therefore each of the smallest individual particles will have their own attractive forces, for exerting an influence on a quantity of matter ; just as above has been shown with terrestrial particles. But at diverse distances, the forces of these also will be reciprocally as the duplicate ratio: for it may be demonstrated mathematically for particles attracting by this law, globes must be composed by the same law.

The preceding conclusions depend on this axiom, which is agreed on by all philosophers; evidently of effects of the same kind, of which truly the properties are the same which are known, the same to be the causes and the same to be the properties which are not yet known. For who may doubt, if gravity shall be the cause of the fall of a stone in *Europe*, why not the same shall be the cause of the descent in *America* ? If the mutual gravitation were the cause between the same stone and the earth in *Europe* ; who will doubt it will not be mutual in *America* ? If the attractive force of the stone and the earth be compared, in *Europe* from the forces of attraction between the parts ; who will deny the same to be the composition in *America*? If the attraction of the earth to all kinds of bodies and at all distances may be extended in *Europe*; why can we not say equally it will extend to *America*? All philosophy is founded in this rule: obviously with which removed we are unable to affirm anything about the universe. The constitution of individual things is known from observations and experiments: thence truly we may judge the nature of the universe only by this rule about such things.

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Now since all bodies shall have gravity, which are found on the earth or in the heavens, which it is permitted to put in place either from experiments or observation; generally it will be required to say, the gravity of bodies is met everywhere. And just as since no bodies must be conceived, which shall not be extended, moveable and impenetrable; thus none must be considered which are without gravity. The extension, mobility and impenetrability of bodies cannot be known without experiment: clearly in the same way gravity is known. All bodies from which we have observations, to be extended and moveable and impenetrable: and thence we conclude all bodies, even those about which we have no observations, are extensive, mobile, and impenetrable. Thus all bodies are heavy [*i.e.* relative to each other], for which we have observations: and thence we infer all bodies, even those with which we have no observations, likewise are heavy. If anyone, who may say the bodies of the fixed stars not to be heavy, since the weight of these has not yet been observed; by the same argument can be said neither to be extended, nor impenetrable, since the conditions of these fixed stars shall not yet be observed. Is there a need to say this? Either gravity has a place amongst all the primary qualities of all bodies; or they do not have extension, mobility and shall not be impenetrable. And the nature of things either will be explained correctly by the gravitation of bodies, or it will not be explained correctly by the extension, mobility, and impenetrability of bodies.

Some I hear reject this conclusion, and which I know to mutter about occult qualitative. Gravitation of course is an occult quality which they are accustomed to prattle on about; truly occult causes are to be banished far from philosophy. But to these [criticisms] they may respond easily; occult is the cause, not indeed those of which the existence may be clearly demonstrated by observations, but these alone of which the occult feigns an existence truly not yet proven. Therefore gravity will not be an occult cause of celestial motions; if indeed it has been shown from [natural] phenomena that this force actually exists. Those flee rather to occult causes; who put in charge I know not what vortices, evidently of this fictitious matter and from all perception completely unknown, by which the same [planetary] motions are governed.

But may not the cause of gravity be said to be occult on that account, and by that name rejected from philosophy, because the cause of gravity itself is hidden and not yet found? Those who take this position, may not consider in the least what they put in place to be absurd, by which finally the whole foundations of philosophy may be shattered. And indeed causes are accustomed continually to proceed from composite ties to the more simple: when you may come upon the most simple cause, it will not now be permitted to progress further [*i.e.* axioms have to be assumed]. Therefore no mechanical explanation of the most simple cause is able to be given: for if it may be given, that cause will not yet be the simplest. Will you call these hence the most simple occult cases, and will you order them to be rejected? Likewise truly these neighbouring depending causes will be banished also, and those again which depend on these, until then philosophy will be empty from all causes and also correctly purged.

Some say that gravitation is outside nature, and they call it an everlasting wonder. And thus they [*i.e.* the followers of Descartes] wish to have it rejected, since preternatural causes may not have a place in physics. It is scarcely worth the effort to tarry towards

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refuting this silly objection, which also undermines the whole of philosophy itself. Indeed either they will deny gravity introduced to all bodies, which yet cannot be said : or they will affirm it to be preternatural by that name, because it may not originate from the influences of other bodies and thus from mechanical causes. Certainly the primary influences of bodies are given; which, because they are primary, do not depend on others. Therefore can it be that they will see all these also shall be equally preternatural: and therefore equally to be rejected : truly then they will see what shall be the future with philosophy.

There are some for which this whole physics or idea of the heavens pleases less, because it may be seen to fight with the Cartesian dogmas and they scarcely may seem possible to be reconciled. It will be permitted for them to profit from his opinion; but they are required they act with equality: therefore they will not deny from others the same freedom that they demand for themselves. And thus it is permitted for us to retain and embrace the NEWTONIAN philosophy, which for us may be considered truer, and causes to follow proven by phenomena, rather than fictions and not yet proven quantities. It concerns the true philosophy, that natural things truly to be derived from existing causes: truly these laws are sought, by which all may have been wished, this Maker of the world wished to put in place the most beautiful order of the world ; not those by which it would have been, if he had considered thus. Indeed it is harmonious to suppose, that from several causes, a little different from each other in turn, the same effect will be able to proceed : but this will be the true cause, from which truly this actually does proceed; the rest have no place in true philosophy. In automatic clocks the same motion of the hour hand can arise either from an appended weight, or to be inferred from a spring within. Because if the cause of the clock's motion actually shall be constructed from a weight ; anyone who devises an explanation from a spring motion will be the subject of mirth, and thus he will undertake to explain the motion of the hand fashioned from a too hasty hypothesis: for it is required that the internal fabrication of the machine be examined more carefully, thus so that the true principle of the proposed motion may have a true confirmation. The same or a not unlike judgement may be made about these philosophers, who have wished the heavens to be filled with a certain most subtle matter, and moreover this to be driven incessantly in vortices. For instance if they might be able to satisfy the phenomena, or to do so more carefully from their hypothesis; yet the true philosophy required to be treated, and the true causes of the motions of the heavens are not yet said to be come upon, unless these [vortices] either actually do exist, or at least they may show that other causes not to exist. Therefore if it were shown, that the attraction of all bodies have a true place in the nature of things, and indeed truly it were revealed, by which account all celestial motions thence may receive a solution; the objection would be met with empty and merited derision, if someone said the same motions must be explained by vortices, even if we might have especially conceded that could happen. But we do not concede: for phenomena are unable to be explained by any agreement with vortices: because it has been overcome by our author indeed most abundantly and with the clearest reasoning ; so that it may be required that those [followers of Descartes] indulge more in the level of dreams, and who being filled again

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with a most silly figment, pass judgement on the unhappy work again by decorating with new comments.

If the bodies of the planets and comets circulating around the sun were carried by vortices; it would be required that the bodies conveyed and also the nearby parts of the vortex to be travelling around with the same velocity and to be moving in the same determined course, and to have the same density or the same force of inertia for the mass of matter. Truly it is agreed the planets and comets, while they are turning in the same regions of the heavens, to move with various velocities and with various determined paths. And thus it follows by necessity, that these parts of the celestial fluid, which are at the same distance from the sun, may be revolving at the same time in different directions and with diverse velocities: even if other bodies have a need for another velocity and direction, so that they may cross over the planets orbits ; so that comets will be able to cross over by another way. Since that cannot be explained; either it will be admitted, that all celestial bodies are not carried around by the matter of vortices ; or it will be required to be said, the motion of the same to be returned not by one and the same vortex, but from several which shall be different from each other in turn, and penetrate the same space surrounding the sun.

If several vortices are to be held in the same space, and they are put in place to revolve with different motions and mutually to penetrate each other ; because these motions must be in agreement with the motions of the carried bodies, which are regular to the highest level, and go on in conic sections now very eccentric, now by approaching nearly to the form of circles; from the law it will be required to find, which will be able to happen, that the same entities may be conserved nor be disturbed by the actions of the matter crossing through any ages whatever. Certainly if these fictitious motions shall be made up of more complicated and are more difficult to explain, truly than the motions of the planets and comets; it may seem in vain to admit these into philosophy : indeed every cause must have its own simpler effect. With the freedom of the stories granted, it will be affirmed several planets and comets to be surrounded by atmospheres, like our earth ; which indeed will be seen to agree more with the hypothesis of reason rather than the hypothesis of vortices. Then it will be affirmed these atmospheres, by their nature, to move around the sun and to describe conic sections ; certainly which motion can be understood much easier, than with the similar motion of a vortex permeating each other in turn. And then it may be decided to believe that the planets themselves and the comets are to be carried around the sun by their own atmospheres, and on that account the causes found of the celestial motions emerge triumphant. But anyone who may consider rejecting this story, likewise also will reject the second story: for is not an egg similar to an egg, as the hypothesis of the atmospheres to the hypothesis of vortices.

Galileo has taught, the deflection from a rectilinear course of a stone projected to be moving in a parabola, to arise from the gravity of the stone on the earth, from some hidden quality as it were. Yet it can happen, as by one with a sharper nose than others, that a philosopher may devise another cause. Therefore he may devise a certain subtle matter, which may not be seen, touched, nor perceived by any sense, to be acting in nearby regions which are in contact with the surface of the earth. But this matter, in diverse directions, to be carried by varied and several contrary motions, acts to describe

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parabolic lines. Then truly the deflection of a stone thus may be arranged beautifully, and will deserve applause from the audience. The stone, it may be said, swims in that most subtle fluid and the course of this cannot choose but to describe the one and the same path. Truly the fluid is moving along parabolic paths; therefore it is necessary for the same stone to move in a parabola. Now who will not admire the acuteness of this ingenious philosopher, from mechanical causes, evidently the matter and the motion, phenomena of nature splendidly deduced and also understood by common people? Now who truly will not mock that good *Galileo*, who with great mathematical effort happily had excluded occult qualities from philosophy, who recalled anew would have it sustained? But it shames me to mention trifles for so long.

The sum of these matters finally may be returned thus: the number of comets is huge; the motions of these are extremely regular, and they observe the same laws with the motions of planets. They are moved in conic orbits, these orbits are definitely of great eccentricity. And they are carried from all sides into all parts of the heavens, and they freely pass through the regions of the planets, and often they enter against the order of the signs. These phenomena most certainly are confirmed from astronomical observations: and are unable to be explained by vortices. Indeed, since they cannot be consistent with the vortices of the planets. Generally there will not be a place for the motion of comets, unless that fictitious matter may be removed completely from the heavens.

If indeed the planets may be conveyed around the sun by vortices; the parts of the vortices, which go around close to each planet, will be of the same density as the planet; as has been said above. And thus all that matter which is close to the perimeter of the great orbit [*i.e.* of the earth], will have a density equal to that of the earth; truly that which lies between the great orbit and the orbit of Saturn, either will be equal or will be had greater. For instance, so that the constitution of the vortex shall be permanent, there must be less dense parts to occupy the centre, and of greater density the further one goes from the centre. For since the periodic times of the planets shall be in the three on two ratio of the distances from the sun, it is necessary that the periods of the parts of the vortex maintain the same ratio. Thence truly it follows, the centrifugal forces of these parts to be reciprocally as the squares of the distances. Those parts therefore, with a greater interval of distance from the centre, and depending on the same law, recede with a smaller force; from which if their density were less, it would be necessary that they go with a greater force, than by which the parts nearer to the centre are trying to escape. Therefore they may move away to denser parts, or approach to less dense parts, and a change is made in turn of the locations, until thus it is ordered properly and with the fluid matter of the whole vortex arranged, so that now it will be established to be at rest in equilibrium. If two [immiscible] fluids, the density of which is different, may be contained in the same vessel; certainly it will come about that the fluid, of which the density is greater, with the greater gravitational force will seek the lower place: and by a not unlike reason generally it is required to be said, the denser parts of the vortex will seek the furthest distance by the greater centrifugal force. Therefore that whole and much greater part of the vortex, which lies beyond the orbit of the earth, will have a density and thus a force of inertia for the mass of matter, which shall be greater than the density and

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force of inertia of the earth: thence truly a huge and very much perceptible resistance will arise in the trajectories of comets ; indeed I may say, which movement of these stops completely and may be seen deservedly to be absorbed. But it is agreed from the motion of comets to be absolutely regular, to experience no resistance themselves or which can perceive a minimum ; and thus by no means to run into any matter, of which there will be some force of resistance, or therefore there shall be some density of this or force of inertia. For the resistances of mediums arises either from the inertia of the fluid matter or from a lack of slipperiness. That which arises from lack of slipperiness, is very small; and certainly scarcely able to be observed in commonly known fluids, unless they were very tenacious like of oil or honey. The resistance which is perceived in the air, water, quicksilver, and of fluids of this kind almost without tenacity is of the first kind; and not able to be lessened by any further degree of subtlety, with the density of the fluid remaining or the force of inertia, to which always this resistance is proportional ; just as has been shown most clearly by our author in the most outstanding theory of resistances, which now is presented with a little more accuracy, here in turn in the second book, and confirmed more fully through experiments with falling bodies.

Bodies on progressing forwards share a little of their motion with the surrounding fluid, and by sharing they lose motion, and by the loss they are retarded. And thus the retardation is proportional to the shared motion ; the true motion shared, where the velocity of the progressing body is given, is as the density of the fluid ; therefore the retardation or resistance will be as the density of the same fluid; nor by any method can it be removed, unless the lost motion may be restored by the fluid returning to the latter parts of the body. But this cannot be said to happen, unless the impression of the fluid on the latter parts of the body were equal to the impression of the body on the forward parts of the fluid, that is, unless the relative velocity by which the fluid has rushed on the body from behind, shall be equal to the velocity by which the body rushes into the fluid, that is, unless the absolute velocity of the fluid of the recurring fluid shall be twice as great as the absolute velocity of the propelled fluid; which cannot happen. Therefore in no way can the resistance of the fluid be removed, which arises from the density and force of inertia of the same. And thus it must be concluded, there is no force of inertia of the celestial fluid, since there shall be no force of resistance: there is no force by which the motion may be shared, since there shall be no force of inertia: there is no force by which any change can be adopted by individual or by several bodies, since there shall be no force that may be shared; nothing to be entirely effective, since there shall be no means by which any change can be induced. Therefore why may this hypothesis not be allowed to be called most derisive and completely unworthy for the philosopher, which plainly from the beginning is destitute [of explanations], and which indeed has not served to explain the nature of things. For those who wish the heavens to be filled with a material fluid, this truly must be established without inertia ; with these words they remove the vacuum, and put this idea in place. For indeed a material fluid of this kind considered will not be able to be made different from empty space ; the whole dispute shall be about the names of things, not concerned with their natures. Because if some thus shall be dedicated to matter to that extent, that a space without bodies cannot be agreed upon, that they may wish to believe in admitting; we may see finally what may be arrived at from that.

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For either they may say this, which they invent, the constitution of the world through everything of plenty has preceded from the will of god for this purpose, so that the operations of nature may be able to have aid presented from a most subtle all pervading and satisfying aether; which yet cannot be said, as now it has been shown from the phenomena of comets that there has been no useful purpose at all of this aether ; or they may say [on this occasion], cut off from the will of god, on account of some unknown reason ; which ought not to be said either, if indeed diverse worlds may be able equally be established by the same argument ; or finally they may say not to proceed from the will of God, but from a certain necessity of nature. Finally therefore it [i.e. the idea of the aether] ought to fall into the sordid dregs of the lowest herd of humanity. Those who dream that the universe is ruled by Fate, not by Providence ; [who consider] matter from its own necessity always to be extant everywhere, to be infinite and eternal. With which put in place, it will be uniform everywhere : for a variety of forms by necessity generally is at odds with necessity. Also it will be immoveable : for if by necessity it may move in some determined direction, with some determined velocity; by equal necessity it will move in a different direction with a different velocity; but since it cannot move in different directions with different velocities, it is unable to move; it is required therefore to be motionless. By no such means surely has the universe arisen. with the most beautiful of forms and with a variety of distinct motions, unless all from the freest will of a foreseeing and guiding God.

Therefore from this font all these laws which are called the laws of nature has flowed: in which there is much apparent indeed of the wisest deliberation, with no vestiges of necessity. These laws hence are not to be sought from uncertain conjectures, for we must learn by observing and by experimenting. Truly anyone who believes himself able to find the physical principles and the laws of things, depending on strength of the mind and from the inward light of reason alone ; this will require either the universe to have been put in place by necessity, and the proposed laws to follow from the same necessity; or if the order of nature shall have been constituted by the will of God, yet he himself, a poor little man, shall have seen that the best has been done. All true philosophy is founded on the phenomena of things: which if they draw us unwilling or resisting to principles of this kind, in which the most illustrious are discerning the best deliberations both of the wisest Master and of the most powerful Being; thus there will be some not admitting these principles, because perhaps for certain men they may soon become less pleasing. By these men they may be called either wonders or occult quantities, which displease: truly wicked names imparted are not themselves required to overturn faults in matters ; unless they may wish to admit finally that philosophy certainly ought to be established in atheism. The influence of these men will not be required to shake philosophy, if indeed the order of things is unwilling to be changed.

Therefore an account will be obtained here about the good and fair judgments of this most outstanding philosophy, which is founded on experiments and observations. For this truly, scarcely anything need be said about how much light may be added, with how much authority, by this work by our most illustrious author ; the joy of this amazing talent of explaining the most difficult problems, and according to that again of extending to that which, nor would there be hope of, the human mind being able to rise ; deservedly

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they who look with wonder and admire with a little more understanding on those things which have been the subject of enquiry. Therefore with the bolts released, the way has been discovered for us into the most beautiful mysteries of things. The most elegant structure of the system of the world thus finally has been revealed and has been required to be given the deepest examination ; so that lest himself, if now he were brought back to life, the king *Alphonsus* would have found all the simplicity or the pleasing harmony he wished for in that. And thus the great majesty of nature can be examined more closely, and to be enjoyed with the sweetest contemplation ; truly the Maker and Master of the universe to be eagerly attended to and venerated, who has the pleasure of being the most fertile of philosophers. He would require to be blind, who from the best and wisest structures of things would not see at once the infinite wisdom and goodness of the all powerful maker: insane, who did not want to so profess.

Therefore the work of Newton will stand out as the best protection against the force of atheists: nor indeed from some more happy place than from this quiver can such darts be drawn forth against that band of wicked men. The first man who demonstrated this uncommonly well, and this was understood to be some time ago, and which was carried out in public meetings in the most learned manner both in the highest Latin and in English, by the exemplary Richard Bentley, generally outstanding in all kinds of literature and likewise the patron of good arts, a great ornament of his secular and of our academic world, and the most worthy and upright master of our *Trinity* college. I myself must acknowledge my debt for this to several names: and for this, benevolent reader, they are owed your gratitude. For he [Bentley], while for a long time enjoying the intimate friendship of our most celebrated author and at the same time consulting his famous friend on his own advancement and of that of the sciences (indeed he did not consider the [Newton's] following works to be of less value, as from the individual writings which the learned of the world are delighted to make clear). And thus since with the very rare copies of the first edition and at a large price they might remain unsold; he had proposed, by making numerous urgent demands - but not by reminding unduly, that the most outstanding of men be compelled, neither with less modesty nor with the greatest conspicuous erudition, that he [*i.e.* Bentley] might produce this new edition of the work, with everything perfected anew and enriched by the above outstanding parts, at his own cost and under his own supervision: truly to me, by his own judgement, he had entrusted a not unpleasant task, so that what needed to be corrected, that I might attend to doing.

Cambridge,

May 12, 1713.

ROGER COTES , fellow of Trinity College,

Plumian professor of experimental philosophy and astronomy.

[Indeed Richard Bentley, as the publisher and editor of the new Latin text, made a handsome profit out of the affair; Newton was given a small number of apparently unbound volumes, Cotes was given 12, which was his entire remuneration for several years of collaborating with the ageing and at times cantankerous Newton over mathematical details; there was the unfortunate matter with the fluid dynamics mistake in

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Prop. X of Book II, pointed out by the nephew Nikolaus of Johan Bernoulli, who appeared unannounced in London at this time for this express purpose. The unfortunate Cotes was to die of consumption within a few years, while Bentley flourished until 1742. See the Appendix to Vol.5 of Newton's Correspondence (CUP) for details.]

PREFACE OF THE AUTHOR TO THE THIRD EDITION.

In this third edition, which Henry Pemberton M.D. has attended to, a man most skilled in these matters, some things in the second book concerning the resistance of mediums are explained in a little more detail than before, and new experiments concerning the resistance of weights which fall in air are added. In book three the argument by which the moon is approved to be retained in its orbit by gravity is explained a little more: and new observations are added about the proportion of Jupiter's diameters in turn, made by Mr. Pound. Also some observations are added of that comet which appeared in the year 1690, to have been made by Mr. Kirk for the month of November in Germany, which came to our hand in recent years, and with aid of which it may be agreed that the motions of comets correspond nearly to parabolic orbits. And with the orbit of that comet, computed by Halley, it is determined a little more accurately than before, and that in an ellipse. And it is shown that a comet in this elliptic orbit, through nine signs of the heavens, to have completed a not less accurate course, than the planets are accustomed to move in elliptic orbits defined by astronomy. Also the orbit of the comet which appeared in the year 1723 is added, computed by Mr. Bradley, professor of astronomy at Oxford.

IS. NEWTON

London

Jan. 12. 1725-6.

PRAEFATIO AD LECTOREM

Cum Veteres Mechanicam (uti Author est Pappus) in rerum Naturalium investigatione maximi fecerint, & recentiores, missis formis substantialibus & qualitatibus occultis, Phaenomena Naturae ad leges Mathematicas revocare aggressi sint: Visum est in hoc Tractatu Mathesin excolere quatenus ea ad Philosophiam spectat. Mechanicam vero duplicem Veteres constituerunt: Rationalem quae per Demonstrationes accurate procedit, & Practicam. Ad practicam spectant Artes omnes Manuales, a quibus utiq; Mechanica nomen mutuata est. Cum autem Artifices parum accurate operari soleant, sit ut Mechanica omnis a Geometria ita distinguatur, ut quicquid accuratum sit ad Geometriam referatur, quicquid minus accuratum ad Mechanicam. Attamen errores non sunt Artis sed Artificum. Qui minus accurate operatur, imperfectior est Mechanicus, & si quis accuratissime operari posset, hic foret Mechanicus omnium perfectissimus. Nam & Linearum rectarum & Circulorum descriptiones in quibus Geometria fundatur, ad Mechanicam pertinent. Has lineas descriptiones Geometria non docet sed postulat. Postulat ut Tyro easdem accurate describere prius didicerit quam limen attingat Geometriae; dein, quomodo per has operationes Problemata solvantur, docet. Rectas & circulos describere Problemata sunt sed non Geometrica. Ex Mechanica postulatur horum solutio, in Geometria docetur solutorum usus. Ac gloriatur Geometria quod tam paucis principiis aliunde petitis tam multa praestet. Fundatur igitur Geometria in praxi Mechanica, & nihil aliud est quam Mechanicae universalis pars illa quae artem mensurandi accurate proponit ac demonstrat. Cum autem artes Manuales in corporibus movendis praecipue versentur, sit ut Geometria ad magnitudinem, Mechanica ad motum vulgo referatur. Quo sensu Mechanica rationalis erit Scientia Motuum qui ex viribus quibuscunq; resultant, & virium quae ad motus quoscunq; requiruntur, accurate proposita ac demonstrata. Pars haec Mechanicae a Veteribus in Potentiis quinque ad artes manuales spectantibus exulta fuit, qui Gravitationem (cum potentia manualis non sit) vix aliter quam in ponderibus per potentias illas movendis considerarunt. Nos autem non Artibus sed Philosophiae consulentes, denique potentiis non manualibus sed naturalibus scribentes, ea maxime tractamus quae ad Gravitationem, levitatem, vim Elasticam, resistentiam Fluidorum & eiusmodi vires seu attractivas seu impulsivas spectant: Et ea propter haec nostra tanquam Philosophiae principia Mathematica proponimus. Omnis enim Philosophiae, difficultas in eo versari videtur, ut a Phenomenis motuum investigemus

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vires Naturae, deinde ab his viribus demonstramus phenomena reliqua. Et haec spectant Propositiones generales quas Libro primo & secundo pertractavimus. In Libro autem tertio exemplum huius rei proposuimus per explicationem Systemis mundani. Ibi enim, ex phaenomenis caelestibus, per Propositiones in Libris prioribus Mathematicae demonstratas, derivantur vires gravitatis quibus corpora ad Solem & Planetas singulos tendunt. Deinde ex his viribus per Propositiones etiam Mathematicas deducuntur motus Planetarium, Cometarum, Lunae & Maris. Utinam caetera Naturae phaenomina ex principis Mechanicis eodem argumentandi genere derivari liceret. Nam multa me movent ut nonnihil suspicer ea omnia ex viribus quibusdam pendere posse, quibus corporum particulae per causas nondum cognitae vel in se mutuo impelluntur & secundum figuras regularas cohaerent, vel invicem fugantur & recedunt: quibus viribus ignotis, Philosophi hactenus Naturam frustra tentarunt. Spero autem quod vel huic Philosophandi modo, vel veriori alicui, Principia hic posita lucem aliquam praebeant.

In his edendis, Vir acutissimus & in omni literarum genere eruditissimus Edmundus Halleius operam navavit, nec solum Typothetarum Sphalmata correxit & Schemata incidi curavit, sed etiam Author fuit ut horum editionem aggrederer. Quippe cum demonstratam a me siguram Orbium Caelestium impetraverat, rogare non destitit ut eadem cum Societate Regali communicarem, quae deinde hortatibus & benignis suis auspiciis effecit ut de eadem in lucem emittenda cogitare inciperem. At postquam Motuum Lunarium inaequalitates aggressus essem, deinde etiam alia tentare caepissem quae ad leges & mensuras Gravitatis & aliarum virium, ad sigures a corporibus secundum datas quascunque leges auractis describendas, ad motus corporum plurium inter se, ad motus corporum in Mediis resistentibus, ad vires, densitates & motus Mediorum, ad Orbes Cometarum & similia spectant, editionem in aliud tempus differendam esse putavi, ut caeterarimarer & una in publicum darem. Quae ad motus Lunares spectant, (imperfecta cum sint), in Corollariis Propositionis LXVI simul complexus sum, ne singula methodo prolixiore quam pro rei dignitate proponere, & sigillatim demonstrare tenerer & seriem reliquarum Propositiones interrumpere. Nonnulla sero inventas locis minus idoneis inserere malui, quam numerum Propositionum & citationes mutare. Ut omnia candide legantur, & defectus, in materia tam difficili non tam reprehendantur, quam novis Lectorum conatibus investigentur, & benigne suppleantur, enixe rogo.

Dabam Cantabrigiae, e Collegio
S. Trinitatis, Maii 8. 1686.

IS. NEWTON.

AUCTORIS PRAEFATIO
IN
EDITIONEM SECUNDAM.

In hac secunda Principiorum editione multa sparsim emendantur, & nonnulla adjiciuntur. In libri primi sectione II inventio virium, quibus corpora in orbibus datis revolvi possint, facilius redditur & amplior. In libri secundi sectione VII theoria resistentiae fluidorum accuratius investigatur, & novis experimentis confirmatur. In libri tertia theoria lunae & praecessio aequinoctiorum ex principiis suis plenius deducuntur, & theoria cometarum pluribus & accuratius computatis orbium exemplis confirmatur.

Dabam Londini,
Mar. 2ct. 1713.

IS. NEWTON.

EDITORIS PRAEFATIO IN EDITIONEM SECUNDAM.

NEWTONIANAE philosophiae novam tibi, lector benevole, diuque desideratam editionem, plurimum nunc emendatam atque auctiorem exhibemus. Quae potissimum contineantur in hoc opere celeberrimo, intelligere potes ex indicibus adjectis: quae vel addantur vel immutentur, ipsa te fere docebit auctoris praefatio. Reliquum est, ut adjiciantur nonnulla de methodo hujus philosophiae.

Qui physicam tractandam susceperunt, ad tres fere classes revocari possunt. Extiterunt enim, qui singulis rerum speciebus qualitates specificas & occultas tribuerint; ex quibus deinde corporum singulorum operationes, ignota quadam ratione, pendere voluerunt. In hoc posita est summa doctrinae scholasticae, ab *Aristotele* & Peripatetics derivatae: Affirmant utique singulos effectus ex corporum singularibus naturis oriri; at unde sint illae naturae non docent; nihil itaque docent. Cumque toti sint in rerum nominibus, non in ipsis rebus; sermonem quandam philosophicum censendi sunt adinvenisse, philosophiam tradidisse non sunt censendi.

Alii ergo melioris diligentiae laudem consequi sperarunt rejecta vocabulorum inutili farragine. Statuerunt itaque materiam universam homogeneam esse, omnem vero formarum varietatem, quae in corporibus cernitur, ex particularum componentium simplicissimis quibusdam & intellectu facillimis affectionibus oriri. Et recte quidem progressio instituitur a simplicioribus ad magis composita, si particularum primariis illis affectionibus non alios tribuunt modos, quam quos ipsa tribuit natura. Verum ubi licentiam sibi assumunt, ponendi quascunque libet ignotas partium figuras & magnitudines, incertosque situs & motus; quin & fingendi fluida quaedam occulta, quae corporum poros liberrime permeent, omnipotente praedita subtilitate, motibusque occultis agitata; jam ad somnia delabuntur, neglecta rerum constitutione vera: quae sane frustra petenda est ex fallacibus conjecturis, cum vix etiam per certissimas observationes investigare possit. Qui speculationum suarum fundamentum desumunt ab hypothesis; etiamsi deinde secundum leges mechanicas accuratissime procedant; fabulam quidem elegantem forte & venustam, fabulam tamen concinnare dicendi sunt.

Relinquitur adeo tertium genus, qui philosophiam scilicet experimentalem profitentur. Hi quidem ex simplicissimis quibus possunt principiis rerum omnium causas derivandas esse volunt: nihil autem principii loco assumunt, quod nondum ex phaenomenis comprobatum fuerit. Hypotheses non comminiscuntur, neque in physicam

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recipiunt, nisi ut quaestiones de quarum veritate disputetur. Duplici itaque methodo incedunt, analytica & synthetica. Naturae vires legesque virium simpliciores ex selectis quibusdam phaenomenis per analysin deducunt, ex quibus deinde per synthesin reliquorum constitutionem tradunt. Haec illa est philosophandi ratio longe optima, quam prae caeteris merito amplectendum censuit celeberrimus auctor noster. Hanc solam utique dignam judicavit, in qua excolenda atque adornanda operam suam collocaret. Huius igitur illustrissimum dedit exemplum, mundani nempe systematis explicationem e theoria gravitatis felicissime deductam. Gravitatis virtutem universis corporibus inesse, suspicati sunt vel finxerunt alii: primus ille & solus ex apparentiis demonstrare potuit, & speculationibus egregiis firmissimum ponere fundamentum.

Scio equidem nonnullos magni etiam nominis viros, praepiudiciis quibusdam plus aequo occupatos, huic novo principio aegre assentiri potuisse, & certis incerta identidem praetulisse. Horum famam vellicare non est animus: tibi potius, benevole lector, illa paucis exponere lubet, ex quibus tute ipse iudicium non iniquum seras.

Igitur ut argumenti sumatur exordium a simplicissimis & proximis; dispiciamus paulisper qualis sit in terrestribus natura gravitatis, ut deinde tutius progrediamur ubi ad corpora caelestia, longissime a sedibus nostris remota, perventum fuerit. Convenit jam inter omnes philosophos, corpora universa circumterrestria gravitare in terram. Nulla dari corpora vere levia, jamdudum confirmavit experientia multiplex. Quae dicitur levitas relativa, non est vera levitas, sed apparens solummodo; & oritur a praepollente gravitate corporum contiguorum.

Porro, ut corpora universa gravitent in terram, ita terra vicissim in corpora aequaliter gravitat; gravitatis enim actionem esse mutuam & utrinque aequalem, sic ostenditur. Distinguatur terrae totius moles in binas quascunque partes, vel aequales vel utcunque inaequales: jam si pondera partium non essent in se mutuo aequalia; cederet pondus minus majori, & partes conjunctae pergerent recta moveri ad infinitum, versus plagam in quam tendit pondus majus: omnino contra experientiam. Itaque dicendum erit, pondera partium in aequilibrio esse constituta: hoc est, gravitatis actionem esse mutuam & utrinque aequalem.

Pondera corporum, aequaliter a centro terrae distantium, sunt ut quantitates materiae in corporibus. Hoc utique colligitur ex aequali acceleratione corporum omnium, e quiete per ponderum vires cadentium: nam vires quibus inaequalia corpora aequaliter accelerantur, debent esse proportionales quantitibus materiae movendae. Jam vero corpora universa cadentia aequaliter accelerari, ex eo patet quod in vacuo *Boyliano* temporibus aequalibus aequalia spatia cadendo describunt, sublata scilicet aëris resistentia: accuratius autem comprobatur per experimenta pendulorum.

Vires attractivae corporum, in aequalibus distantibus, sunt ut quantitates materiae in corporibus. Nam cum corpora in terram & terra vicissim in corpora momentis aequalibus gravitent; terrae pondus in unumquodque corpus, seu vis qua corpus terram attrahit, aequabitur ponderi corporis eiusdem in terrae. Hoc autem pondus erat ut quantitas materiae in corpore: itaque vis qua corpus unumquodque terrae attrahit, sive corporis vis absoluta, erit ut eadem quantitas materiae.

Oritur ergo & componitur vis attractiva corporum integrorum ex viribus attractivis partium: siquidem aucta vel diminuta mole materiae, ostensum est, proportionaliter

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augeri vel diminui ejus virtutem. Actio itaque telluris ex conjunctis partium actionibus conflari censenda erit; atque adeo corpora omnia terrestria se mutuo trahere oportet viribus absolutis, quae sint in ratione materiae trahentis. Haec est natura gravitatis apud terram: videamus jam qualis sit in caelis.

Corpus omne perseverare in statu suo vel quiescendi vel movendi uniformiter in directum, nisi quatenus a viribus impressis cogitur statum illum mutare; naturae lex est ab omnibus recepta philosophis. Inde vero sequitur, corpora quae in curvis moventur, atque adeo de lineis rectis orbitas suas tangentibus jugiter abeunt, vi aliqua perpetuo agente retineri in itinere curvilineo. Planetis igitur in orbibus curvis revolventibus necessario aderit vis aliqua, per cuius actiones repetitas indefinenter a tangentibus deflectantur.

Jam illud concedi aequum est, quod mathematicis rationibus colligitur & certissime demonstratur; corpora nempe omnia, quae moventur in linea aliqua curva in plano descripta, quaeque radio ducto ad punctum vel quiescens vel utcunque motum describunt areas circa punctum illud temporibus proportionales, urgeri a viribus quae ad idem punctum tendunt. Cum igitur in confesso sit apud astronomos, planetas primarios circum solem, secundarios vero circum suos primarios, areas describere temporibus proportionales; consequens est ut vis illa, qua perpetuo detorquentur a tangentibus rectilineis & in orbitis curvilineis revolvi coguntur, versus corpora dirigatur quae sita sunt in orbitalium centris. Haec itaque vis non inepte vocari potest, respectu quidem corporis revolventis, centripeta; respectu autem corporis centralis, attractiva; a quacunque demum causa oriri fingatur.

Quin & haec quoque concedenda sunt, & mathematice demonstrantur: Si corpora plura motu aequabili revolvantur in circulis concentricis, & quadrata temporum periodicorum sint ut cubi distantiarum a centro communi; vires centripetas revolventium fore reciproce ut quadrata distantiarum. Vel, si corpora revolvantur in orbitis quae sunt circulis finitimae, & quiescant orbitalium apsides; vires centripetas revolventium fore reciproce ut quadrata distantiarum. Obtinere casum alterutrum in planetis universis consentiunt astronomi. Itaque vires centripetae planetarum omnium sunt reciproce ut quadrata distantiarum ab orbium centris. Si quis objiciat planetarum, & lunae praesertim, apsides non penitus quiescere; sed motu quodam lento ferri in consequentia: responderi potest, etiamsi concedamus hunc motum tardissimum exinde profectum esse quod vis centripetae proportio aberret aliquantum a duplicata, aberrationem illam per computum mathematicum inveniri posse & plane insensibilem esse. Ipsa enim ratio vis centripetae lunaris, quae omnium maxime turbari debet, paululum quidem duplicatam superabit; ad hanc vero sexaginta fere vicibus propius accedet quam ad triplicatam. Sed verior erit responsio, si dicamus hanc apsidum progressionem, non ex aberratione a duplicata proportione, sed ex alia prorsus diversa causa oriri, quemadmodum egregie commonstratur in hac philosophia. Restat ergo ut vires centripetae, quibus planetae primarii tendunt versus solem & secundarii versus primarios suos, sint accurate ut quadrata distantiarum reciproce.

Ex iis quae hactenus dicta sunt, constat planetas in orbitis suis retineri per vim aliquam in ipsos perpetuo agentem: constat vim illam dirigi semper versus orbitalium centra: constat hujus efficaciam augeri in accessu ad centrum, diminui in recessu ab eadem: & augeri quidem in eadem proportione qua diminuitur quadratum distantiae, diminui in

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eadem proportione qua distantiae quadratum augetur. Videamus jam, comparatione instituta inter planetarum vires centripetas & vim gravitatis, annon eiusdem forte sint generis. Eiusdem vero generis erunt, si deprehendantur hinc & inde leges eadem, eademque affectiones. Primo itaque lunae, quae nobis proxima est, vim centripetam expendamus.

Spatia rectilinea, quae a corporibus e quiete demissis dato tempore sub ipso motus initio describuntur, ubi a viribus quibuscunque urgentur, proportionalia sunt ipsis viribus: hoc utique consequitur ex ratiociniis mathematicis. Erit igitur vis centripeta lunae in orbita sua revolventis, ad vim gravitatis in superficie terrae, ut spatium quod tempore quam minima describeret luna descendendo per vim centripetam versus terram, si circulari omni motu privari fingeretur, ad spatium quod eadem tempore quam minima describit grave corpus in vicinia terrae, per vim gravitatis suae cadendo. Horum spatiorum prius aequale est arcus a luna per idem tempus descripti sinui verso, quippe qui lunae translationem de tangente, factam a vi centripeta, metitur; atque adeo computari potest ex datis tum lunae tempore periodico, tum distantia eius a centro terrae. Spatium posterius invenitur per experimenta pendulorum, quemadmodum docuit *Huygenius*. Inito itaque calculo, spatium prius ad spatium posterius, seu vis centripeta lunae in orbita sua revolventis ad vim gravitatis in

superficie terrae, erit ut quadratum semidiametri terrae ad orbitae semidiametri quadratum. Eandem habet rationem, per ea quae superius ostenduntur, vis centripeta lunae in orbita sua revolventis ad vim lunae centripetam prope terrae superficiem. Vis itaque centripeta prope terrae superficiem aequalis est vi gravitatis. Non ergo diversae sunt vires, sed una atque eadem: si enim diversae essent, corpora viribus conjunctis duplo celerius in terram caderent quam ex vi sola gravitatis. Constat igitur vim illam centripetam, qua luna perpetuo de tangente vel trahitur vel impellitur & in orbita retinetur, ipsam esse vim gravitatis terrestris ad lunam usque pertingentem, Et rationi quidem consentaneum est ut ad ingentes distantias illa sese virtus extendat, cum nullam eius sensibilem imminutionem, vel in altissimis montium cacuminibus, observare licet. Gravitat itaque luna in terram: quin & actione mutua, terra vicissim in lunam aequaliter gravitat: id quod abunde quidem confirmatur in hac philosophia, ubi agitur de maris aestu & aequinoctiorum praecessione, ab actione tum lunae tum solis in terram oriundus. Hinc & illud tandem edocemur, qua nimirum lege vis gravitatis decrescat in majoribus a tellure distantibus. Nam cum gravitas non diversa sit a vi centripeta lunari, haec vero sit reciproce proportionalis quadrato distantiae; diminuetur & gravitas in eadem ratione.

Progrediamur iam ad planetas reliquos. Quoniam revolutiones primariorum circa solem & secundariorum circa jovem & saturnum sunt phaenomena generis eiusdem ac revolutio lunae circa terram, quoniam porro demonstratum est vires centripetas primariorum dirigi versus centrum solis, secundariorum versus centra jovis & saturni, quemadmodum lunae vis centripeta versus terrae centrum dirigitur; adhaec, quoniam omnes illae vires sunt reciproce ut quadrata distantiarum a centrīs, quemadmodum vis lunae est ut quadratum distantiae a terra: concludendum erit eandem esse naturam universis. Itaque ut luna gravitat in terram, & terra vicissim in lunam; sic etiam

gravitabunt omnes secundarii in primarios suos, & primarii vicissim in secundarios; sic & omnes primarii in solem, & sol vicissim in primarios.

Igitur sol in planetas universos gravitat & universi in solem. Nam secundarii dum primarios suos comitantur, revolvuntur interea circum solem una cum primariis. Eodem itaque argumento, utriusque generis planetae gravitant in solem, & sol in ipsos. Secundarios vero planetas in solem gravitare abunde insuper constat ex inaequalitatibus lunaribus; quarum accuratissimam theoriam, admiranda sagacitate patefactam, in tertio huius operis libro expositam habemus.

Solis virtutem attractivam quoquoersum propagari ad ingentes usque distantias, & sese diffundere ad singulas circumjecti spatii partes, apertissime colligi potest: ex motu cometarum; qui ab immensis intervallis profecti feruntur in viciniam solis, & nonnunquam adeo ad ipsum proxime accedunt ut globum eius, in periheliis suis versantes, tantum non contingere videantur. Horum theoriam ab astronomis antehac frustra quaesitam, nostro tandem saeculo feliciter inventam & per observationes certissime demonstratam, praestantissimo nostro auctori debemus. Patet igitur cometas in sectionibus conicis umbilicos in centro solis habentibus moveri, & radiis ad solem ductis areas temporibus proportionales describere. Ex hisce vero phaenomenis manifestum est & mathematice comprobatur, vires illas, quibus cometae retinentur in orbitis suis, respicere solem & esse reciproce ut quadrata distantiarum ab ipsius centro. Gravitant itaque cometae in solem: atque adeo solis vis attractiva non tantum ad corpora planetarum in datis distantiiis & in eodem fere plano collocata, sed etiam ad cometas in diversissimis caelorum regionibus & in diversissimis distantiiis positos pertingit. Haec igitur est natura corporum gravitantium, ut vires suas edant ad omnes distantias in omnia corpora gravitantia. Inde vera sequitur, planetas & cometas universos se mutuo trahere, & in se mutua graves esse: quod etiam confirmatur ex perturbatione jovis & saturni, astronomis non incognita, & ab actionibus horum planetarum in se invicem oriunda; quin & ex motu illo lentissimo apsidum, qui supra memoratus est, quique a causa consimili proficiscitur.

Eo demum pervenimus ut dicendum sit, & terram & solem & corpora omnia caelestia, quae solem comitantur, se mutuo attrahere. Singulorum ergo particulae quaeque minimae vires suas attractivas habebunt, pro quantitate materiae pollentes; quemadmodum supra de terrestribus ostensum est. In diversis autem distantiiis, erunt & harum vires in duplicata ratione distantiarum reciproce: nam ex particulis hac lege trahentibus componi debere globos eadem lege trahentes, mathematice demonstratur.

Conclusiones praecedentes huic innituntur Axiomati, quod a nullis non recipitur philosophis; effectuum scilicet eiusdem generis, quorum nempe quae cognoscuntur proprietates eadem sunt, easdem esse causas & easdem esse proprietates quae nondum cognoscuntur. Quis enim dubitat, si gravitas sit causa descensus lapidis in *Europa*, quin eadem sit causa descensus in *America*? Si gravitas mutua fuerit inter lapidem & terram in *Europa*; quis negabit mutuam esse in *America*? Si vis attractiva lapidis & terrae componatur, in *Europa*, ex viribus attractivis partium; quis negabit similem esse compositionem in *America*? Si attractio terrae ad omnia corporum genera & ad omnes distantias propagetur in *Europa*; quidni pariter propagari dicamus in *America*? In hac regula fundatur omnis philosophia: quippe qua sublata nihil affirmare possimus de

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universis. Constitutio rerum singularum innotescit per observationes & experimenta: inde vero non nisi per hanc regulam de rerum universarum natura judicamus.

Jam cum gravia sint omnia corpora, quae apud terram vel in caelis reperiuntur, de quibus experimenta vel observationes instituere licet; omnino dicendum erit, gravitatem corporibus universis competere. Et quemadmodum nulla concipi debent corpora, quae non sint extensa, mobilia & impenetrabilia; ita nulla concipi debere, quae non sint gravia. Corporum extensio, mobilitas, & impenetrabilitas non nisi per experimenta innotescunt: eodem plane modo gravitas innotescit. Corpora omnia de quibus observationes habemus, extensa sunt & mobilia & impenetrabilia: & inde concludimus corpora universa, etiam illa de quibus observationes non habemus, extensa esse & mobilia & impenetrabilia; ita corpora omnia sunt gravia, de quibus observationes habemus: & inde concludimus corpora universa, etiam illa de quibus observationes non habemus, gravia esse. Si quis, dicat corpora stellarum inerrantium non esse gravia, quandoquidem eorum gravitas nondum est observata; eadem argumento dicere licebit neque extensa esse, nec mobilia, nec impenetrabilia, cum hae fixarum affectiones nondum sint observatae. Quid opus est verbis? inter primarias qualitates corporum universorum vel gravitas habebit locum; vel extensio, mobilitas, & impenetrabilitas non habebunt. Et natura rerum vel recte explicabitur per corporum gravitatem, vel non recte explicabitur per corporum extensionem, mobilitatem, & impenetrabilitatem.

Audio nonnullos hanc improbare conclusionem, & de occultis qualitibus nescio quid mussitare. Gravitatem scilicet occultum esse quid, perpetuo arguari solent; occultas vero causas procul esse ablegandas a philosophia. His autem facile respondetur; occultas esse causas, non illas quidem quarum existentia per observationes clarissime demonstratur, sed has solum quarum occulta est & ficta existentia nondum vero comprobata. Gravitatis ergo non erit occulta causa motuum caelestium; siquidem ex phaenomenis ostensum est, hanc virtutem revera existere. Hi potius ad occultas confugiunt causas; qui nescio quos vortices, materiae cuiusdam prorsus fictitiae & sensibus omnino ignotae, motibus iisdem regendis praeficiunt.

Ideone autem gravitas occulta causa dicitur, eoque nomine reiicietur e philosophia, quod causa ipsius gravitatis occulta est & nondum inventa? Qui sic statuunt, videant nequid statuunt absurdi, unde totius tandem philosophiae fundamenta convellantur. Etenim causae continuo nexu procedere solent a compositis ad simpliciora: ubi ad causam simplicissimae perveneris, iam non licebit ulterius progredi. Causae igitur simplicissimae nulla dari potest mechanica explicatio: si daretur enim, causa nondum esset simplicissima. Has tu proinde causas simplicissimas appellabis occultas, & exulare iubebis? Simul vero exulabunt & ab his proxime pendentes & quae ab illis porro pendent, usque dum a causis omnibus vacua fuerit & probe purgata philosophia.

Sunt qui gravitatem praeter naturam esse dicunt, & miraculum perpetuum vocant. Itaque reiiciendam esse volunt, cum in physica praeternaturales causae locum non habeant. Huic ineptae prorsus objectioni diluendae, quae & ipsa philosophiam subruit universam, vix operae pretium est immorari. Vel enim gravitatem corporibus omnibus inditam esse negabunt, quod tamen dici, non potest: vel eo nomine praeter naturam esse affirmabunt, quod ex aliis corporum affectionibus atque adeo ex causis mechanicis originem non habeat. Dantur certe primariae corporum affectiones; quae, quoniam sunt

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primariae, non pendent ab aliis. Viderint igitur annon & hae omnes sint pariter praeter naturam, eoque pariter rejiciendae: viderint vero qualis sit deinde futura philosophia.

Nonnulli sunt quibus haec tota physica caelestis vel ideo minus placet, quod cum *Cartesii* dogmatibus pugnare & vix conciliari posse videatur. His sua licebit opinione frui; ex aequo autem agant oportet: non ergo denegabunt aliis eandem libertatem quam sibi concedi postulant. NEWTONIANAM itaque philosophiam, quae nobis verior habetur, retinere & amplecti licebit, & causas sequi per phaenomena comprobatas, potius quam fictas & nondum comprobatas. Ad veram philosophiam pertinet, rerum naturas ex causis vere existentibus derivare: eas vero leges quaerere, quibus voluit summus, opifex hunc mundi pulcherrimum ordinem stabilire; non eas quibus potuit, si ita visum fuisset. Rationi enim consonum est, ut a pluribus causis, ab invicem nonnihil diversis, idem possit effectus proficisci: haec autem vera erit causa, ex qua vere atque actu proficiscitur; reliquae locum non habent in philosophia vera. In horologiis automatis idem indicis horarum [non esse *horarii*] motus vel ab appenso pondere vel ab intus concluso elatere oriri potest. Quod si oblatum horologium revera sit instructum pondere; ridebitur qui finget elaterem, & ex hypothesi sic praepropere conficta motum indicis explicare suscipiet: oportuit enim internam machinae fabricam penitus perscrutari, ut ita motus propositi principium verum exploratum habere posset. Idem vel non absimile feretur iudicium de philosophis illis, qui materia quadam subtilissima caelos esse repletos, hanc autem in vortices indesinenter agi voluerunt. Nam si phaenomenis vel accuratissime satisfacere possent ex hypothesibus suis; veram tamen philosophiam tradidisse, & veras causas motuum caelestium invenisse nondum dicendi sunt; nisi vel has revera existere, vel saltem alias non existere demonstraverint. Igitur si ostensum fuerit, universorum corporum attractionem habere verum locum in rerum natura; quin etiam ostensum fuerit, qua ratione motus omnes caelestes abinde solutionem recipiant; vana fuerit & merito deridenda objectio, si quis dixerit eosdem motus per vortices explicari debere, etiamsi id fieri posse vel maxime concesserimus. Non autem concedimus: nequeunt enim ullo pacto phaenomena per vortices explicari: quod ab auctore nostro abunde quidem & clarissimis rationibus evincitur; ut somnis plus aequo indulgeant oporteat, qui ineptissimo figmento refarciendo, novisque porro commentis ornando infelicem operam addicunt.

Si corpora planetarum & cometarum circa solem deferantur a vorticibus; oportet corpora delata & vorticum partes proxime ambientes eadem velocitate eademque cursus determinatione moveri, & eandem habere densitatem vel eandem vim inertiae pro mole materiae. Constat vero planetas & cometas, dum versantur in iisdem regionibus caelorum, velocitatibus variis variaque cursus determinatione moveri. Necessario itaque sequitur, ut fluidi caelestis partes illae, quae sunt ad easdem distantias a sole, revolvantur eodem tempore in plagas diversas cum diversis velocitatibus: etenim alia opus erit directione & velocitate, ut transire possint planetae; alia ut transire possint cometae. Quod cum explicari nequeat; vel fatendum erit, universa corpora caelestia non deferri a materia vorticis; vel dicendum erit, eorundem motus repetendos esse non ab uno eodemque vortice, sed a pluribus qui ab invicem diversi sint, idemque spatium soli circumiectum pervadant.

Si plures vortices in eodem spatio contineri, & sese mutuo penetrare motibusque diversis revolvi ponantur; quoniam hi motus debent esse conformes delatorum corporum

motibus, qui sunt summe regulares, & peraguntur in sectionibus conicis nunc valde eccentricis, nunc ad circulorum proxime formam accedentibus; iure quaerendum erit, qui fieri possit, ut iidem integri conserventur nec ab actionibus materiae occursantis per tot saecula quicquam perturbentur. Sane si motus hi fictitii sunt magis compositi & difficilius explicantur, quam veri illi motus planetarum & cometarum; frustra mihi videntur in philosophiam recipi: omnis enim causa debet esse effectui suo simplicior. Concessa fabularum licentia, affirmaverit aliquis planetas omnes & cometas circumcingi atmosphaeris, adinstar telluris nostrae; quae quidem hypothesis rationi magis consentanea videbitur quam hypothesis vorticum. Affirmaverit deinde has atmosphaeras, ex natura sua, circa solem moveri & sectiones conicas describere; qui sane motus multo facilius concipi potest, quam consimilis motus vorticum se invicem permeantium. Denique planetas ipsos & cometas circa solem deferri ab atmosphaeris suis credendum esse statuat, & ob repertas motuum caelestium causas triumphum agat. Quisquis autem hanc fabulam reiiciendam esse putet, idem & alteram fabulam rejiciet: nam ovum non est ovo similis, quam hypothesis atmosphaerarum hypothese vorticum.

Docuit *Galillaeus*, lapidis projecti & in parabola moti deflexionem a cursu rectilineo oriri a gravitate lapidis in terram, ab occulta scilicet qualitate. Fieri tamen potest ut alius aliquis, nasi acutioris, philosophus causam aliam comminiscatur. Finget igitur ille materiam quandam subtilem, quae nec visu, nec tactu, neque ullo sensu percipitur, versari in regionibus quae proxime contingunt telluris superficiem. Hanc autem materiam, in diversas plagas, variis & plerumque contrariis motibus ferri, & lineas parabolicas describere contendet. Deinde vero lapidis deflexionem pulchre sic expediet, & vulgi plausum merebitur. Lapis, inquiet, in fluido illo subtili natat & cursui ejus obsequendo, non potest non eandem una semitam describere. Fluidum vero movetur in lineis parabolicis; ergo lapidem in parabola moveri necesse est. Quis nunc non mirabitur acutissimum huiusce philosophi ingenium, ex causis mechanicis, materia scilicet & motu, phaenomena naturae ad vulgi etiam captum praeclare deducendis? Quis vero non subsannabit bonum illum *Galilaeum*, qui magno molimine mathematico qualitates occultas, e philosophia feliciter exclusas, denuo revocare sustinuerit? Sed pudet nugis diutius immorari.

Summa rei huc tandem redit: cometarum ingens est numerus; motus eorum sunt summe regulares, & easdem leges cum planetarum motibus observant. Moventur in orbibus conicis, hi orbis sunt valde admodum eccentrici. Feruntur undique in omnes caelorum partes, & planetarum regiones liberrime pertranseunt, & saepe contra signorum ordinem incedunt. Haec phaenomena certissime confirmantur ex observationibus astronomicis: & per vortices nequeunt explicari. Imo, ne quidem cum vorticibus planetarum consistere possunt. Cometarum motibus omnino locus non erit; nisi materia illa fictitia penitus e caelis amoveatur.

Si enim planetae circum solem a vorticibus devehuntur; vorticum partes, quae proxime ambiunt unumquemque planetam, eiusdem densitatis erunt ac planeta; uti supra dictum est. Itaque materia illa omnis quae contigua est orbis magni perimetrio, parem habebit ac tellus densitatem: quae vero iacet intra orbem magnum atque orbem saturni, vel parem vel majorem habebit. Nam ut constitutio vorticis permanere possit, debent partes minus

densae centrum occupare, magis densae longius a centro abire. Cum enim planetarum tempora periodica sint in ratione sesquuplicata distantiarum a sole, oportet partium vorticis periodos eandem rationem servare. Inde vero sequitur, vires centrifugas harum partium fore reciproce ut quadrata distantiarum. Quae igitur majore intervallo distantae centro, nituntur ab eodem recedere minore vi: unde si minus densae fuerint, necesse est ut cedant vi majori, qua partes centro propiores ascendere conantur. Ascendent ergo densiores, descendent minus densae, & locorum fiet invicem permutatio; donec ita fuerit disposita atque ordinata materia fluida totius vorticis, ut conquiescere iam possit in aequilibrio constituta. Si bina fluida, quorum diversa est densitas, in eodem vase continentur; utique futurum est ut fluidum, cuius major est densitas, majore vi gravitatis infimum petat locum: & ratione non absimili omnino dicendum est, densiores vorticis partes majore vi centrifuga petere supremum locum. Tota igitur illa & multo maxima pars vorticis, quae iacet extra telluris orbem, densitatem habebit atque adeo vim inertia pro mole materia, quae non minor erit quam densitas & vis inertia telluris: inde vero cometis trajectis orietur ingens resistentia, & valde admodum sensibilis; ne dicam, quae motum eorundem penitus sistere atque absorbere posse merito videatur. Constat autem ex motu cometarum prorsus regulari, nullam ipsos resistentiam pati quae vel minimum sentiri potest; atque adeo neutiquam in materiam ullam incursare, cuius aliqua sit vis resistendi, vel proinde cuius aliqua sit densitas seu vis inertiae. Nam resistentiae mediorum oritur vel ab inertia materiae fluidae, vel a defectu lubricitatis. Quae oritur a defectu lubricitatis, admodum exigua est; & sane vix observari potest in fluidis vulgo notis, nisi valde tenacia fuerint adinstar olei & mellis. Resistentia quae sentitur in aëre, aqua, hydrargyro, & hujusmodi fluidis non tenacibus fere tota est prioris generis; & minui non potest per ulteriorem quemcunque gradum subtilitatis, manente fluidi densitate vel vi inertia, cui semper proportionalis est haec resistentia; quemadmodum clarissime demonstratum est ab auctore nostro in peregrina resistentiarum theoria, quae paulo nunc accuratius exponitur, hac secunda vice, & per experimenta corporum cadentium plenius confirmatur.

Corpora progrediendo motum suum fluido ambienti paulatim communicant, & communicando amittunt, amittendo autem retardantur. Est itaque retardatio motui communicato proportionalis; motus vera communicatus, ubi datur corporis progredientis velocitas, est ut fluidi densitas; ergo retardatio seu resistentia erit ut eadem fluidi densitas; neque ullo pacto tolli potest, nisi a fluido ad partes corporis posticas recurrente restituatur motus amissus. Hoc autem dici non poterit, nisi impressio fluidi in corpus ad partes posticas aequalis fuerit impressioni corporis in fluidum ad partes anticam, hoc est, nisi velocitas relativa qua fluidum irruit in corpus a tergo, aequalis fuerit velocitati qua corpus irruit in fluidum, id est, nisi velocitas absoluta fluidi recurrentis duplo maior fuerit quam velocitas absoluta fluidi propulsi; quod fieri nequit. Nullo igitur modo tolli potest fluidorum resistentia, quae oritur ab eorundem densitate & vi inertiae. Itaque concludendum erit; fluidi caelestis nullam esse vim inertiae, cum nulla sit vis resistendi: nullam esse vim qua motus communicetur, cum nulla sit vis inertiae: nullam esse vim qua mutatio quaelibet vel corporibus singulis vel pluribus inducatur cum nulla sit vis qua motus communicetur; nullam esse omnino efficaciam, cum nulla sit facultas mutationem quamlibet inducendi. Quidni ergo hanc hypothesin, quae fundamento plane destituitur,

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quaeque naturae rerum explicandae ne minimum quidem inservit, ineptissimam vocare liceat & philosopho prorsus indignam. Qui caelos materia fluida repletos esse volunt, hanc vero non inertem esse statuunt; hi verbis tollunt vacuum, re ponunt. Nam cum huiusmodi materia fluida ratione nulla secerni possit ab inani spatio; disputatio tota sit de rerum nominibus, non de naturis. Quod si aliqui sint adeo usque dediti materiae, ut spatium a corporibus vacuum nullo pacto admittendum credere velint; videamus quo tandem oporteat illa pervenire.

Vel enim dicent hanc, quam confingunt, mundi per omnia pleni constitutionem ex voluntate dei profectam esse, propter eum finem, ut operationibus naturae subsidium praesens haberi posset ab aethere subtilissimo cuncta permeante & implente; quod tamen dici non potest, siquidem iam ostensum est ex cometarum phaenomenis, nullam esse huius aetheris efficaciam: vel dicent ex voluntate dei prosectam esse, propter finem aliquem ignotum; quod neque dici debet, siquidem diversa mundi constitutio eodem argumento pariter stabiliri posset: vel denique non dicent ex voluntate dei prosectam esse, sed ex necessitate quadam naturae. Tandem igitur delabi oportet in faeces sordidas gregis impurissimi. Hi sunt qui somniant fato universa regi, non providentia; materiam ex necessitate sua semper & ubique extitisse, infinitam esse & aeternam. Quibus positis, erit etiam undiquaque uniformis: nam varietas formarum cum necessitate omnino pugnat. Erit etiam, immota: nam si necessario moveatur in plagam aliquam determinatam, cum determinata aliqua velocitate; pari necessitate movebitur in plagam diversam cum diversa velocitate; in plagas autem diversas, cum diversis velocitatibus, moveri non potest; oportet igitur immotam esse. Neutiquam profecto potuit oriri mundus, pulcherrima formarum & motuum varietate distinctus, nisi ex liberrima voluntate cuncta providentis & gubernantis dei.

Ex hoc igitur fonte promanarunt illae omnes quae dicuntur naturae leges: in quibus multa sane sapientissimi consilii, nulla necessitati apparent vestigia. Has proinde non ab incertis conjecturis petere, sed observando atque experiendo addiscere debemus. Qui vere physicae principia legesque rerum, sola mentis vi & interno rationis lumine fretum, invenire se posse confidit; hunc oportet vel statuere mundum ex necessitate fuisse, legesque propositas ex eadem necessitate sequi; vel si per voluntatem dei constitutus sit ordo naturae, se tamen, homuncionem misellum, quid optimum factu sit perspectum habere. Sana omnis & vera philosophia fundatur in phaenomenis rerum: quae si nos vel invitos & reluctantes adhuiusmodi principia deducunt, in quibus clarissime cernuntur consilium optimum & dominium summum sapientissimi & potentissimi entis; non erunt haec ideo non admittenda principia, quod quibusdam forsitan hominibus minus grata sint futura. His vel miracula vel qualitates occultae dicantur, quae displicent: verum nomina malitiose indita non sunt ipsis rebus vitio vertenda; nisi illud fateri tandem velint, utique debere philosophiam in atheismo fundari. Horum hominum gratia non erit labefactanda philosophia, siquidem rerum ordo non vult immutari.

Obtinebit igitur apud probos & aequos iudices praestantissima philosophandi ratio, quae fundatur in experimentis & observationibus. Huic vero, dici vix poterit, quanta lux accedat, quanta dignitas, ab hoc opere praeclaro illustrissimi nostri auctoris; cuius eximiam ingenii felicitatem, difficillima quaeque problemata enodantis, & ad ea

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porro pertingentis ad quae nec spes erat humanam mentem assurgere potuisse, merito admirantur & suspiciunt quicumque paulo profundius in hisce rebus versati sunt. Claustris ergo referatis, aditum nobis aperuit ad pulcherrima rerum mysteria. Systematis mundani compagem elegantissimam ita tandem patefecit & penitus perspectandam dedit; ut nec ipse, si nunc revivisceret, rex *Alphonsus* vel simplicitatem vel harmoniae gratiam in ea desideraret. Itaque naturae maiestatem propius iam licet intueri, & dulcissima contemplatione frui, conditorem vero ac dominum universorum impensius colere & venerari, qui fructus est philosophiae multo uberrimus. Caecum esse oportet, qui ex optimis & sapientissimis rerum structuris non statim videat fabricatoris omnipotentis infinitam sapientiam & bonitatem: insanum, qui profiteri nolit.

Extabit igitur eximium NEWTONI opus adversus atheorum impetus munitissimum praesidium: neque enim alicunde felicius, quam ex hac pharetra, contra impiam catervam tela deprompseris. Hoc sensit pridem, & in pereruditis concionibus anglice latineque editis, primus egregie demonstravit vir in omni literarum genere praeclarus idemque bonarum artium fautor eximius RICHARDUS BENTLEIUS, seculi sui & academiae nostrae magnum ornamentum, collegii nostri *S. Trinitatis* magister dignissimus & integerrimus. Huic ego me pluribus nominibus obstrictum fateri debeo: huic & tuas quae debentur gratias, lector benevole, non denegabis. Is enim, cum a longo tempore celeberrimi auctoris amicitia intima frueretur, (qua etiam apud posteros censi non minoris aestimat, quam propriis scriptis quae literato orbi in deliciis sunt inclarescere) amici simul famae & scientiarum incremento consuluit. Itaque cum exemplaria prioris editionis rarissima admodum & immani pretio coëmenda superessent; suasit ille crebris efflagitationibus, & tantum non obiurgando perpulit denique virum praetiantissimum, nec modestia minus quam eruditione summa insignem, ut novam hanc operis editionem, per omnia elimatam denuo & egregiis insuper accessionibus ditatam, suis sumptibus & auspiciis prodire pateretur: mihi vero, pro iure suo, pensum non ingratum demandavit, ut quam posset emendate id fieri curarem.

Cantabrigiae,
Maii 12. 1713.

ROGERUS COTES collegii *S. Trinitatis* socius,
astronomiae & philosophiae experimentalis
professor *Plumianus*.

AUCTORIS PRAEFATIO
IN
EDITIONEM TERTIAM.

IN editione hacce tertia, quam Henricus Pemberton M. D. vir harum rerum peritissimus curavit, nonnulla in libra secundo de resistentia mediorum paulo susius explicantur quam antea, & adduntur experimenta nova de resistentia gravium quae cadunt in aëre.

In

libra tertia argumentum quo lunam in orbe suo per gravitatem retineri probatur, paulo fusius exponitur: & novae adduntur observationes de proportione diametrorum Jovis ad invicem a D. Poundio factae. Adduntur etiam observationes aliquot cometae illius qui anna 1690 apparuit, a D. Kirk menfe Novembri in Germania habitae, quae nuper ad manus nostras venerunt, & quarum ope constet quam prope orbis parabolici motibus cometarum respondent. Et orbita cometae illius, computante Halleio, paulo accuratius determinatur quam antea, idque in ellipsi. Et ostenditur cometam in hac orbita elliptica, per novem caelorum signa, non minus accurate cursum peregisse, quam solent planetae in orbitis ellipticis per astronomiam definitis moveri. Orbis etiam cometae qui anna 1723 apparuit, a D. Bradleio astronomiae apud Oxonienses professore computatus adiicitur.

IS. NEWTON

Dabam Londini
Jan. 12. 1725-6.