Theses from General Physics

As Addressed in the Clementine College

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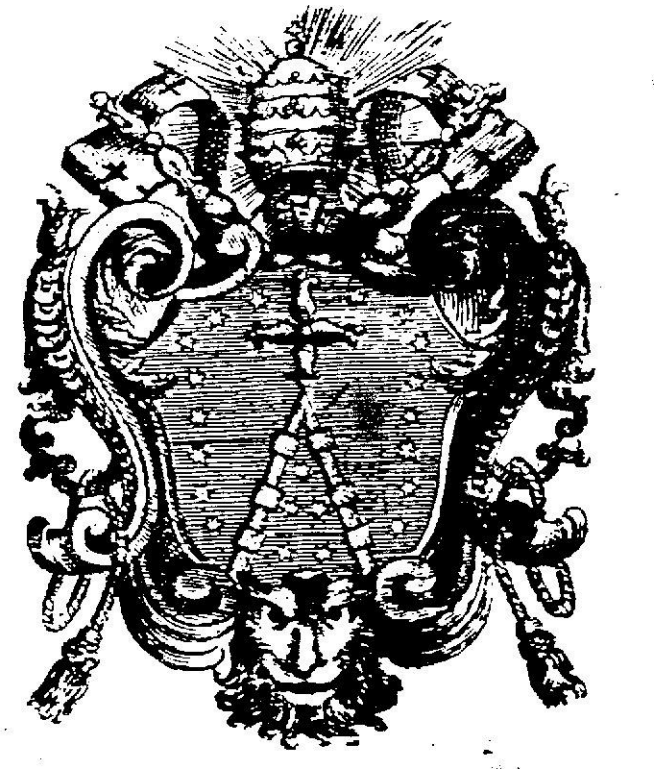

Facta cuilibet singulas impugnandi facultate.

[Everyone is authorised to rebut them one by one.]

Rome 1771

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With the Approval of the Superiors.

Of the Fundamental Principles of Physics

Since the serious study of the philosopher looks above all to this end, that he might achieve certain and clear knowledge of things, we ourselves have determined at the outset to consider the principles on the basis of which, in this our treatise of physics, our mode of thinking should be directed towards Nature. With John Keill,[a,1] we consider four schools of naturalists to stand out from the rest, the first being the Pythagoreans and Platonists; another has its origin in the Peripatetic School;[2] the third group of Philosophers pursues the experimental method; and the last school of Physicists is commonly known as the Mechanists. While not all the precepts propounded by these Schools gain our assent, yet in each there are certain things of which we approve, especially since we abhor the fault with which Leibniz charges the Cartesians,[b,3] namely that of regarding the Ancient Authors, almost as if this were their right, with contempt. And since

> *Those things last long, and are fixed firmly in the mind,*
> *Which we, once born, have taken in from our earliest years,*

we select what will be of most use in the future, and of all this we present to our Scholars an ordered account, lest it appear to anyone that what we have heard or read[c,4] has been adapted by us contrary to the method by which, in the Colleges, Youth is instructed in the disciplines generally and especially in those that are Philosophical.

Since outside Geometry and Arithmetic[d,5] very little concerning natural causes could be established with certainty, each of these, among the ancient Pythagoreans and Platonists, was judged necessary to the proper practice of philosophy. In fact, we cannot carefully observe the matter of bodies except by taking notice of the dimensions, motion and other properties of bodies which are capable of increment and decrement, or, as Newton says, which can be *increased* or *decreased*.[6] Wherefore, since the elements of Mathematics are concerned with quantity, we cannot fail to use the same in instilling the

[a] *Introductio ad veram Physicam*, lect. 1.
[b] *Life of the Illustrious Leibniz* written by M. de Neufville, p. 43.
[c] Preface to *Les Elémens de Mathematiques* by Rev. Fr. Bernard Lamy.
[d] Galileo in *The Assayer*.

Basic Principles of Physics, in order to avoid the necessity of concealing from our Scholars many things respecting the nature of bodies. Thus it is that we wish our scholars to be thoroughly familiar not only with the elements of Geometry but also with the rudiments of Arithmetic and Analysis. Nor, in agreement with the Peripatetics, will we be afraid to borrow the words "Quality," "Faculty," "Attraction" and others of that sort; not because it has occurred to us that through the use of these terms may be determined the true cause, physical reason or mode of motion, but because through them it is possible to establish the principles governing the increase and decrease of forces. And if their true causes lie hidden from us, why indeed should they not be called "*Occult Qualities*"?[a,7] By the same sound rule according to which we use the letters *x* and *y* to stand for unknown quantities in an algebraic equation, we can also, using an only slightly dissimilar method, investigate the increase and decrease of these quantities resulting from certain given conditions. Once the principles of forces have been deduced from the given conditions, it remains to compare these principles with the phenomena of Nature, so that it may be evident which kinds of force apply to each kind of body. For this, we need have recourse, with Philosophers of the third School, to experiment. To their efforts Philosophy owes no small part of its advancement, though greater progress would have occurred, perhaps, if the Adherents to the Experimental method had themselves avoided inventing false theories, and wrongly directing their experiments to their confirmation. It is remarkable how easy it is for experiments to fool even prudent men, *especially through those deeds for which*, according to van Musschenbroek,[8] *Jupiter created the left hand*. Therefore the mind which abhors the study of parts must rely on experiments alone, and on those done correctly. In the end it is through both the Ancient Atomists and the Recent Disciples of Philosophy that we shall find out which things and what kind of phenomena can be explained in terms of matter, motion, and the established laws of mechanics; always remembering that most famous saying: Man, being the servant and interpreter of Nature, can do and understand so much and so much only as he has observed in fact or in thought concerning the order of Nature.[b,9]

[a] Keill, *ibid*., lect. 1, and Jacquier *Inst. Phil*., sect. 1, c.3, art. 2.
[b] Bacon, *Novum Organum Scient*., Book 1, Aphorism 1.

Wherefore, in accordance with the custom of the Eclectics of not being bound by the rules of any single School that we are required to obey, we adopt no particular guide among the Physicists, but, on the whole preferring none to another, shall choose to drink from all of their springs to the extent that we judge appropriate:

> *……. My mind is persuaded*
> *By reason alone; reason is the faithful guide of the wise;*
> *Let him who seeks Truth love and follow it above all.*[10]

To the extent, however, that Gravesande[a,11] is correct in applying the name *Newtonian Philosophy* to that in which the conclusions are deduced from the observation of phenomena once the hypotheses have been rejected, the *First Principles* of *Newtonian Philosophy* can be defined using the same criterion. If therefore we sometimes adduce such hypotheses, let it be only tentatively, so that their truth may be debated rather than that the phenomena of Nature be explained definitively in their terms. Whatever is not inferred directly from experiment and observation we countenance only as bare conjecture. Hence, we inquire into not merely the plausible[b,12] but the true causes of things. There will be some, perhaps, who care only, as Quintilian[13] says, *to call everything to judgment but in reality to prove nothing*, who will throw scorn on this method as too slow and pedantic, and as too constraining of human intellect, since they think that what is to be investigated is not only what Nature brings to us, but also what she *might* bring. On this let everyone follow his own counsel. My judgment has always been that Physics[c,14] is full of toil, advancing by slow steps and consolidating itself through observation and experiment, so that finally we may establish something certain.

From this it follows that we ourselves, while calling ourselves Eclectics, do not seek to ground form of knowledge which van Musschenbroek called "Patchwork,"[d] sullied by innumerable trifles and old wives' tales, and full of shameful nonsense; neither can Bacon blacken our name;[e] nor de Volder[15] proclaim our method the worst in

[a] *Ad Philosophiam Newtoniam.* Introduction prefixed to both of the earlier editions.
[b] Van Musschenbroek, *Introductio ad Philosophiam Naturalem*, ch. 1, §32.
[c] Van Musschenbroek, *Ephemeridibus Metheorologicae Ultrajectinae.*, 1728. *Physicae Experimentales et Geometricae*, Additional Dissertations.
[d] *Oratione de Methodo instit. Experimenta Physica*.
[e] Ibid.

Philosophy.[a] In fact, these worthy men among Physicists would be right to declare war only on those who, content to collect the observations and experiments of many other Writers on Physics, themselves make trial of nothing, but instead rashly confound truth with falsity. The investigation of those experiments which are remembered as having been conducted on bodies falls to us; in which matter, that we may more easily avoid error and succeed in becoming experts through practice, we follow in general in the footsteps of van Musschenbroek,[b] Deslandes[c] and Poleni;[d] and, in truth, out of all the members of the Accademia del Cimento,[e] in those of 's Gravesande,[f] Nollet,[g] Wolff,[h] and others without distinction,[i] of whose brilliance we say, with van Musschenbroek, *may it be clear for all to see*.[16]

For indeed we do not reject all the principles of Physics put forward by Philosophers, as if they were less accomodated to use. In particular, the eight proposed by Jacques Rohault,[j,17] as well as the two added to them in his *Reflections*,[k] and above all the sixteen Physical Axioms of John Keill,[l] are by no means lacking in utility. We maintain only that it is necessary, following in his footsteps, to base our view on the three principles of philosophising which Newton used as Postulates,[m] grounded as they are in the infinite wisdom of God and the continual and consistent observation of Nature,[n] and to accept as useful and fruitful everything in this field that others have bequeathed us to this day.

Of this we present everything we must observe carefully in our investigation of the science of natural bodies.[o] And since

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[a] Ibid.
[b] In his very fine *Oratione de Meth.* etc.
[c] *Discours sur la manière le plus avantageuse de faire des Expériences*.
[d] *Specimen Instit. Phil. Mechanicae Experiment*.
[e] *Tentamina Experimentorum Naturalium*.
[f] *Physices Elementa Mathematica Experimentis confirmata*.
[g] *Lezioni di Fisica Sperimentale*.
[h] *Physica Experimentalis* translated idiomatically from the German into Latin.
[i] Among these we make frequent mention of Galileo, Torricelli, Boyle, Newton, Pascal, Mariotte, Boerhaave, von Guericke, Sturm.
[j] *Traité de Physique*, part.1, cap. V.
[k] Antoine le Grand, quoted in Rohault, Reflection 4.
[l] *Introductione ad Ver. Phys*., lect. 8.
[m] *Philosophiae Natural. Principiis Mathemat*. lib. 3.
[n] 's Gravesande, *Physices Element. Mathemat*. chap. 1, n. 4; Musschenbroek *Essai de Physique* chap. 1.
[o] Keill had already called this the science of *natural bodies*, and Father Jacquier likewise argues for using the same words in his *Inst. Phys*. cap. 1. n. 1.

> *The soul leads us to write of many and various things,*
> *not to be spun around in a single eddy: where the winds*
> *lead we go,breasting the waves now here, now there.*
> *Now we seek the wastes of Pontus, now some safer shore.*
> *And even though at times, with reason my guide,*
> *I brave the hidden ways of Nature and pry open her secrets,*
> *yet first of all shall I follow everything that appears,*[18]

we look first to the Philosophers who investigate natural bodies by the precepts of the method to be set forth. I myself examine these as one half-learned among the learned; in order to avoid rashly assenting to what is either false[a] or insufficiently studied, it seems to me appropriate that we also scrupulously compare argument with argument.

[a] Cicero, I. 1. *de Divinitate*.

Of the Science of the Elements

Of Body in General, and of its Attributes

ANALYSIS

I

Since, before Descartes, almost everyone held that human knowledge has its first origin in the senses, and since it seems obvious that the existence of bodies is made manifest through the power of the senses, it is no surprise that philosophers were little concerned to prove the existence of the same. However, since that esteemed follower of the teachings of the Platonists sought to show that our mind becomes aware of its own existence prior to that of body, the prime object of consideration has become by what rational explanation the existence of bodies might be demonstrated. Hence several philosophers, the most prominent among whom are Locke, Arnauld and Clarke, have assembled numerous arguments by which the existence of bodies might be proved.[19]

II

Many have attempted to call the *Existence* of bodies into question. Malebranche, against whom Arnauld was perfectly right to contend, believed it very difficult to prove, and then only through Faith in the Divinity. Michelangelo Fardella, in his *Logic*, held that sensations do indeed derive their origin from a substance supposed to exist outside us, but that it cannot be safely inferred hence that this is body. Bayle added his opinion, in so far as he seized readily upon everything by which skepticism might be supported. George Berkeley, indeed, denied it [the existence of body] utterly.[20]

III

Leaving aside the trifling cavils of the Idealists, and, as Pietro de Martino[21] advises us, following the more renowned Philosophers, we take the Existence of Bodies as a postulate, after the fashion of Geometers, and prefer to lead off the inquiry with the question of what idea of bodies we could therefore acquire. We place the origin of this idea in the sense of *Touch*; for through tactile sensations we perceive to co-exist a

multiplicity of things, each of which excludes the others, in such a way that it is not possible for them to interpenetrate one another. On the other hand, what is presented to *sight*, about which suspicion might arise, appears to stand in need of further definition, and, if not informed by touch, to fall short of the idea to be acquired.

IV

We say that the real *Essence* of bodies must be counted among the many things that before now have escaped our understanding entirely. However, we shall first review and refute the opinions of the [relevant] Philosophers, so that in this way it will be clear what and how many disadvantages we may avoid by disagreeing with those others.

V

Among the Ancients, then, Pythagoras and the Stoics were deluded in thinking that, as Plato taught, the essence of bodies resided in their having three dimensions. Aristotle himself said that body is that which is extended in every direction. And no one has defended this claim more vehemently than Descartes and his followers, of whom Malebranche leads the pack.

VI

Those have also been led into error who place the essence of bodies either in *actual solidity*, as Gassendi, following Epicurus, appears to have done;[22]

VII

or else in the *natural necessity of occupying space impenetrably*, as Fortunatus [Girolamo Ferrari] of Brescia judged, agreeing with the opinion of many others though on the basis of better reasoning;[23]

VIII

or again in three essential properties together, namely *extension*, *inertia* and *motive force*, which is the approach of Leibniz, and of his more rigorous Followers.

IX

Accordingly, we must rest content with the essence which they call *nominal*, which is revealed through the senses owing to just this collection of attributes. All we know for certain that all bodies on which we can conduct experiments possess certain common properties, upon which it is our intention to touch briefly here. Yet whereas extension may be the property by which body is distinguished from Spiritual substances, it is in truth *solidity* by which the same body differs from an extended vacuum: therefore, body will be defined, through its nominal essence, as *substance extended and solid*, in other words impenetrable.

X

No one can accept the hypothesis explaining the origin of matter that, as Pierre Coste reports, Newton communicated to John Locke and the Earl of Pembroke, who notes, with Coste himself, that the matter of bodies cannot be derived from the fact alone that God allows nothing whatever to display a greater number of dimensions of extension.[24]

XI

When we consider the first elements of things, that opinion most deserves our assent, out of all that have been put forward, which posits the existence of the most minute particles of matter, impenetrable and extended, which by their coming together constitute molecules of various kinds, and which have the capacity for motion and, by their multiple combination, for producing the whole variety of sensible things.

> *These compose the sky, the sea, the earth, the rivers, the sun;*
> *Likewise the fruits of the fields, the trees, the animals:*
> *The elements can change only in their arrangement.*

Thus was it expressed astutely by Lucretius.[25] However, what the inner nature of these particles is, in truth, I believe no man knows.

XII

Are we not also ignorant of whether these smallest things are of the same or of different sizes? Whether they are of the same or of different shapes? What precise size they have when we understand them to compose a given object? For even today it is not possible to descry them with the help of a Microscope.

XIII

Moreover, whatever even the more renowned Metaphysicians, both Ancient and Modern, may have essayed in relation to these things, no conclusion can be drawn about them on the basis of reason.

XIV

Yet there are those who wish to ascribe[26] everything to a precise image: many hold that all these smallest things have the same shape, and are indeed round, since their being of the same size and shape is more suited to the utmost simplicity of the working of *God.*

XV

The size and shape of these ultimate solids depend only on the will of God, who wishes them to be no different from such as they were at the Creation. Wherefore we shall inquire with quiet diligence and subtlety into the reason why these things are as they are. Since these ultimate things are of limited extent, they had to be given *some* size and shape: God gave them the best, and the most convenient to His ends.

XVI

Now it could be the case that the smallest corpuscles form an entirely solid and densely packed mass, adhering together in a fixed assemblage containing no empty space, as is easily shown by [the example of] a collection of equal parallelepipeds, if not by the five regular solids.[27]

XVII

In truth, however, if the smallest corpuscles were of the shape mentioned above, or if they were packed together in such a way that their surfaces were not touching at every point, there would be left between these solids other expanses of space which were not solid. We gladly agree, and do not support those who postulate that the greater part of such spaces are filled with a substance very rarified and extremely fluid.

XVIII

Thus, it is necessary to admit a *Vacuum* not only between the gross particles of matter itself, but also, within these, between the smallest components of bodies, calling the latter, with Gassendi, [*Vacuum*] *Disseminatum*.[28]

XIX

Descartes maintained quite plainly that *Vacuum* is so repugnant that it was not to be had even through Divine Omnipotence; which view, however, is easily shown to be in error. We demonstrate through innumerable and irrefutable proofs not only the possibility but also the very existence of negative extension, or Vacuum,. [Fig. 1]

XX

The Cartesians beg the question and make the claim that space is completely full, yet in fact they also deny it when, in order to ascribe motion to the plenum, they resort to the contrivance of an infinite and perfectly yielding fluid. [Fig. 2]

> *Fluid bodies, clearly, consist of parts freely moving,*
> *And with a surface smooth on every side;*
> *No leash, not even the lightest, might restrain them,*
> *But lightly they glide along in flow:*
> *Since they roll on slippery and polished sides.*[29]

The greatest disciple among the Cartesians puts it thus: elegantly, though incorrectly.

XXI

As indeed Huet rightly and most deservedly urges against Descartes when accusing him, on this point, of taking refuge in the obscurity of talk of the *Indefinite*.[30]

XXII

In order to disprove utterly the existence of Space, the Leibnizians object that negative extension is imaginary and a fiction of Mathematicians, for, if there were extension other than body, then, when there were bodies *in* that extension, one substance would be penetrating inside another. But it is in vain that the Leibnizians thus threaten war on the Vacuum: for, rightly understood, the interpenetration of substances can present no difficulty whatsoever.

XXIII

There are two Philosophers who ask, in relation to vacuum *Coacervatum*,[31] whether it can truly exist in the world, and whether it can be created by the forces of nature. On the question of its existence, Newton and his Followers are of the affirmative opinion; others, some indeed men of great account, of the negative: for us the jury is still out on this matter.[32] We are acquainted with the Boylean Vaccum, which occurs on account of their great capacity in Torricellian Tubes; yet we believe that in all probability a vacuum Coacervatum cannot be created.

XXIV

The parts of Space are filled with bodies, in such a way that nothing could be added to or taken away: by the same token it remains immobile and immutable. Accordingly I fear that someone should believe that one could accept the reasoning by which, van Musschenbroek says, some claim to prove that Space is mutable; for this reasoning has no weight.

XXV

Yet some will still wonder whether Space is eternal or created. Besides the Cartesians, the Adherents to the existence of vacuum also raise this most difficult question, about which it is far easier to say what is not thought than what is thought. It has been investigated since by many authors, and above all by van Musschenbroek, though by way of arguments which I fear might persuade others to the following: Gassendi in particular, and others besides, judge it [space] to be uncreated, eternal, and independent; but, by Hercules, these say what is apt to fool only the least observant. To Francesco Patrizi, Henry More, Joseph Raphson, Newton, Clarke, Lessius,[33] especially, and, if we are to believe Arnauld, Malebranche, space was seen as indistinguishable from God Himself in His Immensity: however, despite its being held by such illustrious men, one must recognise that this opinion cannot be admitted. How much those who uphold the opinion may be in conflict with Religion is clear from our propositions, published two years ago, on Natural Theology. What then should we conclude? It seems to us that in truth Space is distinct from all body, although Keill abandons to Metaphysics the decision on what is the origin of Space and what its nature: for us, however, this state of affairs constitutes no danger: we dare not take a position; for it is better to believe nothing than to believe what is either false or absurd.

XXVI

Although it may be right to conclude that space is truly distinct from body, yet the two may have in common that extension is a universal and essential attribute of each. Therefore, it will be appropriate to describe a general property of Extension, namely its Divisibility. Two senses of extension must be distinguished: the *Geometric* and the *Physical*. We believe that geometric division is subject to no limits, which claim (as can easily be shown from Euclid's *Elements* 1) refers, especially considering the notion of separation, only to the fact that any extension may [in thought] be resolved into parts. [Fig. 3]

XXVII

By contrast, for *Physical* or real division limits have been established which the power of neither Nature nor art can exceed.

XXVIII

The divisibility of matter is truly a marvel, and if we are to attend to reason and experiments, clearly exceeds vulgar comprehension entirely.

> *Notice how the smallest piece of ductile gold*
> *Is stretched wide with oft-repeated blows;*
> *How swiftly the dye permeates the liquid mass;*
> *Just as the thinnest breath of burning sulphur*
> *Brings to wine the foulest smell and taste.*[34]

We explore this area, repeating their most fruitful experiments, under the guidance of Mersenne, Boyle, John Keill, Leeuwenhoek, Halley in the Royal Society's *Philosophical Transactions*, no. 194, and Réamur in the *Records of the Royal Academy of Sciences*, in Paris, for the year 1713.[35]

XXIX

Meanwhile, as we bid farewell to the Leibnizian doctrine concerning the prior division of perceptible extension, we deny that Extension is [merely] an Appearance to Monads, that is to say, Simple substances.

XXX

On the same point, we contend that the geometrical hypotheses, both true and possible, are contrary to what is said by du Hamel, a writer of the Burgundian School of Philosophy,[36] and, what is more, affirmed by others. [Figs. 4, 5, 6, 7]

XXXI

Hence it is easy to understand what our opinion might be about the mathematical principles of Xenocrates and Zeno, and about the indivisible parts of Leucippus and Democritus, as also about the opinion of Sagüens, which differs little from these.[37]

XXXII

Although indivisible corpuscles seem to appeal to Nollet, yet he does not allow any kind of limitation on the *possibility* of physical division.

XXXIII

Galileo, although he did not expound his view as perspicuously as Newton or Leibniz, believed that extension has parts which are indivisible not in reality but only in name; indeed, he asserted that these could be considered as existing in *any* possible number, which is of course tantamount to positing *infinite* divisibility, as Keill observes at length.

XXXIV

From our view about physical divisibility, it also seems impossible for there to exist in Nature a *fluid* whose parts may be divided in reality to infinity.

XXXV

Here, the intellect refuses to assent to view of the Cartesians, who suppose an all-pervasive *Aether* permeating all bodies, and divisible into an infinite number of parts.

XXXVI

The arguments about divisibility which its adversaries have assembled can be reviewed under two main heads. First, they take pains to show that infinite division is simply an invention, an empty concept created by the mind. Under the other are included the absurdities which might be thought to follow from it. We reject both lines of reasoning, so that the intellect may be not only convinced but also enlightened. For there are certain kinds of proofs in the sciences which exact agreement by the force they exert on our feelings, yet which do nothing to illuminate the faculty of understanding. We should therefore desire not to complain that at times the sacred word “Demonstration,” is used equally in serious discourse about concepts and in that of dilettantes. [Fig. 8]

XXXVII

As a result of their division into parts, the surfaces of bodies increase in area. However, since in the case of similar solids the ratio of surface area to volume is reciprocal to that of their corresponding sides, we may, with D. Pitot,[38] determine how big an increase each surface of the bodies receives through division alone; from this we can explain many phenomena which are both useful and most agreeable. [Fig. 9]

XXXVIII

Since indefinite bodies could not exhibit extension, yet be bounded by certain limits, it follows that the *Figurability* attributable to bodies could not in any way be separated from their matter itself, and is nothing other than that relation which exists between the parts constituting their solid extension.

XXXIX

No one can justly question the fact that all bodies are provided with some shape; yet some of the old Scholastics did indeed deny shape to the smallest parts of bodies, albeit incorrectly.

XXXX

Whether the parts which are united in bodily extension be infinitesimal, or finite but vanishingly small, they always coexist in such a way that they cannot at all interpenetrate and become interfused. On account of this resistance which the parts of solids exert on one another, they have also been called *Impenetrable*.

XXXXI

Those Philosophers who truly understand how to distinguish space from matter agree that *Impenetrability* (as the Cartesians, following the Peripatetics, call it) or Solidity (as John Keill prefers) touches upon the essence of matter.

XXXXII

Therefore, whatever Hooke may have said casually in response to an observation of Hauksbee, we attribute to him [a belief in] that property, applying to all bodies, by which each resists any other. Unless bodies were impenetrable they would be annihilated by the least pressure.[39]

XXXXIII

On the other hand, those things that Madame du Chatelet espouses in her singular *Dissertation*, denying probability to the impenetrability of fire, are nothing more than ingenious attempts.[40]

XXXXIV

The Peripatetics were surely in error regarding what they call *prime matter*, when they conceive it as lacking both magnitude and shape. According to them, impenetrability does not pertain to the essence of matter, but is the natural effect of its physical magnitude. Hence this hypothesis expresses the idea of potential, not actually existing, matter.

XXXXV

While solidity implies a resistance to penetrability, hardness is in fact constituted by the firm cohesion of the parts of the body; it is easy to comprehend that the one is clearly distinct from the other. In this too many excellent Philosophers have fallen badly into error, perhaps through conceding too much to authority and too little to reason. It is a subject on which the most influential of poets:

> *It happens often that the grave and great, deserving of fame,*
> *Fall into error and stumble; and these, with their eyes closed,*
> *Have dragged many authors of high repute,*
> *Into the same darkness where they themselves abide*.[41]

XXXXVI

Solidity does not arise from extension; for we acquire the idea of this attribute, in fact, by exerting pressure on other bodies with our hand, or by observing them resist external pressure: which is clearly evident, says van Musschenbroek, from the images of bodies reflected in a concave spherical mirror, and suspended in air.

XXXXVII

Whereas some Philosophers have been at great pains to show that this is false, maintaining that it can happen that one volume of a cubic foot in size is occupied by another such volume, if the second volume is not annihilated by the first, I ask, do they reason thus from their own [preconceived] Idea of extension, or from Experience? If the former, are Mathematicians forbidden to conceive mentally a Sphere within a Cube, a Cone within a Sphere, a Cube or a solid of another shape? Since, in truth, without resistance the images of bodies reflected in a concave mirror would be penetrable, our Opponents have taken refuge in an entirely misleading Experiment.

XXXXVIII

Although we may form the idea of Solidity by exerting pressure on bodies and meeting resistance, this does not reveal to the mind what produces such resistance in bodies. We do not know, then, how solidity inheres in an extended body. Nor is this surprising; indeed, the manner in which properties belong to a subject is plainly beyond human understanding, as we are best reminded by Maupertuis.[42]

IL

Distinguishing clearly between solidity and the force of Inertia is to the best advantage of the physical sciences. *Inertia* is common to all odies, in so far as it maintains the body in its state either of rest or of motion.

L

On the basis of the Impenetrability and Inertial force of bodies, certain Defenders of Newton’s opinions agree in attributing to matter the power of resistance; which yet

they call *passive*, because bodies do not exhibit it unless they are acted on by something external.

LI

From this it has come about that several Philosophers who have overlooked not the word Inertia but rather its innate character and effects, have erroneously decided, in agreement with Descartes, that this force arises from the resting state of the parts.

LII

Now, if a body be moved, its inertia sustains the motion, and it will continue to move forever, with the same velocity and direction, as long as it is moving in a vacuum. Hence a freely-moving body is neither accelerated nor retarded; and its inertia has two effects, one of which is to maintain the same velocity, the other the same direction.

LIII

A body at rest strives with a body in motion, trying to remain at rest, and the moving body strives with the first, trying to retain its motion: each struggle displays inertia.[43] The larger a body is, the more it resists external forces tending to impart motion to it; and the more slowly it is moved by forces of equal strength.

LIV

Therefore Inertia is proportional to the quantity of [matter in] a body, and this applies equally to the smallest solids. Therefore what appears in Solid bodies is also true of Fluids. Wherefore, the quantity of [matter in] the body remaining the same, whether it is solid or has been melted into a fluid mass of extremely fine particles, the inertia of the entire mass will be the same.

LV

From these considerations, furthermore, it can be shown that the very subtle fluid which, as we have said, the Cartesians call Aether, and which lacks any pores or internal vacua, cannot exist.

LVI

Joseph Privat de Molières,[44] indeed, thinks that the minimal resistance of the aether arises from the fact that the aether is not heavy: but since it is not possible to demonstrate, as Privat asserts, that all bodily resistance is derived from weight, this leaves him in a rather difficult position.[45]

LVII

A body at rest displays inertia in all the conceivable directions in which another body can impinge upon it: likewise inertia inheres in a body in motion in any direction in which it may be moved; therefore inertia does not depend on the magnitude or direction of gravity.

LVIII

Hence those who have confounded these effects with the effects of Gravity, as Nollet's experiment attests with especial brilliance, were wrong, having

Wandered a long way from true reason.[46]

LIX

Thus it is perfectly clear that a body, as long as it is undergoing change, to which it is always subject, is endowed with inertia, and indeed displays the same [amount of inertia] in equal changes; which an Italian Author,[47] admirably, first illustrates through experiment and then corroborates through reason by reference to van Musschenbroek's *Introduction to Natural Philosophy*.

LX

What this force of Inertia may be physically, whence it arises, or how it inheres in a body, we cannot deduce by the understanding [alone]; in truth, it inheres in the inner substance, through which it is uniformly distributed; therefore we observe and know only whatever effects it produces.

LXI

However, we consider it superfluous to conceive of some force, a new entity distinct from the substance itself of bodies, which we might call the Inertia of bodies.

LXII

There is no doubt that Inertia is a real attribute of bodies, and not merely some privation. It is certain that a body displays greater Inertia against a force that moves it faster than against one that moves it more slowly. Therefore, quantity applies to Inertia, whereas it must be entirely denied to a privation. Hence Inertia is proportional not only to the quantity of matter, but also to the magnitude of the impact.

LXIII

Unless inertia remained constant in the component bodies of the Universe,[48] the beautiful motion and order of all things would not last long. The Geometrical laws of motion, as Leibniz reminds us, would not be in force; and also the laws governing Collision might be very different from the way they are. Likewise, only an utter clod in Physics is unaware that the principle of action and reaction, and centrifugal and tangential force, arise clearly from this same inertia: otherwise, what state of disorder might not exist in the Universe?

LXIV

Wherefore Malebranche, Jean Le Clerc and de Molières fill the bladder with air, while they strain all their sinews to rob bodies of inertia.[49]

LXV

Here it seems to me necessary to point out that I do not sufficiently understand with how much justice the author of the annotations in van Musschenbroek's *Elements of Physics* may maintain that there is, in the doctrines touching on inertia of Newton, Keill, Clarke, 's Gravesande and van Musschenbroek himself, something expressed in a rather obscure and confused way.

LXVI

Surely Gravity, Elasticity, the Human Mind, God, as well as other spiritual causes, so we may believe, show that the inertia of bodies does not engender on its own all the changes that occur in the world; but that other forces exist in the nature of things; nor do these arise from inertia: devoting oneself to this investigation is for many a source of great pleasure.

LXVII

We have claimed that inertia exists in bodies both at rest and moving from one place to another. Therefore we take it that certain bodies are actually moved. This actual motion is to be distinguished with the utmost care from *Mobility*. Whereas all bodies entirely can be conceived of as Mobile, it is not true that all are actually moved. Therefore every body, whether it be great or small, is capable of being transported from one place to another; and, in truth, Motion is an affection of bodies which we often consider to be absent.

LXVIII

Pure extension, despite its being the first property of all bodies, is not endowed with Mobility. Hence there is merit in what we have said about space, namely that, by the same token, it subsists immobile, while its parts may or may not be filled with bodies.

LXIX

Mobility depends on several conditions, which are not the same in all bodies. Hence certain bodies are endowed with greater Mobility than others, that is to say less force is required for some resting bodies to be put in motion than for others. Now, first among these conditions are the shape, the smoothness of the surface, and the quantity of matter contained within the volume of the body to be moved.

LXX

It is not necessary that every body be moved in order to exist, since it could have remained forever in the place where it was created; if in fact it be moved, then a body's

motion may [also] be removed while it continues to exist; to this extent every body can be said to be *Quiescible* [sc. capable of rest]. However, it is necessary that a body be in a state either of motion or of rest. While it is at rest, its mobility still remains in it; likewise, when the body is moved, its quiescibility is not destroyed. Wherefore *Quiescibility* is an attribute just as much as *Mobility* is. Thus argue van Musschenbroek, Jacquier and others; Tschirnhausen, Leibnitz and Hoffmann,[50] however, disagree.

LXXI

Whether bodies are at rest or being moved, therefore, it must be admitted that they have some kind of disposition to motion; one thing is certain, namely that the particles out of which they are composed are not interconnected in such a way that they fill completely the whole space occupied by the body. Wherefore, there is no body, as far as a Physicist may suppose, which is entirely lacking in *Pores*.

LXXII

If many corpuscles fill a small space, then the mass [they compose] is Dense; whereas it is Rare if a few corpuscles occupy a large void. The greater the number of corpuscles packed into a small space, the Denser will be the body; the greater in number or in size the Pores in masses of the same magnitude are, the Rarer will be the body they compose..

LXXIII

Whatever is solid in bodies cannot be penetrated by a body; therefore any mass into or through which another body can pass is of necessity Porous. The observed fact that many fluids, both thin and thick, may be both penetrated and absorbed by bodies, demonstrates that all bodies, whether they are from the Mineral, Animal or Vegetable kingdom, are perforated by Pores. We take great pleasure in the investigation of such matters, adopting here and there whatever was found more useful by Pliny, du Hamel, de Lanis, Homberg, Hooke, Hauksbee, Réamur and the Historia Academiae for the years 1713, 1728, 1732 and 1733.[51]

LXXIV

Since so far not a single corporeal mass accessible to touch has been found to be completely solid, it is well nigh impossible to determine how much is solid and how much is porous in any given volume. Hence, to the great benefit of our Scholars in their study, we delight them with observations of the most pleasing variety, abundance, magnitude and shape of the Pores of various bodies, as well as with experiments with the Pneumatic Machine[52] and, most of all, with the Microscope, skilfully perfected in both Simple and Solar forms.

LXXV

Although it is easy to understand, from the way in which large bodies are formed, how the penetration of other bodies occurs, yet it sometimes happens that even small particles cannot pass through large pores in bodies. Van Musschenbroek recounts the observation that water passes through a moist pig's bladder, but the smell of wine does not, though this is much subtler than water. Van Musschenbroek himself contends that this and several other similar effects can be attributed to some kind of repulsive force. Nollet sets out to explain the same through certain proportions, in size and shape, of the pores and solid parts, though this ingenious Author acknowledges finally that it cannot be denied that dubious explanations are drawn from certain principles founded and established by unanimous agreement when, in our conjectures, principles are used merely to account for appearances, and experience fails to demonstrate that we have grasped the thing itself.

LXXVI

The *Rarity* of bodies can be increased or decreased; it is increased when the parts recede more and more from one another, or when, the volume remaining constant, solid parts are successively removed from the interior of the mass.[53]

LXXVII

However, from the fact that the parts of matter may end up in renewed contact is deduced the explanation of *Compressibility*, which is observed in both elastic solids and elastic fluids.

LXXVIII

As has been clearly established by the Florentine Academicians, du Hamel, van Musschenbroek and Nollet, it has not yet been shown possible, by the effect of any force whatsoever, to squeeze any liquid, especially water, in such a way that it displays to the senses the property of Compressibility; into which matter little investigation has been made by those who agree with us, compared to the great deal made in support of the contrary position by Bacon, Fabri,[54] Boyle and others, in which they argue, as 's Gravesande so astutely notes, that the apparent decrease in space [occupied] can easily be attributed to other causes.

LXXIX

Given, however, the distinction between absolute compression and compression that is accessible to sight and touch, we do not accept the unproved animadversions of Honoré Fabri on Raffaello Magiotti,[55] who asserted that water cannot in any way be compressed.

LXXX

Chauvin[56] says that water is indeed capable of Degrees[57] of density, since in its naturally inert state it can be made to produce waves: but these are pure figments with no basis in either reason or experiment.

LXXXI

It is surely a great wonder that Water, a body endowed with no Elasticity, as far at least as can be perceived by the senses, seems when heated to acquire such great powers to expand. Yet anyone who is overly surprised by the fact that, because of its elasticity, steam is able to lift water and heavy bodies to remarkable heights, shows that he is

unaware of the degree of grace and beauty the science of Mechanics has achieved.[58] The use of these machines for practical human ends was pioneered in Britain by Savery and in Germany by Papin. An outstanding automaton of this kind in London is described by Weidler.[59]

LXXXII

When expansion continues, and heat is dissipated, water loses the ability to produce all these and other wondrous effects; on this the steam engine experiments conducted for the benefit of our Scholars throw the most excellent light.

LXXXIII

Descartes' cannot explain the *Elastic* force of bodies in terms of the infiltration of aethereal matter into the pores of elastic bodies.[60]

LXXXIV

Similarly for Malebranche, and with him Fr. Mapier,[61] through minute vortices balancing one another with centrifugal force.

LXXXV

And again for those who, with Bernoulli,[62] have recourse to small pockets of dense air interleaved between the different layers of bodies.

LXXXVI

To be sure, we do not deny that the elasticity of air is increased by heat; but we reject utterly the opinion of some that identifies Heat as the cause of Elasticity.

LXXXVII

That Gravity joins together all the material parts of any body, no matter how great or small, and therefore should be ascribed to bodies as a generic property, is overlooked only by those who are ignorant of the experiments and observations of Wallis, the Accademia *del Cimento*, Borelli, Clarke, Santorio, James Keill, and Hales.[63]

LXXXVIII

To whom then does the doubtful claim of certain Philosophers *that clearly the elements do not gravitate to their own places*, i.e. water to water, air to air, sound reasonable?

LXXXIX

As far as concerns whether fire is subject to Gravity, we deny that the experiments so far undertaken by the illustrious Duclos, Boyle, Homberg and Lémery, and in particular those using scales in an attempt to prove its weight, fail to render the judgment uncertain.[64]

XC

Hence, we differ from Boerhaave[65] and du Chatelet, both of whom take a firm position against the gravity of fire, while also deviating[66] from van Musschenbroek's absolutely contrary opinion.

XCI

Although, as Galileo pointed out and Newton was the first of all to confirm by experiment, [the force of] Gravity is proportional to the quantity of matter, it is not everywhere the same, but stronger in places near the Poles and weaker near the Equator; as we know from having made multiple observations with the help of Pendula.[67]

XCII

The above variation is usually assigned to four causes, either Cartesian Vortices, or the non-uniform Density of the earth, or the latter's ovate Figure,[68] or its Motion around its own axis. Which of these causes might be the more plausible we leave it to others to determine.

XCIII

In the absence of a determinate comparison of these, our opinions are as follows: [first] that the Cartesian hypotheses is utterly inconsistent with experience; indeed, the observed diminution of gravity as one moves from the poles to the equator shows that the gravity of bodies does not arise by a fixed law from their matter [alone]. [Fig 10]

XCIV

[Second], even if the non-uniform density of the earth be conceded, the hypothesis is in every way inconsistent with the phenomena of diminishing gravity; thus, it is shown by observation that the increase in gravity is strictly proportional to the square of the sine of the angle of latitude of the place in question, in other words certainly does follow a constant law. The arguments of Boscovich in favour of his hypothesis are truly ingenious, but cannot surpass the limits of the possible: moreover, Fr. Frisi has given sufficient answer to the difficulties raised by this illustrious man when he seeks to call into question the vain observations of the Parisian Academics who claim that the earth is flattened between the Poles and wider at the Equator.[69]

XCV

Many observations prevent our subscribing to the third Hypothesis, as also to the opinion of Mairan and Boskovich. These are certainly of importance, even if it is allowed that in the primeval state of the earth a constant [force of] gravity acted either (with Boscovich) in the direction of two points on the major axis of the earth, which are referred to as the Poles [sc. foci?] of the terrestrial Ellipse, or (with Mairan) along lines tangent to the four parts of the curves he imagines around the centre of the earth, from the evolution of which, this most excellent Author contends, has arisen the ovate shape of the globe.[70] [Fig 11]

XCVI

Finally, the diurnal motion of the earth around its own axis is believed by some, and especially Dr. Sigorgne,[71] to account more adequately for the observed variation in Gravity. However, we think it more prudent to wait for the ingenuity of Physicists to throw greater explanatory light on these matters. [Fig 12]

XCVII

From another law of Gravity it follows that the weight of a body depends on the number of its particles of matter, since its weight is nothing other than its own gravity spread throughout its material parts, and is proportional to the latter.

XCVIII

Hence weight does not depend on the Form of the body, as Aristotle argued; nor on the *shape*, *location*, *arrangement* or *surface-texture* of bodies, as Descartes believed.

XCIX

Aristotle proposed, and defended against Democritus and Plato, the belief that there exists *positive lightness*, through which, as if it were a principle inhering in some bodies, they are made to rise. Many of the Peripatetics have followed him, some of them fabricating the view that therefore there is a Sphere of fire, above that of air, which is constantly aflame: but such talk has now fallen silent.

C

On the subject of the origin and cause of Gravity, having rejected the ideas of Paolo Casati, Andreas Rüdiger and others that gravity can be explained in terms of *desire*, *conatus*, *power*, *appetite* or by other words without substance, we assert that neither [can it be explained], as it is by William Gilbert, Gassendi and the latter's follower François Bernier, by appeal to particles emanating like so many rays from the centre of the earth.[72]

CI

Nor by Descartes in terms of vortices of subtle matter, as agreed among Huygens, Rohault, Malebranche, Jacob Bernoulli, Privat de Molières and other Cartesians both old and new.[73]

CII

Nor can it be correctly explained through the various hypotheses proposed by Bülffinger, Hartsoeker and Varignon, which more clearly indicate a fervent imagination than closeness to the truth.[74]

CIII

Moreover, what Newton says in his *Optics*, and in the letter to Boyle on the tenuous and elastic Fluid, where the Author undertakes to explain gravity in order to humour those who delight in these hypotheses, is not sufficient. On the contrary, that the [Cartesian] hypothesis did not please Newton himself is quite clear from the conditions which, in the General Scholium to *Principia Mathematica*, he requires to produce gravity in such a Fluid.

CIV

Since, therefore, the Hypotheses examined so far are inadequate to explain the phenomena at hand, or the laws of Gravity, and since this cause (if we have understood correctly) is distributed inside the whole body, and cannot arise through impulse; and since there is no reason for thinking of Gravity as an effect, rather than as a cause, except when, in line with the hoary practice of the Schools, one is inquiring into the cause of gravity, it seems that Gravity is the initial impulse or motion imparted by God to every individual part of matter, so that they might all, at the same time and in accordance with fixed laws, be directed towards the earth.

CV

We who have emulated the Philosophical restraint of Newton, 's Gravesande, Jacquier and Nollet, by no means proclaim that there is no external cause of Gravity which arises from some or other Fluid.

CVI

We contend only that Gravity does not result from any Impact acting in accordance with laws known to us, nor therefore by the action of any *Fluid* which[75] has the known properties of Fluids.

CVII

Here is what we say about what Newtonian *Attraction* can do, whether it is manifested in the form of Elasticity, Gravity or just in general. Attraction, in the context of the phenomena of coherence, must certainly be admitted; but on the other hand it is not sufficient answer to the questions raised in the investigation of the cause of the [relevant] effects.

CVIII

Truly, something understood as a Cause, however abstractly and vaguely considered, cannot simply be denied; in truth, if neither its nature, nor its mode of action, nor its fixed laws is specified, scarcely anything will have been brought forward besides the word itself. And then Attraction will be almost on the same footing as Occult Qualities.[76]

CIX

If it is proposed that Attraction is indeed a force intrinsic to the body, the body in which it inheres being drawn towards another in accordance with certain laws, then it is necessary that the laws be laid out. Even if we grant that the Laws of Terrestrial Attraction proposed by others fit some of the various phenomena, we must admit that they do not explain them all equally well.

CX

Even if we do not easily concede the opinion of those who, overwhelmed by enthusiasm for studying [material] parts, are led astray, so that they believe themselves to have intuitive evidence of the power of Attraction, we cannot allow ourselves to believe it so absurd and repugnant; or, as we say with Polignac:

> *All-powerful Attraction creates the miracle of the World,*
> *And, though in itself it is nothing, is made ruler of all.*[77]

Hence it is not inappropriate to include it in the explanation of natural effects. In these things again virtue lies in avoiding error, and

> *Sweet it is, when the vast sea is disturbed by storms,*
> *To watch from the land another's great misfortune:*
> *Sweet too to watch the dreadful strife of war*
> *In the fields, when you have no part in the danger.*[78]

THE END

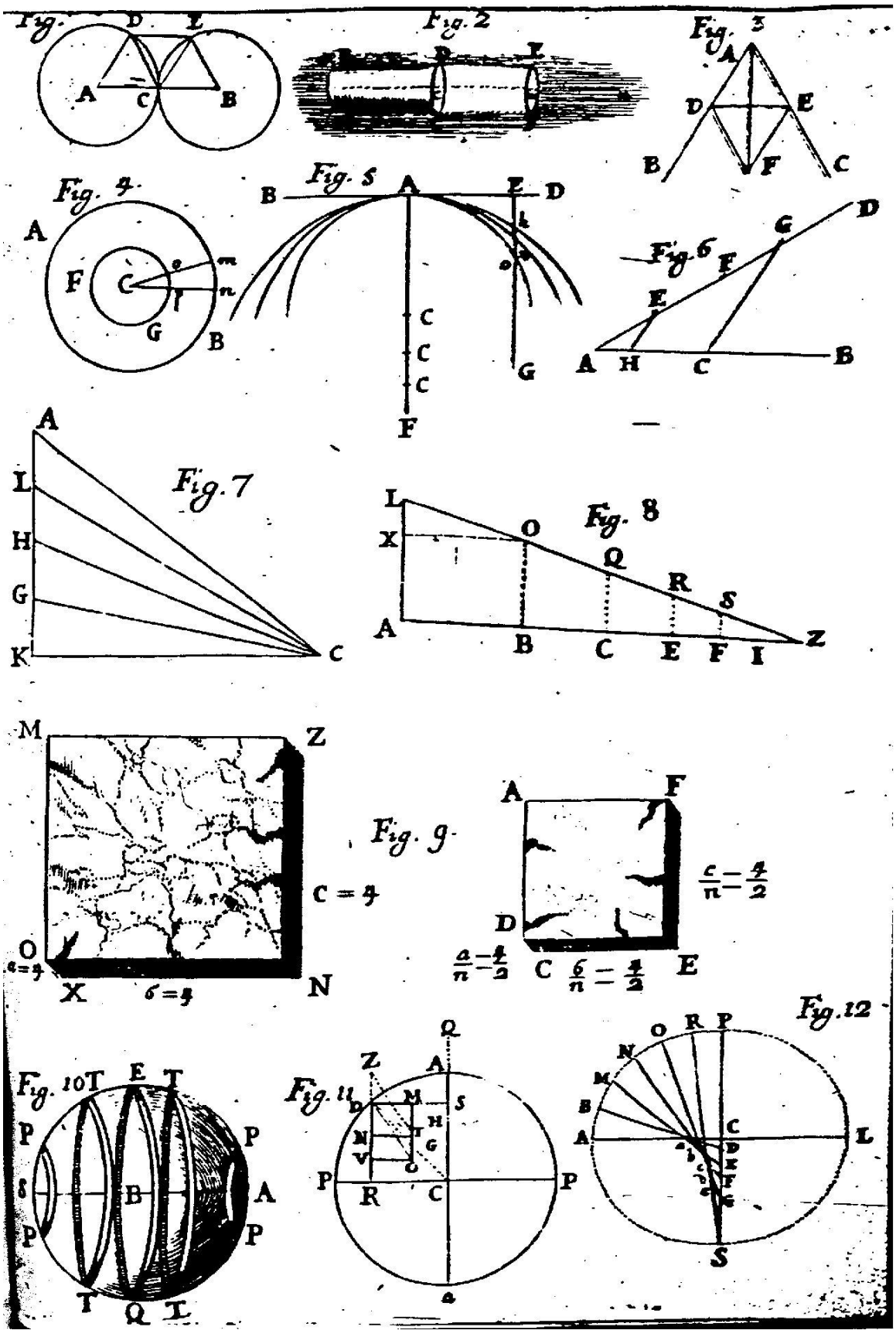
Fig. 1
Fig. 2
Fig. 3
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Fig. 5
Fig. 6
Fig. 7
Fig. 8
Fig. 9
Fig. 10
Fig. 11
Fig. 12

Endnotes

[1] John Keill (1671-1721), Scottish mathematician, in his *Introductio ad veram physicam: seu lectiones physicae Habitae in Schola Naturalis Philosophi Academi Oxoniensis*, Oxford, 1705.

[2] These terms refer to the followers of the ancient Greek philosophers, respectively, Pythagoras of Samos (c.570-c.495 BCE), Plato (428/7 or 424/3-348/7 BCE), Athenian founder of the Academy, and Aristotle (384-322 BCE).

[3] Malaspina refers to the *Vie de Mr. Leibnitz* by L. de Neufville (a pseudonym for Louis de Jaucourt, 1704-1779) included in the 1734 Amsterdam edition of the *Theodicy*. The precise accusation occurs on p. 44 of that edition. The full text is available online at <https://books.google.ca/books?id=XvQOAAAAQAAJ>, consulted August 6, 2008.

[4] Available online at <https://books.google.ca/books?id=MFY4AAAAMAAJ>, consulted June 29, 2018.

[5] See for example Maurice A. Finocchiaro (ed. And trans.), *The Essential Galileo*, Indianapolis, Hackett, 2008, p.183. https://books.google.ca/books?id=scpgDwAAQBAJ, consulted June 29, 2018.

[6] The connotation of the Latin terms here italicised by Malaspina, *intendi* and *remitti* (respectively *be stretched* and *be released*) cannot be expressed in English without doing violence to Newton's own usage. In the *Principia* he uses variously increment/decrement, increase/decrease, and augment/diminish and their cognates. See the latter text online at <https://books.google.ca/books?id=Tm0FAAAAQAAJ>, consulted August 8, 2008. Malaspina's point seems to be that Newton has alerted us to the possibility of referring to the *rates of change* of more straightforwardly observable physical characteristics.

[7] Malaspina refers in the footnote to François Jacquier (1711-1788), *Institutiones Philosophicæ ad studia theologica potissimum accommodata*, 6 vols, Rome, 1757. See especially p. 19. The full text is available online at <https://books.google.ca/books?id=lN49AAAAIAAJ>, consulted August 11, 2008. Jacquier contributed to the 1760 French edition of Newton's *Principia*.

[8] Pieter van Musschenbroek (1692-1761) of the University of Leiden, Dutch polymath.

[9] Malaspina here quotes from Francis Bacon, 1st Viscount St. Alban (1561-1626), *The New Organon*. I have used the translation from the standard edition by James Spedding et al. (eds.), *The Works of Francis Bacon*, London, Longman and Co., 1857-74. Bacon is sometimes known as Baron Verulam from the Roman name, Verulamium, of the town of St. Alban's associated with his peerage.

[10] The quotation is from Marcello Stellato (c.1500-before 1551), known in Latin as Marcellus Palingenius Stellatus, and usually referred to as "Palingenius"), *Zodiacus vitae*, Book 8, Scorpio, ll. 136-8. <https://books.google.ca/books?id=IvlOAAAAYAAJ>, consulted July 20, 2018.

[11] Willem Jacob 's Gravesande (1688-1742), Dutch mathematician and physicist, in his *Physices elementa mathematica, experimentis confirmata, sive introductio ad philosophiam Newtonianam*, Leiden, 1720.

[12] Pieter van Musschenbroek, *Introductio ad Philosophiam Naturalem*, which is available online at <https://books.google.ca/books?id=mpMAAAAAMAAJ>, consulted August 12, 2008. Ch. 1, §32 appears on p. 13.

[13] Marcus Fabius Quintilianus (c.35-c.100 CE), Roman rhetorician.

[14] Malaspina refers slight inaccurately to van Musschenbroek's *Physicæ experimentales, et geometricæ, de magnete, tuborum capillarium vitreorumque speculorum attractione, magnitudine terræ, cohærentia*

corporum firmorum dissertationes: ut et Ephemerides meteorologicæ ultrajectinæ, Samuel Luchtmans, 1729.

[15] Burchard de Volder (1643-1709), Dutch author of *De Natura*, 1664.

[16] André-François Deslandes (1689-1757), French philosopher. Giovanni Poleni (c.1683-1761), Venetian author of *Institutionum Philosophiae Mechaniae Experimentalis Specimen*, 1741. The Florentine "Academy of Experiment" was set up in 1657 by followers of Galileo. Jean-Antoine Nollet (1700-1770), French physicist. Presumably Christian Wolff (1679-1754), German philosopher.

[17] Jacques Rohault (1618-1672), French mathematician, physicist and philosopher.

[18] Marcello Stellato, op. cit., Bk 1, Aries, ll. 62-68. <https://books.google.ca/books?id=IvlOAAAAYAAJ>, consulted June 18, 2018.

[19] John Locke (1632-1704), English empiricist philosopher. Antoine Arnauld (1612-1694), French philosopher and mathematician. Samuel Clarke (1675-1729), English philosopher.

[20] Nicolas Malebranche (1638-1715), French philosopher. Michelangelo Fardella (1650-1718), Italian philosopher and follower of Descartes. Pierre Bayle (1647-1706), French philosopher. George Berkeley (1685-1753), Irish idealist philosopher and Bishop of Cloyne.

[21] Pietro de Martino (1707-1746), Italian astronomer and mathematician.

[22] Pierre Gassendi (1592-1655), French philosopher, mathematician and astronomer. Malaspina appears to follow Gassendi when he refers to physical as opposed to merely mathematical solidity. For a summary of Gassendi's views on the essence of bodies, see Ivor Leclerc's *The Nature of Physical Existence*, London: Routledge, 2004, esp. p. 181 ff. <https://books.google.ca/books?id=_B2KaiGu038C>, consulted December 30, 2008.

[23] Malaspina presumably has in mind Girolamo Ferrari (1701-1754), *Philosophia sensuum mechanica methodice tractata atque ad usus academicos accomodata*, Brescia: Rizzardi, 1745-48. The author is also known as Fortunatus.

[24] Pierre Coste (1668-1747), French theologian who lived for many years in England, where he became a Fellow of the Royal Society. Thomas Herbert (c.1656-1733), 8th Earl of Pembroke and President of the Royal Society 1689-90. See Howard Stein's chapter, "Newton's Metaphysics," in I. Bernard Cohen & George E. Smith (eds.), *The Cambridge Companion to Newton*, Cambridge University Press, 2002, p. 271 ff. <https://books.google.ca/books?id=3wIzvqzfUXkC>, consulted June 18, 2018.

[25] At line 821-2 and 827 of *De Rerum Natura*. There is a misprint in the quotation of l. 822: "animantes" for "animantis." <http://ae-lib.org.ua/texts-c/lucretius_de_rerum_natura_lt.htm>, consulted June 18, 2018.

[26] Reading "deferre" rather than "differre" for the text's "diferre."

[27] Malaspina adverts to the Pythagorean view, expressed in Plato's *Timaeus*, which assigns one of the five regular solids to the atoms of each of the four elements: fire, air, water and earth. However, one of the solids, the cube, which is assigned to earth, can be packed to fill space without interstices. See also John Black, *The Four Elements in Plato's* Timaeus, Lewiston, Edwin Mellen Press, 2000.

[28] Gassendi followed Epicurus in distinguishing the macroscopic vacuum of space in which material objects exist (*vacuum separatum*) from a microscopic vacuum inside material objects (*vacuum disseminatum*). See Steven Shapin & Simon Schaffer. *Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental Life.* New Jersey: Princeton University Press, 1985, p.83. See also Charles Hutton's *Mathematical and Philosophical Dictionary*, 1795, p. 631, consulted online (March 2, 2009) at <http://archimedes.mpiwg-

berlin.mpg.de/cgi-bin/toc/toc.cgi?page=1359;dir=hutto_dicti_078_en_1795;step=textonly>. On varieties of vacuum see also endnote 31.

[29] Malaspina is quoting from *Anti-Lucretius, or Of God and Nature* by Melchior de Polignac (1661-1742), published posthumously in 1748 < https://books.google.ca/books?id=0hwBAAAAMAAJ>, Book II, p. 65, lines 655-9, consulted June 26, 2009.

[30] Pierre-Daniel Huet (1630-1721), presumably in his *Censura Philosophiae Cartesianae*, Helmstadt, 1690.

[31] This term is used by Gassendi to refer to vacuum created artificially (as for example in the experiments of Torricelli and Boyle): see Antonio Clericuzio, *Gassendi y el Atomismo del Siglo XVII*, consulted online at <http://www.gobiernodecanarias.org/educacion/3/Usrn/fundoro/act11_12pdf_web/capitulos/16.pdf> on March 5, 2009, as well as endnote 28.

[32] Literally "for us, the water [in the water-clock, used to time the speeches of advocates] stops" – a common usage in Latin.

[33] Francesco Patrizi (1529-1596), Venetian Platonist philosopher and scientist of Croatian descent. Henry More (1614-1687), English Platonist. Joseph Raphson (c.1648-1715), English mathematician. Leonardus Lessius (1554-1623), Flemish theologian.

[34] Malaspina again quotes from de Polignac (see endnote 29), Book III, p. 105, lines 596-602; it appears that he omits lines 598-9, gives a preferable variant spelling of the first word ("aspice" for "adspice") and, in order to preserve the sense of the passage, corrects what appears to be a typographical error in the final word by substituting the antonym "adsit" for "absit." It may be, of course, that Malaspina had access to a more accurate edition than the one currently available online; or the fault may lie with the typesetter.

[35] Marin Mersenne (1588-1648), French mathematician and physicist. Robert Boyle (1627-1691), Anglo-Irish physicist, chemist and inventor most renowned for his work on gases. Antonie Philips van Leeuwenhoek (1632-1723), Dutch scientist best known for his work in microbiology. Edmond Halley (1656-1741/2), English physicist and mathematician best known for his work on the eponymous comet. René Antoine Ferchault de Réamur (1683-1757), French natural historian best known for the eponymous temperature scale.

[36] Jean-Baptiste du Hamel (1624-1706), French natural philosopher. Eusebius Amort (1692-1775), German theologian and author of *Philosophia Pollingana ad normam Burgundicae*, 1730. Consulted July 20, 2018, at: <https://books.google.ca/books?id=W-Ebc-yTgZsC>.

[37] Xenocrates (c.396/5-314/3 BCE), Chalcedonian mathematician. Zeno of Elea (c.490-c.430), Greek mathematician famous for his paradoxes of motion and time. Leucippus (fl. 5th C. BCE) and his student Democritus (c.460-c.370 BCE), the two ancient Greek founders of atomism. The historical existence of Leucippus is disputed by some, beginning with Diogenes Laertius in his life of Epicurus. Jean Sagüens, French theologian and atomist whose views were very influential in Spain.

[38] Malaspina refers probably to Henri Pitot (1695-1771), initially a mathematician and astronomer, who later in life made significant contributions to fluid dynamics.

[39] Robert Hooke (1635-1703), English mathematician, architect and physicist most renowned for his work on gravity. Francis Hauksbee (1666-1713), English scientist best known for his work on electrostatics.

[40] Malaspina refers to the Marquise Émilie du Chatelet (1706-1749), *Dissertation sur la nature et la propagation du feu*.

[41] The quotation is again from Marcello Stellato (Palingenius), *Zodiacus vitae*, Book XII, ll. 131-134. Available online at <https://books.google.ca/books?id=tfU_AAAAMAAJ >, consulted June 27, 2018.

[42] Pierre-Louis Moreau de Maupertuis (1698-1759) makes this general point in his *Discours sur les différentes figures des astres*, Paris, Jean-Baptiste Coignard & les frères Guérin, p. 24.
< https://gallica.bnf.fr/ark:/12148/bpt6k5822771k/f43.image.texteImage>, consulted June 29, 2018.

[43] Malaspina seems to have in mind here the collision of two bodies.

[44] Presumably in his *Leçons de Physique, Contenant les Elémens de la Phisique determinés par les seules Loix des Mécaniques*, published in several volumes from 1739.

[45] Literally "it may be that he is holding a wolf by the ears."

[46] Lucretius (99-c.55 BCE), *De Rerum Natura*, Bk. I, l. 350.
<https://books.google.ca/books?id=uxcYvpj59CMC>, consulted July 2, 2018.

[47] The reference is obscure.

[48] Reading "Universi" for the text's "Universum."

[49] Jean Le Clerc (1657-1736), Swiss theologian. Joseph Privat de Molières (1677-1742), French mathematician and astronomer and member of the French Academy of Science.

[50] Ehrenfried Walther von Tschirnhaus (also Tschirnhausen, 1651-1708), German mathematician and physicist who wrote on medicine and corresponded with Leibniz and Spinoza. Possibly Friedrich Hoffmann (1660-1742), German chemist.

[51] Pliny the Elder (23-79 CE), Roman author of *Naturalis Historia*. Tertius de Lanis (1631-1687), author of various works on physics, including *Magisterii Naturae et Artis*. Possibly Wilhelm Homberg (1652-1715), Dutch natural philosopher, born in Indonesia, who became a member of the French Academy of Science. In the final item in the list Malaspina may possibly be referring to *Historia et Commentationes Academiae Electoralis Scientiarum et Elegantiorum Litterarum Theodoro-Palatinae*.

[52] Probably referring to the two-cylinder vacuum pump.

[53] Reading "massae" for the text's "massa."

[54] Honoré Fabri (1608-1688), French theologian, mathematician and physicist.

[55] Raffaello Magiotti (1597-1656), Italian mathematician and physicist who published *The Resistance of Water to Compression* in 1648.

[56] Étienne Chauvin (1640-1725), French author of *Philosophical Lexicon*.

[57] Here the text contains the word "Stairs." My translation is tentative, and based on the assumption that the Latin "gradi" – which however does not appear in this paragraph – can mean both "stairs" and "degrees." Is it possible that Malaspina's source for this attribution to Fabri was in English?

[58] Malaspina seems to have fountains in mind.

[59] Thomas Savery (c. 1650-1715), military engineer and inventor of a steam engine for pumping water. Denis Papin (1647-1713), French mathematician and scientist who, while in Germany and with the help of Leibniz, invented a steam engine on the model of Savery's. Probably Johann Friedrich Weidler (1691-1755), German mathematician and astronomer.

[60] Reading "explicat" for the text's "explicant."

[61] I have not been able to trace this reference.

[62] Out of the many members of the family of mathematicians and scientists, this is probably Jacob Bernoulli (1654/5-1705), Swiss mathematician, who is mentioned by name later in the text. Alternatively, it could possibly be Johann II Bernoulli (1710-1790), who was awarded a prize by the French Academy for his work on aether.

[63] John Wallis (1616-1703), English mathematician who made important contributions to calculus and the physics of elasticity. Giovanni Alfonso Borelli (1608-1679), Italian mathematician, physiologist and physicist briefly involved in the Accademia del Cimento, who wrote on, among other subjects, gravity and the physics of collisions. Santorio Santorio (1561-1636), Venetian physiologist who was instrumental in introducing physical and mathematical considerations into medicine. James Keill (1673-1719), younger brother of John Keill and advocate of mechanical approaches in medicine. The text contains the misspelling "Kiell." Probably Stephen Hales (1677-1761), English theologian and physiologist, who studied blood pressure.

[64] Possibly Charles Pinot Duclos (1704-1772), French Academician. Probably Nicolas Lémery (1645-1715), chemist and French Academician, though just possibly his son Louis (1677-1743). Malaspina refers to them collectively, using a standard abbreviation, as "clarissimi vires," a phrase which for him seems more of a title than a description.

[65] Herman Boerhaave (1668-1738), Dutch physiologist and chemist.

[66] Reading "desciscimus" for the text's "descissimus."

[67] In his major scientifico-political voyage of 1789-1794, Malaspina and his subordinate officers made many measurements of the acceleration due to gravity in different latitudes, with the intent of establishing the degree of polar flattening of the earth. The value reached was extremely close to the one accepted today. He refers briefly to this work in his *Meditation on Beauty in Nature*, trans. John Black and Oscar Clemotte-Silvero, Lewiston, Edwin Mellen Press, 2007, p.71.

[68] Malaspina refers here to the view that the earth is elongated between the poles, in other words that the distance between the poles is greater than the equatorial diameter. This is the converse of the view that the earth is flattened between the poles.

[69] Roger Joseph Boscovich (1711-1787), Croatian polymath and author of *A Dissertation on the Shape of the Earth*, among many other works. He and Paolo Frisi (1728-1784), Italian astronomer and mathematician, ended up on opposite sides of a bitter dispute between Jesuits and others on various theoretical, philosophical and theological issues.

[70] Jean-Jacques d'Ortous de Mairan (1678-1771), French geophysicist and astronomer. For an explication of his views on the evolution of the shape of the earth and its connection with gravitational phenomena, hence for some elucidation of this difficult (because far too compressed) passage in Malaspina's text, see John L. Greenberg, *The Problem of the Earth's Shape from Newton to Clairaut*, Cambridge, Cambridge University Press, 1995, esp. Chapter 2. See pp. 28-29 for an explanation of the curves here mentioned. Malaspina's reference to "the four parts" of these curves is however obscure.

[71] Pierre Sigorgne (1719-1809), French theologian, mathematician and philosopher who propagated the ideas of Newton and argued against the physical theories of Descartes and Privat de Molières.

[72] Paolo Casati (1617-1707), Italian mathematician. Johannes Andreas Rüdiger (1673-1731), German philosopher and physicist. William Gilbert (1544-1603), English natural philosopher who investigated magnetism. François Bernier (1620-1688), French physician who travelled to Mughal India, after his return writing a summary of Gassendi's philosophy.

[73] Christiaan Huygens (1629-1695), Dutch physicist and mathematician.

[74] Georg Bernhard Bülffinger (1693-1750), follower of Leibniz and member of the Academy of St. Petersburg. Nicolaas Hartsoeker (1656-1725), Dutch mathematician, physicist and inventor of scientific instruments. Pierre Varignon, French mathematician.

[75] Reading "quis" for the text's "quos."

[76] Literally, "will be the true sister of occult qualities."

[77] Polignac, op. cit, Bk. IV, ll.1006-7.

[78] Lucretius, *De Rerum Natura*, Bk. 2, ll.1-2 and 5-6.