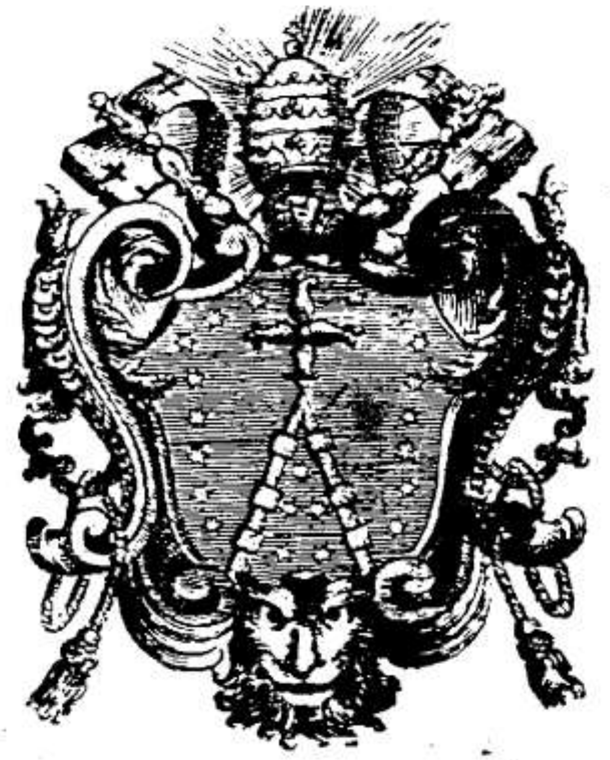
General Theses from Physics

As Taught in the Clementine College

Don Alexandro Malaspina

of the Imperial Marquisate of Mulazzo,

Member of the said College.



Facta cuilibet singulas impugnandi facultate.

[Great deeds are achieved by attacking them singly.]

Rome 1771

From the Press of Lorenzo Capponi.

With the Sanction of the Higher Authorities.

Of the Principles of Education in Physics

Since the serious study of a philosophical man looks above all to this end, that he might achieve certainty and clear knowledge of things, we ourselves have taken pains at the outset to render an account according to reason, so that through our careful investigation of physics, the mind might thus be drawn towards Nature. Of physicists, we consider, with John Keill,[a,1] four schools to be pre-eminent among the rest, the first being the Pythagoreans and Platonists; another has its origin in the Peripatetic School;[2] the third tribe of Philosophisers pursues the experimental method; and the final class of physicists is commonly known as the Mechanists. While not all that is propounded by these schools is worthy of assent, yet in each there are certain things of which we approve, abhorring as we do the fault with which Leibniz charges the Cartesians,[b,3] namely that of judging the ancient authors with contempt, punishing them, as it were, according to one's own law. And since

Those things last long, and are fixed firmly in the mind,
Which we, once born, have imbibed 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: no one would think it suitable for us to hear or read anything contrary to method,[c,4] for in general it is through habit, and especially through philosophical habit, that youth is first instructed in the colleges.

Without geometry and arithmetic[d,5] very little concerning natural causes could be established with certainty; hence, among the ancient Pythagoreans and Platonists, both were judged necessary to the practice of philosophy. We are utterly incapable of observing a composite body except by taking notice of the size, motion and those 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 could not fail to use the same in the required education in

---

[a] *Introductio ad veram Physicam*, lect. 1.
[b] *Life of Mr. Leibniz* written by M. de Neufville, p. 43.
[c] Preface to *Les Elemens des Mathematiques* by R.P. Bernard Lamy.
[d] Galileo in *The Assayer*.

physics, unless it were necessary to conceal from our scholars many things respecting the nature of bodies. Thus it is that we wish our scholars to learn not only the elements of geometry but also the rudiments of arithmetic and analysis. Nor, in agreement with the Peripatetics, are we afraid to make use of the words "quality," "faculty," "attraction" and others of that sort; not because through the use of these terms the mind may determine the true cause, physical reason or mode of action, but because through them it is possible to calculate the strength of forces, that is of [the] increase and decrease [of motion]. 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 a very similar method, investigate the increase and decrease of these quantities resulting from certain given conditions. Once the calculations of the strength of forces are made through deduction from the given conditions, it remains to compare the reasons for phenomena of that 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, the greater progress having arisen, perhaps, when adherents to the experimental method have themselves avoided inventing false theories, and wrongly directing their experiments to their confirmation. It is remarkable, the saying goes, 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*. And, with experiments alone, it would be thus in the mind which abhors both the effort required in lessons and reliance on customary practice. In the end it is through both the ancient atomists and the latter-day disciples of philosophy that we shall find out which and what kind of phenomena concerning matter, its motion and properties, and the established laws of mechanics, it is possible to set forth; 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 of the course of nature.[b,9]

---

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

Wherefore, in accordance with the custom of the Eclectics of being bound by the rules of no single approach, which custom we must of necessity follow, we adopt no particular guide in Physics, but, on the whole preferring none to another, shall drink to the full from all their springs, using our own powers of discernment and judgment, however great they may be:

> *……… 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 's Gravesande[a,11] is correct in applying the name *Newtonian Philosophy* to that in which one deduces from the observation of phenomena that certain hypotheses are to be rejected, these can be called the *First Principles* of *Newtonian Philosophy*. 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 seek not merely the plausible[b,12] but the true causes of things. Some, perhaps, especially those inclined to believe that, as Quintilian[13] says, *to call everything to judgment is to examine nothing truly*, condemn this slow and cautious method 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. By their counsel one must be impartial to all. My judgment has always been that Physics[c,14] is full of toil, advancing by slow steps, extending 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 that form of knowledge which van Musschenbroek called "patchwork,"[d] sullied by innumerable trifles and old wives' tales, and full of ugly inventions; nor can Verulam blacken our name;[e] nor can de Volder[15] proclaim this 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] For those renowned physicists are in fact their own worst enemies who, content out of the many writers on physical matters to collect the observations and experiments of others, themselves make trial of nothing, but instead rashly mix together truths with falsities. It is often left to us to discover what has been recorded through the examination of bodies themselves; to our advantage, that we may avoid error more easily and become more successful in our work, we follow in the footsteps of the likes 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, but only those which are less conformable to experience and use. In particular, all eight of those proposed by Jacques Rohault,[j,17] as well as the two added to them in his *Reflections*,[k] and certainly the sixteen Physical Axioms of John Keill,[l] are by no means lacking in utility. We strive only to follow with firm tread 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 marry with them whatever is useful and relevant that others have bequeathed us later.

Of this we present everything observed carefully by us in our investigation of the science of natural bodies.[o] And since,

---

[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.

In writing the mind bears many diverse things, not to
be spun in a single eddy: where the winds lead we go,
breasting the waves now here, now there. Now
we raise the cliffs of Pontus, now some safer shore.
And as often as, with reason my guide, I brave the
hidden ways of Nature and pry open her secrets,
yet at the start I follow those seen there before,[18]

we look first to the Philosophers who weigh carefully the precepts of the method set forth for approaching natural bodies. I examine these as one half-learned among the learned; lest we assent rashly to what is either false[a] or insufficiently known, it seems necessary that we ever more 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 ultimate 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 their existence. However, since that esteemed follower of the teachings of the Platonists sought to show that our mind becomes certain of its own existence prior to that of body, the prime object of consideration has become by what reasons, principally, 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 a 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 that this is body. Bayle added his small weight, 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, after the fashion of geometers, as a postulate; we prefer to lead off the inquiry with the question of how we might acquire the idea of bodies. We can locate 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, so that it is not possible for them to be intermingled. On the other hand, what is presented to *sight*, about which suspicion has arisen, appears to stand in need of further differentiation, and, if not informed by touch, to fall short of the idea to be acquired.

IV

The real *essence* of bodies is something, among many things that before now have escaped our attention entirely, which we wish to bring back for consideration. However, we shall first review and refute the opinions of the [relevant] philosophers, so that thus it will be clear how many and how great are the disadvantages we may avoid by taking a different view.

V

Among the Ancients, then, Pythagoras and the Stoics were wrong to think that, as Plato taught, the essence of bodies resides 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 Girolamo Ferrari of Brescia did, agreeing with many others, though on the basis of better reasons;[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 serious followers.

IX

Accordingly, we must rest content with the essence which they call *nominal*, in other words the assortment of attributes revealed with certainty by the senses. In adopting this recourse, we recognise simply that all bodies about 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 is defined, through its nominal essence, as *substance extended and solid*, in other words impenetrable.

X

No one who has studied the thoughts of Pierre Coste on Newton's comments when he was explaining the creation of matter to John Locke and the Earl of Pembroke can entertain the hypothesis that the matter of bodies could not be conceived even if (God forbid) nothing at all were to display the several dimensions of extension.[24]

XI

When we are considering the first elements of things, that view most deserves our assent, out of all that have been put forward, which posits the existence of the smallest 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 woods, the animals:*
> *The elements can change only in their arrangement.*

Thus was it astutely expressed by Lucretius.[25] However, what the inner nature of these particles truly is, 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 it is not possible to descry them even with the most powerful 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 alone.

XIV

Yet there are those who wish to ascribe[26] everything about their form to necessity: 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

[On this view] 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 it is clearly useless to inquire with great diligence and subtlety into the reason why these things are as they are. When these ultimate things were created extended they had to be given *some* size and shape answering to reason: 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 a collection of equal parallelepipeds, though not by the five regular solids.[27]

XVII

In truth, however, if the smallest corpuscles were of the shape mentioned above, and packed together in such a way that their surfaces were just touching, there would be left between these solids other expanses of space which were empty. We gladly concede to the proponents, and indeed ourselves embrace, the claim that the rarest and most fluid substance is for the most part full of such cavities.

XVIII

Thus, it is necessary to admit a *vacuum* both between the gross particles of matter itself and within these between the smallest components of bodies, calling it in the second case, with Gassendi, *vacuum disseminatum*.[28]

XIX

Descartes argued 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 not only the possibility but the very existence of negative extension, or vacuum, through innumerable and irrefutable proofs. [Fig. 1]

XX

The Cartesians beg the question and declare 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 surely it is not difficult to understand what happens here in terms other than those of the interpenetration of substances.

XXIII

There are two sets of philosophers who ask, in relation to vacuum *coacervatum*,[31] whether it might 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: hence 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

If all the parts of space were filled with bodies, so that nothing could be added to or taken away from it, then by the same token it would remain immobile and immutable. Accordingly I suspect that, whether one should believe it or not, some weight should be given to the argument by which, van Musschenbroek says, anyone can prove that space is mutable.

XXV

Yet some will still ask whether Space is eternal or created. Besides the Cartesians, those who assert the existence of vacuum also raise this most difficult question, about which it is far easier to say what you do not think than what you do think. It has been investigated since by many authors, and first by van Musschenbroek, though by way of arguments which I fear might not persuade others. 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, that opinion cannot be allowed. How much those who uphold the opinion may come into conflict with religion is clear from our propositions, published two years ago, on natural theology. What then can we conclude? It seems to us that in truth space is given distinct from all body; moreover, whatever is the origin of space may also be its nature; Keill abandons the decision to metaphysics: as for us, lest we ourselves fall into danger, we surely dare settle on nothing; 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 agree in this, that extension is a universal and essential attribute of each. Therefore, a certain general property of extension, namely its divisibility, cannot in the nature of things be fully described through these words [alone]. Two senses of extension must be distinguished: the *geometrical* and the *physical*. *Geometrical* division, which (as can easily be shown from Euclid's *Elements* 1) refers only to the fact that any extension may [in thought] be resolved into parts, and which is different from [any notion of actual] splitting apart, we believe to be subject to no limits. [Fig. 3]

XXVII

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

XXVIII

The divisibility of matter, if we are to attend to reason and experiments, is truly a marvel, and 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 elegant experiments, under the leadership 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 du Hamel, the writer of Burgundian philosophy,[36] and most significantly to others too. [Figs. 4, 5, 6, 7]

XXXI

Hence it is easy to understand what our views might be about Xenocrates, and the mathematical points of Zeno, 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, 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 indivisible parts 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 physically divided to infinity.

XXXV

Here, the mind is drawn towards the view of the Cartesians, who suppose an all-pervasive *Aether* permeating all bodies, and divisible into an infinite number of parts.

XXXVI

Those matters in relation to divisibility on which our adversaries have come to agreement can be reviewed under two main headings. Under the first, they take great pains to show that this infinite division is simply an invention, an empty concept of the mind. Under the other are included the absurdities which might be thought to follow from it. We reject both, not only so that the mind may be convinced but also that it may rest enlightened. For there are certain kinds of proofs in the sciences which extract agreement from our will by force, yet which do nothing to illuminate the faculty of understanding. Since, then, we are in love with the sacred word "demonstration," we are in no position to complain about its use in ordinary discourse. [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 welcome. [Fig. 9]

XXXVIII

If indefinite bodies were not to exhibit extension, but were bounded by certain limits, it would follow that the *figurability* attributable to bodies could not in any way be separated from their matter itself, and would be 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

The parts which are united in bodily extension may be infinitesimal, or finite but vanishingly small, and thus may always subsist, so that they may interpenetrate and be less subject to dispersal. On account of this resistance which the parts of a solid exert on one another, they have also been called *impenetrable*.

XXXXI

Those Philosophers who truly understand that space is distinct 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, what Hooke may have said casually in response to an observation of Hauksbee we ourselves lay claim to as applying to all bodies, for no body that resists another may occupy the same place at the same time. Unless bodies were impenetrable they would be annihilated by the least pressure.[39]

XXXXIII

On the other hand, nothing is so ingenious as the attempt made by Madame du Chatelet, particularly in her *Dissertation*, to deny probability to the impenetrability of fire.[40]

XXXXIV

The Peripatetics are 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 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 slipped up badly, perhaps through too closely assimilating authority to reason, as has been well understood by the most serious of poets:

Often do the grave and great, deserving of fame,
Happen to slip into error; and many men of talent
Have gathered in the shadows with authors of high repute,
Where, with eyes closed, they are led astray.[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 to reason, says van Musschenbroek, from the images of bodies reflected in a concave spherical mirror, or suspended in air.

XXXXVII

However, some Philosophers have been at great pains to show that this is false, maintaining that it could not happen that one volume of a cubic foot in size is occupied by another such volume, unless the first volume has been destroyed. But, I ask, do they reason thus from their own *idea* of extension, or from *experience*? If the former, are mathematicians forbidden to conceive mentally a sphere in a cube, a cone in 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 experience.

XXXXVIII

Although we may frame the idea of solidity by pressing bodies and meeting resistance, this does not suggest to the mind what brings about that resistance in bodies. We do not know, then, how solidity inheres in an extended body. Nor is this surprising; if anything is clear, it is that the way in which properties belong to a subject passes 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 bodies, 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 recourse to speaking not of inertia but rather of innate characters and their effects, have decided, not strictly in accordance with Descartes, that this force arises from the resting state of the parts.

LII

Now, when a body is 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] That body is more likely to remain at rest which resists to a greater extent the external forces tending to impart motion to it; and that same body will be moved more slowly under the impact of equal forces.

LIV

Therefore inertia is proportional to the quantity of [matter in] a body, and this applies equally to the individual smallest solids. Therefore what is revealed about 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 small resistance of the aether arises from the fact that it is not heavy: but since it is demonstrably false that, as Privat asserts, 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 this effect with the effect of gravity, as Nollet's experiment attests with especial brilliance,

Wander a long way indeed from 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, wonderfully, an Italian author[47] first illustrated through experiment and then corroborated through reason by reference to van Musschenbroek's *Introduction to Natural Philosophy*.

LX

What this power 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 whatever effect it produces, and then we know.

LXI

However, we consider it unnecessary to add some power, 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 clear that a body displays greater inertia against a faster [sc, greater] force than against another slower [sc. weaker] force. 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 different in some way from what they are. Likewise, only an utter clod in physics is unaware that the principle of action and reaction, and centrifugal and tangential force, arise easily from this same inertia. In this case what state of disorder might not exist in the Universe?

LXIV

Wherefore Malebranche, Jean Le Clerc and de Molières fill the bladder with wind, then 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 think 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 convoluted way.

LXVI

Surely gravity, elasticity, the human mind, God, as well as other spiritual causes, so we may believe, do not cause the inertia of bodies to engender on its own all the changes that happen in the world; but cause other forces to exist in the nature of things, in so far as these arise from inertia: to take part in investigating this is to many a 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 moveable, 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, while it is the first place of all bodies, is not endowed with mobility. Hence there is merit in what we have said about space, by the same token, subsisting immobile, while its parts may or may not be filled up 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. However, to be distinguished from 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 might have been able to remain 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, they have in the end 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 we are permitted to conclude from Physics, which is entirely lacking in *pores*.

LXXII

If many corpuscles fill a small space, then the mass [they compose] is dense; it is rare when a few corpuscles occupy a large void. When [in one of two bodies] many corpuscles are squeezed into a smaller space, that body will be the denser; when the pores in [one of two] masses of the same magnitude are greater in number or in size, then it will be the rarer.

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, everywhere tasting what 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 only barely possible to determine how much is solid and how much is porous, and so forth, 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 skilful work with the microscope, set up in both simple and solar formats.

LXXV

Although it is easy to understand, from the way in which large bodies are connected, how the penetration of other bodies happens, 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, of size and shape, of the pores and solid parts, though this ingenious author acknowledges that it cannot be denied that dubious explanations are drawn from certain principles as well as from those established by unanimous agreement, when experience attests that principles are distorted if we try merely to account for appearances, and not to grasp in detail 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

All liquids, and most of all water, through whatever forces, have not yet been able to solidify, so that they display to the senses the signs of compressibility, as is well known from the Florentine Academics, du Hamel, van Musschenbroek and Nollet, into whom little inquiry relevant to this matter has been made by many of us, compared to the great deal made from the contrary position by Verulam, Fabri,[54] Boyle and others, in which they seem to suggest, as ’s Gravesande so astutely notes, that the 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 entirely accept the unsupported animadversions of Honoré Fabri on Raffaello Magiotti,[55] who asserts that water cannot in any way be compressed.

LXXX

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

LXXXI

It is 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. We must admit to ignorance about our ability to understand in terms of mechanics how, through its elasticity, steam is able to lift water to such remarkable heights, and create that much-admired balance of forces, in itself how graceful and decorous.[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 matter the experiments conducted in our auditorium on the best use of balloons throw great light.

LXXXIII

Descartes' explanation of the elastic force of bodies in terms of the infiltration of aethereal matter into the pores of elastic bodies is incorrect.[60]

LXXXIV

Likewise that of Malebranche, and with him Fr. Mapier,[61] through minute vortices balancing one another with centrifugal force.

LXXXV

And again that of 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 deny that the elasticity of air is increased by heat; we reject utterly the specific claim that identifies heat as the cause of elasticity.

LXXXVII

That gravity is what holds together all the material parts of a body, no matter how great or small, and therefore should be ascribed to bodies as a generic property, is quite unknown to anyone who has no experience or is 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 and enlightened men Duclos, Boyle, Homberg and Lémery, and in particular those with the scales aimed at proving its weight, fail to render 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; for this reason we are thoroughly trained to the habit of making 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 shape,[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], while the non-uniform density of the earth may 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 closely 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 and enlightened man when he sought to call into question the observations of the Parisian Academics who claimed that the earth is lower at the poles and higher near the equator.[69]

XCV

Many observations prevent our subscribing to the third hypothesis, as also to that of Mairan and the opinion of 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 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 suit, 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 in other ways by 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 he lays down, in the General Scholium to *Principia Mathematica*, for producing gravity.

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 a fluid which[75] has the known properties of fluids.

CVII

Here is what we say about how attraction, whether in the form of elasticity, gravity or just in general, can be [brought under the explanatory scheme of] Newtonian [mechanics]. Attraction, in the context of the phenomena of coherence, must 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, anything understood as a cause, however abstract and vague, cannot be denied merely by raising considerations; 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. The laws of terrestrial attraction proposed by others, even if it is conceded that they fit the various phenomena, do not all explain them equally well.

CX

Even if we do not easily concede the opinion of those who, overwhelmed by enthusiasm for learning their lessons, are led astray, so that they believe themselves to have intuitive evidence of the power of attraction, we cannot allow ourselves to believe something so absurd and repugnant; or, as we say with Polignac:

All-powerful Attraction creates the miracle of the World,
And, though nothing exists, 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 sin, 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

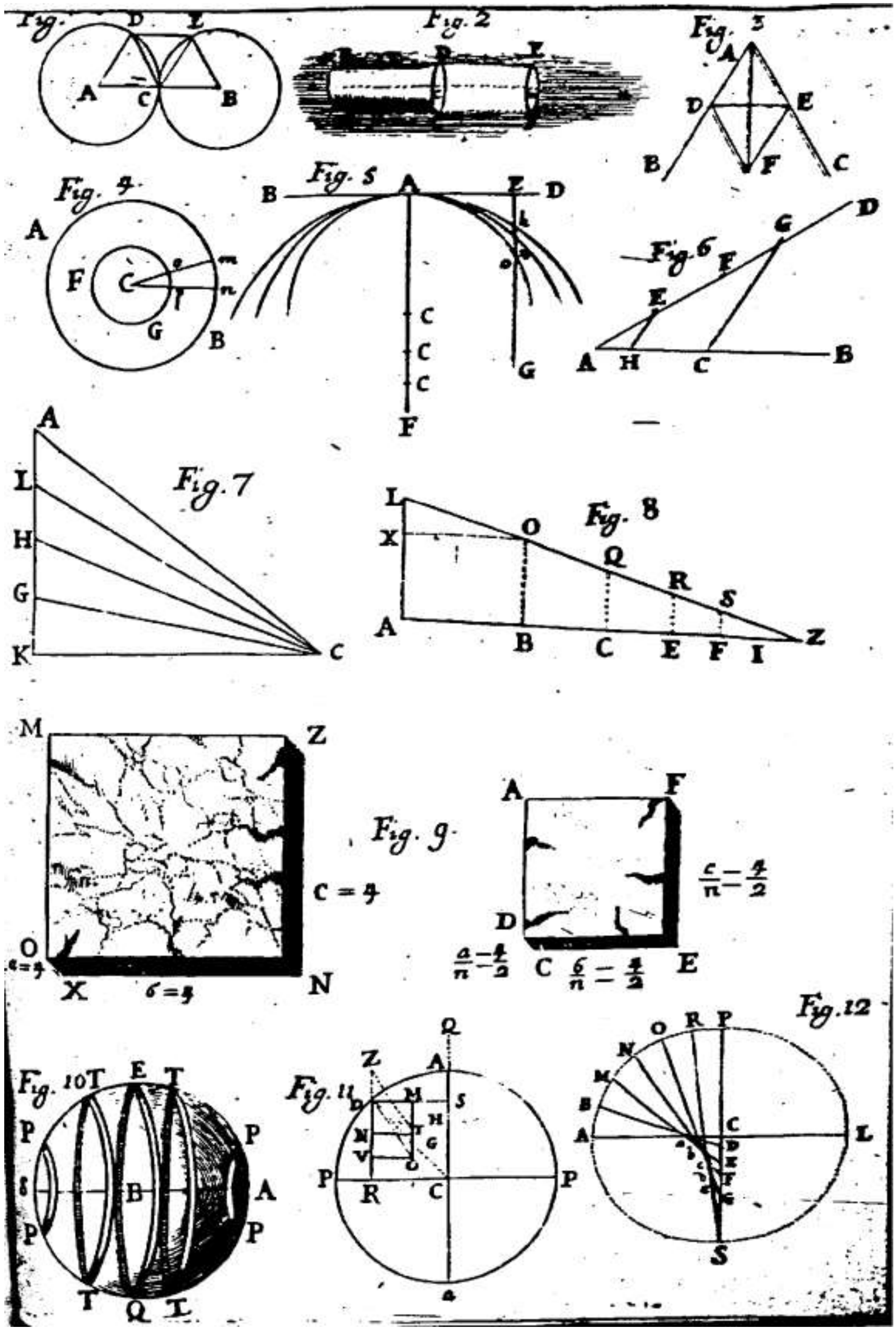


Fig. 2
Fig. 3
Fig. 4
Fig. 5
Fig. 6
Fig. 7
Fig. 8
Fig. 9
C = 4
Fig. 10
Fig. 11
Fig. 12

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.