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8 Newton's metaphysics

When one speaks of Newton's "metaphysics," it should be noted that the word itself was rarely used by Newton; further, that in point of general philosophical usage, that word has not had in our own time a fixed and well-established acceptation. For the purposes of the present study, a rather broad view will be adopted – suggested on the one hand by Newton's most influential near predecessor, the previous author of a book called *Principia Philosophiae*,[1] Descartes, according to whom metaphysics treats of *the principles of* [all] *knowledge*, and serves as *the root* of the "tree of philosophy" (whose "trunk" is physics, and whose "branches" are what we should call the "applied sciences");[2] and on the other by the author of the article "Metaphysics" in the eleventh edition of the *Encyclopaedia Britannica*, Thomas Case, who summarizes the concern of this discipline in the two questions: "1. What is the world of things we know? 2. How do we know it?"[3] Thus metaphysics will here be understood to be the discussion of the most general features, *both* of the constitution of the world, *and* of the principles of human inquiry into the nature of the world.

It will be useful for our discussion to put Newton's position in comparison with that of Descartes; for the work of the latter was both enormously influential in general – in the seventeenth century, and also, so far as metaphysics (in contrast to natural philosophy) is concerned, right down to the present day – and of great moment for Newton in particular.

On the methodological side, Descartes's program for a reformation of knowledge – for the establishment of a science that should be both secure in its theoretical attainments and of unexampled power in its aid to the control of the natural conditions of human life[4] – was

based upon the demand that every item of knowledge be either *immediately clear and certain beyond a doubt*, or be *connected* to such clear and certain foundations by clear and certain links. Both the guarantee of the truth of what the mind perceives clearly and with no possible doubt,[5] and the identification of the fundamental principles so perceived, come, according to Descartes, from metaphysics or "first philosophy"; therefore this science is indeed "first" in the order of investigation: as already remarked, metaphysics is the "root" of that tree of which physics – natural philosophy – is the "trunk."

It is important to emphasize that this radical position does *not* mean, as it has sometimes been taken to, that Descartes thinks all of physics can be *deduced* from principles known through "pure reason." In his program for the investigation of the natural world, *experiment* plays a central role. But to characterize that role, something must be said about the deliverances of Cartesian metaphysics on what one might call its "ontological" side. The chief points that are relevant here are these:

Descartes, like Aristotle and the scholastic tradition, takes "substance" to be the primary category of "being" in the world: the "things that are" are "substances." A central *innovation* by Descartes is his principle that there are two fundamentally distinct sorts of substance, each distinguished by its characteristic essential "attribute": "thinking things" (*res cogitantes*) or minds, and "extended things" (*res extensae*) or bodies. Bodies form the subject of natural philosophy. Since it is of the essence of these simply *to be extended*, the notion of empty space – extension void of body – is just contradictory; so the world is a plenum: body is everywhere. The only distinctions or diversities that are conceivable among bodies *as* extended things are diverse *motions.* Therefore, the processes of nature consist solely in the motions of bodies and the changes of those motions; and the foundations of physics consist in the principles that govern those motions and changes of motions. The task of natural philosophy, therefore, is to account for all natural phenomena by describing the motions and changes of motion in which they consist, and exhibiting those processes of motion and change of motion as consequences of such fundamental principles.

Now, at the very base of this conception lies a serious difficulty: namely, how to characterize "motion" *at all*, when it has been declared that there is nothing more to body than its attribute of

extension. In his earliest treatise on physics, *The World*, Descartes takes for granted what one may call the "naive" conception of motion: it is "that by which bodies pass from one place to another and successively occupy all the spaces between"; and what *place* is, is a question not even raised. If, however, bodies are essentially just "what is extended," there is no real distinction between "bodies" and "spaces"; so one is baffled what to make of the notion of *the same body* successively occupying *different spaces.* It is in fact clear that in *The World* Descartes is taking it for granted that we possess – presumably as clear and innate ideas – two distinct notions of *identity* (over time) for "the extended": (1) identity of place, and (2) identity of body. On the other hand, since Descartes himself does not explicitly signalize this twofold notion of identity – which, as we shall see presently, Descartes drastically revises in his decisive work, the *Principles of Philosophy* – it seems impossible to acquit him of a *lack* of "clarity and distinctness" on this point.

The World was not published during Descartes's lifetime. In a letter to Mersenne of 22 July 1633, Descartes says that the treatise is nearly finished. In late November, he wrote again. This time he says that he had intended to give Mersenne a copy of the completed work as a New Year's present. But he has just learned that Galileo's *World System*[6] has been condemned in Rome; and the only reason he can think of for such a condemnation is the fact of its having "tried to establish that the earth moves" – on which issue, he continues: "I must admit that if the view is false, so too are the entire foundations of my philosophy, for it can be demonstrated from them quite clearly. And it is so closely interwoven in every part of my treatise that I could not remove it without rendering the whole work defective." Consequently, Descartes set the work aside, and – after a considerable lapse of time – proceeded to revise its foundations so far as the nature of motion is concerned.

The *Principles of Philosophy*, published in 1644, is repeatedly referred to by Descartes in his correspondence as a new version of "my *World*." In it he presents, in place of what has above been called the "naive" conception of motion, a new and sophisticated one. Motion "in the ordinary sense of the term" is still "the action by which a body travels from one place to another";[7] but *place* is now said to be an ambiguous, or relative, notion[8] and, "rightly taken," to be defined by *the surface of the surrounding body*.[9] Accordingly, "motion

in the strict sense of the term" is defined as "the transfer of one piece of matter, or one body, from the vicinity of the other bodies which are in immediate contact with it, and which are regarded as being at rest, to the vicinity of other bodies." (This "sophisticated" – and semi-relativist[10] – conception raises new problems of its own, as Newton's critique will make plain.)

In any case, having posited the realm of "extended things" and its character as a plenum, Descartes appeals to the testimony of the senses (itself warranted as reliable on such an issue by God's necessarily non-deceptive character) to establish both that this realm *actually exists*,[11] and that *it is in continual and very diversified motion.*

The principles that govern such motion are on the other hand *not*, according to Descartes, to be ascertained by means of, or with any help from, empirical observation: these principles or rules he claims to infer directly from God's immutability – from the *constancy of his action* in preserving the world from moment to moment, which implies (a) the conservation of all states which are not necessarily altered through the postulated fact of motion, and (b) the conservation of the total "quantity of motion" itself (of all bodies together – not, of course, of each individually), from moment to moment. The actual rules stated by Descartes need not concern us (although it should be remarked that they – and the arguments he gives for them – are really bizarre); what is important is that these principles of motion constitute, in Descartes's system, the analogue of what the physicists of our own time call the "fundamental forces" of nature. Thus Descartes's position is (1) that a sound physics presupposes a (certain, indubitable) knowledge of the fundamental forces; (2) that such knowledge – prior to the rest of physics – is indeed possible; and (3) that this knowledge is possible through, and *only* through, unaided thought. In *this* sense, Descartes demands, and claims to have achieved, a "purely rational" physics – more accurately, a purely rational *foundation* for physics. In his *Rules for the Direction of the Mind*, this demand is expressed, in connection with the particular example of a problem in optics, as the stipulation that for a satisfactory solution of the problem it must be traced back to a knowledge of *what a natural power in general is* – "this last being the most absolute term in [the] whole series" (of conditions upon which the solution depends).[12]

The role of experiment in Cartesian method can now be briefly characterized as follows: by experiment we learn the existence of features of our natural environment, which pose *problems* for science. The *solution* of such problems, the very task of physics, consists in the tracing back of these observed natural phenomena to their *fundamental causes* – that is, the demonstration that the phenomena do (or would) result from the fundamental principles of physics, themselves derived as we have seen from first philosophy, when we have correctly attributed the phenomena we observe to underlying structures of Cartesian matter-in-motion: that is, when we have constructed (to use a later terminology) the appropriate *mechanical model* for each phenomenon. How *this* is to be done is certainly the most vexing problem in the interpretation of Descartes's scientific method; but what is most important in respect of Descartes's historical influence on later seventeenth-century investigators is the fact that the early attempts of Descartes to proceed *systematically and with certainty* from observed phenomena to their causes (that is, to mechanical models that represent the *true* nature of the processes underlying the observed phenomena) were abandoned – perhaps even in some degree by Descartes himself – in favor of a far more tentative procedure of seeking for *likely* models, that might "save" or "satisfy" the phenomena, and whose correctness could be rendered at least *highly probable* by their success in doing so.[13] In short, the method of investigation of nature that eventually came to complement Cartesian metaphysics – a method that grew out of the *failure* of his more stringent original prescription – was that of attempting to *invent mechanical hypotheses* that would explain, with the help of "rational" deduction from the fundamental principles of motion, whatever was discovered by experiment.

One other feature of the intellectual environment in which Newton developed should be mentioned: namely, that many adherents to some variety of the "new philosophy" came to reject Descartes's identification of matter with whatever is extended, in favor of the classical view of *atomism*: that (a) there is void space as well as occupied space – the world is not a plenum; and (b) the ultimate parts of matter are "corpuscles" or "atoms": *rigid* and *indivisible* bodies.[14] Within this "revisionist" conception – also known as the "corpuscular philosophy" – it was still maintained as a fundamental tenet that all the processes of nature consist in the

motions of bodies, and that all natural *changes* of motion are occasioned by direct actions of one body *pushing* on another.[15] The features common to this position and Descartes's constituted the framework of the celebrated "mechanical philosophy." It is *from* the mechanical philosophy that the metaphysics, as well as the natural philosophy, of Newton *departed*: that philosophy was Newton's point of departure; and he indeed departed from it, in profound ways.

Taking Descartes as the first point of comparison, a radical difference between his view of metaphysics and Newton's lies in the fact that for Newton metaphysics is *not* the "root" or foundation of natural philosophy – the "beginning of wisdom." His position may rather be said to agree with that of Aristotle – a conception symbolized by the fact that the followers of Aristotle placed his treatises on first philosophy "after the physical ones."[16] Aristotle, distinguishing between what is "first and better known to nature" and what is "first and better known to us," regards the most basic principles – "prior," *in nature*, to those of the special sciences – as *to be known* only *after* the special sciences themselves have been established. An indication that Newton thought similarly is to be seen in the fact that his chief published discussions of the metaphysics of nature, and of his views concerning God in relation to nature, occur *at the end* of his two great treatises: in the General Scholium to the *Mathematical Principles of Natural Philosophy*, and at the end of the long concluding Query 31 in Book 3 of the *Opticks*. In his discussion of theological matters in the General Scholium, Newton says of God: "We know him only by his most wise and excellent contrivances of things, and final causes"; and concludes that discussion with the words: "And thus much concerning God; to discourse of whom *from the appearances of things*, does certainly belong to Natural Philosophy" (emphasis added). In Query 31 of the *Opticks*, after a long review of the most diverse phenomena (chiefly of chemistry), he says: "*All these things being consider'd*, it seems *probable* to me, that God in the Beginning form'd Matter in solid, massy, hard, impenetrable, moveable Particles, [etc.]" (again, emphases added here). In both places the views put forward are thus expressed as, in point of knowledge, *a posteriori*; and in the latter place, the view is explicitly described as *probable* (this is a lower degree of confidence than Newton attaches to his principal results in physics).[17] Further, it is not only man's knowledge of God, among doctrines one would call metaphysical,

that Newton describes as deriving from experience rather than from pure reason. In the preface to the first edition of the *Principia*, and in the third of the "Rules of Philosophizing" at the beginning of Book 3 of that work,[18] Newton expresses the opinion that (a) *geometry* is founded in experience (in, as he says, "mechanical practice"), and (b) so is *everything* we know about *bodies* (in particular, their "extension, hardness, impenetrability, mobility, and *vis inertiae*"). This is a matter to which we shall return later; for the present, let it suffice to note that these statements leave little scope, in Newton's view of knowledge, whether in "first philosophy" or in natural philosophy, for the *a priori* or purely rational.[19]

Let us now turn to the content of Newton's metaphysical doctrine: what, according to him, is the basic constitution of the world – what are its constituents, and how are they interconnected?

The question does not have an entirely straightforward answer. In order to see why – and in order to arrive at as clear as possible a picture of his mature doctrine – it will be useful to pay some attention to the apparent development of Newton's view over time.

It is clear from Newton's early notebooks[20] that he moved rapidly, in his student years, towards adherence to the general views in natural philosophy represented by Galileo and – in part – Descartes, in opposition to the scholastic ("peripatetic") teachings; and also that he quickly became critical of some of the basic tenets of Descartes. For example, in a very early manuscript Newton discusses with evident skepticism various scholastic views about projectile motion;[21] argues against Aristotle's rejection of a vacuum;[22] and notes without comment Descartes's definition of motion in the strict sense of the term: "Cartes defines motion . . . to be the Transplantation of one part of matter or one body from the vicinity of those bodys which immediately touch it and seem to rest, to the vicinity of others."[23] Not long afterwards, in what is clearly an attempt (somewhat awkward) to sketch a systematic theory of motion, Newton states his own definition: "When a Quantity is translated/passeth from one parte of Extension to another it is saide to move"[24] – a definition not very remarkable, but which clearly deviates from the conception advocated by Descartes in his *Principles.* The result was a position that fell within the framework of the corpuscular philosophy. It is important to note, in particular, that in the manuscript last cited Newton offers a general characterization of

force, as follows: "Force is the pressure or crouding of one body upon another."[25]

We come now to a crucial document, and what the present commentator regards as a crucial turn in the character and depth of Newton's thought on fundamental issues. The document – first published in 1962, in the original Latin followed by an (unfortunately defective) English translation[26] – is of a curious kind. It is an incomplete and untitled draft of what was evidently intended to be a treatment of hydrostatics, and begins with the statement: "De Gravitatione et aequipondio fluidorum et solidorum in fluidis scientiam duplici methodo tradere convenit"; that is: "It is fitting to treat the science of the gravitation [i.e., the "weighing down"] and equilibrium of fluids and of solids in fluids by a twofold method."[27] The opening phrase, "De gravitatione et aequipondio fluidorum," is the title by which the piece has come to be known.

What makes the fragment both odd and extraordinarily interesting is the fact that, after a brief introduction and four definitions, there occurs a digression into questions of metaphysics, taking up about two-thirds of the entire length of the manuscript; then the technical presentation resumes, with another fifteen definitions followed by two propositions (with five corollaries) – and breaks off. Thus in spite of the title under which it is known, and its evident original intent, the entire interest of the piece is as an essay in metaphysics – of a kind that is unique among Newton's writings.

The first four definitions are introduced and stated as follows:

Definitions

The terms quantity, duration, and space are too well known to be susceptible of definition by other words.

Def: 1. A place is a part of space that a thing fills adequately.
Def: 2. A body is that which fills a place.
Def: 3. Rest is remaining in the same place.
Def: 4. Motion is change of place.

Newton explains that in saying that a body *fills* (Latin: *implet)* a space, he means to imply "so fully occupies it as utterly to exclude other things of the same kind (other bodies) as if it were an impenetrable thing." Why, one may ask, "as if"? Does not a body's exclusion of other bodies mean that it *is* an "impenetrable thing"? The answer to this emerges later: Newton believes that *minds*, as well as bodies,

have their definite places in space; and he believes that bodies and minds can occupy the same – or overlapping – places; so bodies are not absolutely impenetrable, but are so only to one another.

After a few further preliminary clarifications, Newton calls attention to the fact that in these definitions he has departed fundamentally from the doctrines of the Cartesians: both in *distinguishing* between space and bodies, and in that he has "determined motion with respect to the parts of that space, not with respect to the positions of the contiguous bodies." It is this remark that leads to the metaphysical digression, in which Newton is concerned, first, to refute the theory of space and motion of Descartes's *Principles of Philosophy*; then to present his own conception of the nature of space (and, with less elaboration, of time); finally – and with greatest originality – to present his conception of the nature of *body* – how it is related to, and how distinguished from, space.

The refutation of Descartes on place and motion has two main parts. In the first, Newton argues that Descartes himself, in the development of his physics in Parts 2 and 3 of his *Principles*, proceeds in a way that is inconsistent with his own theory of motion, and thus "seems to acknowledge" its inadequacy. Since we are not here primarily concerned with Descartes, one example may suffice – the one that is most directly connected with Newton's evidence for the view he himself favors. According to Descartes, the earth – and, indeed, each of the planets – is, "if we are speaking properly and according to the truth of the matter" (Newton paraphrases the second phrase as "according to the philosophical sense"), *not moved*, but rather *at rest*; since each of these bodies, according to Descartes's theory of the planetary system, is carried around the sun by a material vortex: each planet, then, is at rest *relative to the bodies that immediately surround it*, and is therefore at rest in the "proper" sense of the word.[28] This is the basis of Descartes's claim that his view in the *Principles* is immune to the charge of attributing motion to the earth. But, Newton points out, in his *dynamical theory* of the planetary system Descartes attributes to the planets *a tendency to recede from the Sun* on account of *their motion around it*. So in developing the principles *of his philosophy* Descartes makes use of a conception of motion that is *not* the one he puts forward as "proper and according to the truth of the matter"; or, again to use Newton's paraphrase, "according to the philosophical sense."[29]

In the second main part of his argument against the Cartesian theory of place and motion, Newton shows that the basic principles of the physics of motion generally agreed upon in his time cannot even be *formulated* within the conceptual framework provided by that Cartesian theory. (Thus we may say that whereas in the first part Newton had shown Descartes to be in contradiction with himself, in the second part he shows that the contradiction is not merely with some *special* features of *Cartesian* physics: rather, it is with the general principles – to which Descartes himself was a contributor – that underlie all of what for him is "modern" physics.) Again it will suffice here to consider one central point. Newton says it follows from Descartes's position "that a moving body has no determinate velocity and no definite line in which it moves. And," he adds, "what is much more, that the velocity of a body moving without resistance cannot be said to be uniform, nor the line straight in which its motion is accomplished." In other words, what is still called the "first law of motion" *does not make sense* in Cartesian terms. The reason is straightforward. In Descartes's terms, "according to the truth of the matter," a body's motion should be described in relation to bodies in immediate contact with it that "are regarded as at rest"; these define the body's "place" (at a given time). But over time, bodies that were once relatively at rest will in general no longer be so – they will disperse. Therefore, over time, these (former) "places" will no longer exist; so that it will be impossible to speak of the *distance a body has traveled* (the distance between its present and its former place) – and equally impossible to speak of the *path* it has followed (the ordered array of places through which it has passed).[30]

It is important to note that this argument of Newton's does not claim to rest on principles that are epistemologically *a priori.* When he claims that Descartes's concept of motion is *not the one needed for physics*, he is speaking of the *existing* physics of his time – and, indeed, of features of that physics that are *accepted* by the Cartesians as well as by himself. This physics had had some considerable success; therefore it was reasonable to make use of its principles, and to frame basic conceptions so as to be consistent with them. Objections should be considered out of order, unless (a) they are drawn from demonstrable inadequacies in the application of the accepted theory to phenomena, or (b) the objector has an alternative to offer that is

at least as good as that theory, and better in respect of the points he objects to.[31]

Newton summarizes his results so far in the following words:

> It follows indubitably that Cartesian motion is not motion, for it has no velocity, no direction, and hence there is no space or distance traversed by it. So it is necessary that the determination of places, and hence of local motion, be referred to some immobile being, such as extension alone, or space in so far as it is seen to be truly distinct from body. And this the Cartesian Philosopher may the more willingly acknowledge, if only he notices that Descartes himself had an idea of extension as distinct from bodies, which he wished to distinguish from corporeal extension by calling it "generic." Art. 10, 12, & 18, part 2 Princip. And that the whirlings of the vortices, from which he deduced the force of the aether in receding from the centers (and therefore his whole mechanical Philosophy), are tacitly referred to this generic extension.

He turns, then, to the question of what, in his own view, the nature is of the "immobile being" – *space* or *extension* itself, distinguished from body – to which places and motions are to be referred. He raises three possibilities, arising out of the philosophical tradition, as to how he might "now be expected" to define extension: either as itself a kind of *substance*; or as a kind of *accident* (note: this was the standard philosophical term for an *attribute*: anything that can be "predicated" of a substance); or, third, as "*simply nothing*." The third alternative looks odd, but is undoubtedly meant to refer to the anti-establishment ancient tradition of atomism, in which the fundamental ontological contrast of atoms and the void was also expressed as that of "being" and "non-being." Newton repudiates all three answers, and offers instead something rather new: he says that extension "has a certain mode of existence of its own, which agrees neither with substances nor accidents." It is not substance for two reasons: (1) "because it subsists, not absolutely of itself, but as, so to speak, an emanative effect of God, and a certain affection of every being"; (2) because it is not something that *acts*.[32] The first point we must presently examine more closely. The second is of capital importance for Newton's view: he says that although philosophers do not traditionally define substance as "a being that can *act* upon something," they in fact all tacitly hold such a definition – "as for instance is plain from this, that they would easily concede extension to be a substance like a body if only it could move and could

exercise the actions of a body; and on the other hand, they would by no means concede a body to be a substance if it neither could move nor arouse any sensation or perception in any mind whatever." To be noted well, then: (a) the definitive criterion of substantiality is the ability to act; (2) one of the characteristics that belongs to the essential nature of *bodies*, to their character as substances, is their ability to arouse perceptions in a mind. As to the question whether space is an "accident" – something that can exist only as "inhering in some subject" – Newton denies this emphatically: we can, he says, clearly conceive of empty space, and thus of "extension existing as it were without any subject"; "we believe it to exist wherever we imagine there to be no bodies; nor are we to believe that, if God were to annihilate some body, its extension [that is: the *place* of that body] would perish with it." This leads Newton to his repudiation of the third putative answer as well: so far is extension from being "nothing," that "it is more 'something' than is an accident, and rather approaches to the nature of substance" – namely, in that it needs no "subject" to "support" its existence. Further: "Of nothing, no Idea is given, nor has it any properties, but of extension we have an Idea the clearest of all, namely by abstracting the affections and properties of body so that there remains only the uniform and unlimited stretching out of space in length breadth and depth."[33]

But what does Newton mean by the statement quoted under (1) in the preceding paragraph, that space or extension "subsists . . . as, so to speak, an emanative effect of God, and a certain affection of every being"? There are a number of problems to be considered here: What are we to understand by an "emanative effect"? What *reason* can there be for Newton's statement that space is "an emanative effect of God"? And if space subsists as "a certain *affection*" – that is, a kind of "qualification" or "mode" – of every thing ("every being"), then how can it to be said *not* to be an "accident," but more like substance than accident? Of these questions, the first is very much clarified by what Newton goes on to say, in six numbered articles in which he proposes "to show not only that [space] is something, but what it is."

The fourth of these articles begins as follows:

> Space is an affection of a being just as a being. No being exists or can exist that does not have relation in some way to space. God is everywhere, created minds are somewhere, and a body in the space that it fills; and whatever is

neither everywhere nor anywhere is not. And hence it follows that space is an emanative effect of the first-existing being, for if I posit any being whatever I posit space. And the like may be affirmed of Duration: namely both are affections or attributes of a being in accordance with which the quantity of the existence of any individual is denominated, as to amplitude of presence and perseverance in its being. So the quantity of the existence of God, according to duration has been eternal, and according to the space in which he is present, infinite; and the quantity of the existence of a created thing, according to duration has been just so much as the duration since its first existence, and according to the amplitude of its presence, as much as the space in which it is.[34]

This paragraph sheds great light on the statement that extension is an emanative effect of God. In the first place, although Newton's theology is deeply involved in that statement, *and* in this paragraph, the latter actually makes it quite explicit that Newton does *not* derive his "Idea" of space – its ontological status included – *from* his theology (as has often been claimed); for he tells us that if *anything* is posited, space is posited. He infers – quite simply – that space (in some sense) "results from" *the existence of anything*. Now, in Newton's theology – which in some respects was heterodox, but certainly not on this point – the "first-existing being" was God, whom he regards as the creator of the universe; so space (in some sense) "results from" the existence of God. However, what follows from Newton's "metaphysics of space" is precisely the weaker statement he makes in this paragraph: that space is (some kind of) effect of the existence of anything; and therefore, of the first-existing thing.

But what kind of effect? What is here meant by an "emanative effect"? Here some historical consideration of the word is helpful. In the philosophical tradition of the neo-Platonic school, there was a quite elaborate doctrine of "emanations" from the godhead; and Newton was closely acquainted with members of the group at Cambridge University known as the Cambridge Platonists – most closely with Henry More. However, the neo-Platonist doctrine, in its ancient version, was concerned with the origin of the universe; whereas – as we shall presently see – Newton in the piece we are discussing sharply distinguishes between space, as an emanative effect of God, and both bodies and minds, as God's "creations." As for the Cambridge doctrines, it is instructive that the *Oxford English Dictionary*, under "emanation," I.1, quotes the following

from Henry More's philosophical *Poems*: "Man's soul's not by Creation . . . Wherefore let't be by emanation." On the one hand, this supports the view that "emanation," whatever it is, is to be *distinguished* from creation; on the other hand, it is clearly *not* in agreement with Newton's view – expressed in the very paragraph we are discussing – that human "souls" (or "minds") are *created*; indeed, that *all* minds save that of God are so[35] (for Newton writes, clearly intending a complete survey of *all* the kinds of "being" [or "beings"]: "God is everywhere, *created minds* are somewhere, and a body is in the space it fills"). So the grounds for thinking that Newton's theory of emanation is neo-Platonic, or "Cambridge Platonic," are very weak. On the other hand, the *OED* in the same entry, 1.1.c, gives the definition (noted as obsolete): "Logical development from premises; inference" – with an illustrative quotation from the *Logic* of T. Spencer (1628); and gives in II.3.b the related definition *(not* designated obsolete): "A necessary consequence or result" – with two illustrative quotations, the first from Richard Steele in *The Tatler* (1710), the other the following phrase, from John Stuart Mill's *Utilitarianism* (1861): "A direct emanation from the first principles of morals."

But this sense of the word – simply *a necessary consequence*, with no connotation of "causal efficacy" or "action" – *exactly* fits the rest of what Newton says; indeed, this meaning might have been inferred directly from Newton's words: "[S]pace is an emanative effect of the first-existing being, for *if I posit any being whatever I posit space*": the second clause tells us precisely what the first clause *means.*

For our second question – what reason Newton thought there was that justified this view of space as an "emanative effect" of whatever exists – it is to be noted that he describes the proposition as *inferred from* a preceding one: that "no being exists or can exist that does not have relation in some way to space"; and this in turn he founds upon an enumeration of all the kinds of "beings" he takes actually to exist, and their several relations to space. In the light of this, and of the fact that there is no suggestion – here or indeed anywhere the present writer knows of in Newton's writings – of an *a priori* epistemological ground for any item of knowledge, it appears reasonable to conclude that the reason in question is an empirical one: our experience affords no grounds for a conception of real existents – beings capable of acting – that do not have an appropriate relation to space.

It might well be asked how *experience* could be said to ground Newton's assertion that "God is everywhere." But first – although the claim that God is everywhere *present in space* was a controversial one, and even somewhat dangerous to advocate – Newton thought the doctrine of the *ubiquity* or *omnipresence* of God amply founded in the tradition of revealed truth; and second, he clearly thought experience shows that *minds* can act only *where they are*;[36] so the doctrine of God's omnipotence (likewise founded in revelation) itself entails his omnipresence. As to the possible outright heretical implications of the doctrine, Newton guards himself in the following passage (the second paragraph of the same fourth article as quoted above), which is of interest in its own right for its further elaboration of Newton's view both of space and of time ("duration"):

> Moreover lest anyone imagine from this that God is extended and made of divisible parts like a body: it should be known that spaces themselves are not actually divisible, and furthermore that each being has its own proper mode of presence in spaces. Thus, the relation to space of duration is far different from that of body. For we do not ascribe different durations to the different parts of space, but say that they all endure together. A moment of the duration of Rome and of London is the same, as is one of the Earth and of [any] star in the entire heavens. And just as we understand any one moment of duration to be thus diffused through all spaces, in its own way, without any conception of its parts: so it is no more contradictory that a Mind can likewise, in its own way, be diffused through space without any conception of parts.

But this in turn calls for commentary. What does Newton intend by the statement that "spaces themselves are not actually divisible"? He certainly does *not* mean that, for instance, a line-segment is not, in the ordinary sense, "divisible into two equal parts." That space has parts is implied by Newton's definition of *place*, quoted earlier; and the first numbered article in the series enumerating the properties of extension begins with the assertion: "Space can be distinguished everywhere into parts whose common boundaries we are accustomed to call surfaces; and these surfaces can be distinguished everywhere into parts, whose common boundaries we call lines; and these lines in turn can be distinguished everywhere into parts that we call points." Newton means, rather, that this "distinguishing into parts" is not an "*actual*" division: the parts of space are not "divisible," or *separable* from one another, as the parts of a(n ordinary) body[37] are.

So we must say: *spaces* have *parts*, but are not "actually divisible"; God, furthermore, who is present everywhere in space, *not only* is indivisible, but *does not have parts at all*: this is what the analogy of "durations" emphasizes: moments of duration, too, are present throughout space, but do not have spatial – or any – parts; just as, again, on Newton's conception of ("absolute") space, *points of space* are present throughout time, but do not have temporal – or any – parts.

Finally (in this series of questions), as to the sense in which space can be said to subsist "as a certain affection" of every being, and yet not to be an "accident," but "more like substance than accident," Newton has already given a part of the answer explicitly: space is not an accident because *we can conceive it to exist without any subject.* But, says the objector, can we – on Newton's view – conceive space without *any* subject of which it is an "affection"? Can we conceive space without God? We face again the question of the relation of Newton's conception of space to his theology, on which a view contrary to the one that has perhaps most often been held has already been stated above. But there is in fact explicit testimony from Newton himself. Later in the piece under discussion, in reverting to his objections to the Cartesian identification of body with extension, Newton says the following (emphases added here):

> If we say with Descartes that extension is body, do we not manifestly offer a path to Atheism, both because extension is not a creature but has existed eternally, *and because we have an absolute Idea of it without any relationship to God*, and therefore *we are able to conceive of it as existent while feigning the non-existence of God*?[38]

That, surely, is decisive! Space, the existence of space, or extension, *follows from* that of anything whatsoever; but extension does not require a subject in which it "inheres," as a property; and it can be conceived as existent without presupposing any *particular* thing, God included. On the other hand, it is an "affection of every being." We can perhaps understand this better with the help of another article in Newton's enumeration of the fundamental characteristics of space – the third article:

> The parts of space are immobile . . . For just as the parts of duration are individuated by their order, so that (for example) if yesterday could change places with today and become the later, it would lose its individuality and be no

longer yesterday but today: So the parts of space are individuated by their positions, so that if any two could interchange their positions, they would at the same time interchange their individualities, and each be converted numerically into the other. The parts of duration and of space are understood to be the same as they truly are solely by their order and mutual positions; nor have they any other principle of individuation beyond that order and those positions – which therefore cannot change.

This can be taken, in rather modern terms, as saying that space is a *structure*, or "relational system," which can be conceived of independently of anything else; its constituents are individuated just by *their relations to one another, as elements of this relational system*. But the system, or its constitutive elements, none the less can *and must* "affect," in the appropriate way, all things that exist: all existing things have spatial and temporal relations to one another by virtue of their having, each one of them, the appropriate kind of relation to the parts of space and of duration (again: *God is everywhere, created minds are somewhere, and a body is in the place it fills* – but, for the last two, we must add: *at each moment of its own duration*).

Having presented his view of the ontological status of space, Newton turns to the corresponding question about *bodies.* Before describing his answer, a comment about a rather curious historical connection seems in order – both for its intrinsic interest, and because it bears upon the question whether the views of this manuscript fragment can be taken to be those held by Newton in his mature years (opinion being divided as to the date of the fragment itself).[39]

In Locke's *Essay concerning Human Understanding* (Book 4, ch. x, §18) the following remark appears (but not in the first edition – 1690; it was introduced only in the second edition – 1694): "possibly, if we would emancipate ourselves from vulgar Notions . . . we might be able to aim at some dim and seeming conception how Matter might at first be made, and begin to exist by the power of [the] eternal first being"; but he immediately adds that to discuss this "would perhaps lead us too far from the Notions, on which the Philosophy now in the World is built," and so excuses himself from saying more about it. In his commentary on Locke's *Essay*, his *New Essays on Human Understanding* (in dialogue form), Leibniz's representative, Theophilus, responding to Philalethes, who presents the thoughts expressed by Locke, says of this: "You have given me real pleasure, sir, by recounting something of a profound thought of your able author,

which his overscrupulous caution has stopped him from offering in its entirety. It would be a great pity if he suppressed it and, having brought us to a certain point with our mouths watering, left us standing there. I assure you, sir, that I believe there is something fine and important hidden under this rather enigmatic passage."[40] The second French edition of the *Essay* (1729 – after the deaths of all three concerned: Locke, who died in 1704; Leibniz, 1716; Newton, 1727) contained a note to this passage by the translator, Pierre Coste: "Here Mr. Locke excites our curiosity, without being inclined to satisfy it. Many persons, imagining that he must have communicated to me this mode of explaining the creation of matter" – Coste had served as Locke's amanuensis for several years, and had translated the work under Locke's supervision – "requested, when my translation first appeared, that I would inform them what it was; but I was obliged to confess that Mr. Locke had not made even me a partner in the secret. At length, long after his [Locke's] death, Sir Isaac Newton, to whom I was accidentally speaking of this part of Mr. Locke's book, discovered to me the whole mystery. He told me, smiling, that he himself had suggested to Mr. Locke this way of explaining the creation of matter; and that the thought had struck him one day, when this question chanced to come up in a conversation between himself, Mr. Locke, and the late Earl of Pembroke. He thus described to them his hypothesis:" – and there follows a brief statement of the same account of the creation of matter that appears in the present chapter.[41] It is clear, then, that the account we are about to consider, whenever it may have been written down, was in its general lines communicated by Newton to Locke at some time in the early 1690s. It is clear, also, that this account was considered by Locke to be a very radical philosophical departure – and that Leibniz thought that it must indeed be so, and was very eager to learn what it was.[42]

As all this has intimated, Newton's analysis of the fundamental nature of bodies takes the form of a discussion of *how bodies might have been created*. In one respect, this is of secondary importance; for one can reasonably see it as merely a vivid way of focusing attention on what bodies "fundamentally *are*" – to "create a body somewhere," God has to bring it to pass that *whatever* bodies "fundamentally are," by hypothesis not there before, *comes to be* there (for Newton is not going to tell us "how" God does this in the sense of analyzing his *power* to bring such-and-such to pass: this power he takes for granted,

since he takes God to be omnipotent; he is going to tell us "how" a body is created, rather, in the sense of *exactly what has to be brought about* to achieve such a creation). To put the point another way: what "God creates" is simply "the fundamental constitution of corporeal nature"; we might leave God out of the story, and take it to be a description, or analysis, *of* the fundamental constitution of corporeal nature.

In another respect, however, there is something very important that this strategy of Newton implies – something that can be seen from the words with which this part of his discussion is introduced:

> Extension having been described, for the other part the nature of bodies remains to be explained. Of this, however, since it exists not necessarily but by the divine will, the explanation will be more uncertain, because it is not at all given to us to know the limits of the divine power – namely, whether matter could have been created in one way only, or whether there are several ways by which other beings similar to bodies might have been produced. And although it hardly seems credible that God could create beings like bodies, that should perform all their actions and exhibit all their phaenomena, and yet in essential and metaphysical constitution should not be bodies: since nevertheless I do not have a clear and distinct perception of this matter, I should not dare to affirm the contrary, and accordingly I will not say positively what the nature of bodies is, but rather shall describe a certain kind of beings, in every way similar to bodies, whose creation we cannot fail to acknowledge to be within the power of God – and which thus we cannot certainly declare not to be bodies.

So Newton distinguishes between the epistemological status of his theory of space – which he has presented as something he regards as exceptionally clear in conception (or "Idea"), and as entirely convincing in its doctrine – and that of his theory of body, which is fundamentally *conjectural*, because bodies, unlike space, are *effects of God's will*;[43] and it is not given to us to know all the ways in which the exercise of that will might accomplish given observable effects. This, again, is a proposition that can be paraphrased non-theologically: "Our conception of the fundamental constitution of nature – that is, of the *substantial world* of *things capable of acting* – is a conception of how every phenomenon we observe *could be* effected; but since we have no epistemologically *a priori* knowledge of this, the possibility always remains that those phenomena *are* effected in some (perhaps even very) *different* way."

Newton's creation story starts by supposing that a corporeal world already exists; what, Newton asks, would God have to do to create a *new* body – or, rather, what *might* he do that would create a new entity *indistinguishable from the bodies we know*?

First, he says, "let us feign empty spaces scattered through the world, some one of which, defined by certain limits, by the divine power becomes impervious to bodies": bodies simply cannot enter this region, but are, let us say, constrained to bounce back from its boundary. Such a "region of impenetrability" will be like a body, except that (so far as we have gone) it will be immobile. Second, then, we may "feign that impenetrability not conserved always in the same part of space, but able to be transferred hither and thither according to certain laws, yet so that the quantity and shape of that impenetrable space are not changed."[44]

This is not the last step, but it is worth pausing over. First, one may ask whether, according to Newton, it is in some way a "conceptual necessity" that bodies be impenetrable. The answer to this question – at least, at the stage of the composition of the third of the "Rules of Philosophizing" in Book 3 of the *Principia*[45] – is unequivocally negative; for in the discussion of that Rule, Newton says: "That all bodies are impenetrable, we gather, not from reason, but from sensation." Second, we should note that in conferring mobility upon the new (quasi-)bodies – that is, in making the property of impenetrability "able to be transferred hither and thither" – it is essential that this "transfer" be regulated by suitable *laws.* Of these, all Newton specifies is that the transfer *preserve the size and shape* of the regions of impenetrability; this, in effect, gives to the new (quasi-)*particles* the distinguishing property of (rigid) *atoms.* It is, however, clear that the motion of these new things is to be governed by the "first law of motion": namely, that, in the absence of encounters with bodies (or with other "quasi-bodies"), a quasi-particle is propagated through space with uniform speed in a straight line (understood to include the case of *rest* – that is, no "transfer" at all); and that when encounters do occur, they are to be governed by the ordinary laws of impact (which, in turn, implies that each quasi-particle is characterized by a parameter corresponding – in "ordinary" particles – to their *mass*).

So far, we have a constitution for (quasi-)corporeal nature that looks very much like just what is needed for bodies, according to the corpuscular philosophy: rigid and indivisible ultimate particles,

interacting only by impact – "*by impulse*, and nothing else," as Locke says: "It being impossible to conceive, that Body should operate on what it does not touch . . . or when it does touch, operate any other way than by Motion."[46] Yet Locke *also* tells us the following:

> Another *Idea* we have of Body, is the power of *communication of Motion by impulse*; and of our Souls, the power of *exciting of Motion by Thought*. These *Ideas*, the one of Body, the other of our Minds, every days experience clearly furnishes us with: But if here again we enquire how this is done, we *are equally in the dark*. For in the communication of Motion by impulse, wherein as much Motion is lost to one Body, as is got to the other, which is the ordinariest case, we can have no other conception, but of the passing of Motion out of one Body into another; which, I think, is as obscure and unconceivable, as how our Minds move or stop our Bodies by Thought; which every moment we find they do . . . I think, we have as many, and as clear *Ideas* belonging to Spirit, as we have belonging to Body, the Substance of each being equally unknown to us; and the *Idea* of Thinking in Spirit, as clear as of Extension in Body; and the communication of Motion by Thought, which we attribute to Spirit, is as evident, as that by impulse, which we ascribe to Body. Constant Experience makes us sensible of both of these, though our narrow Understandings can comprehend neither. For when the Mind would look beyond those original *Ideas* we have from Sensation or Reflection, and penetrate into their Causes, and manner of production, we find still it discovers nothing but its own short-sightedness.[47]

In other words, according to Locke, the only way in which we can conceive bodies to act, is a way in which we *cannot* conceive bodies to act: it is a way that is "*obscure and unconceivable*," and is beyond the capacity of "our narrow Understandings [to] comprehend."

Locke is here wrestling with a fundamental incoherence in the philosophical foundations of the corpuscular philosophy; the fact that he appears to contradict himself – that he *does* contradict himself! – is testimony to the basic honesty of his mind, and to his penetrating insight. For although he accepts the corpuscular philosophy as the most plausible hypothesis about nature, and accepts the widespread view that it represents the only basis on which we can *hope* to understand natural processes, he also sees (sometimes, at least) that the underpinnings of that philosophy are *not* "clear and distinct principles" such as the Cartesians thought they had, but principles whose *own* grounds are *obscure*. Partly for this reason, Locke draws very pessimistic conclusions concerning the possible

advance of science; indeed, he thinks that a truly *systematic* knowledge of nature is beyond human capacity.[48]

Newton sees the very same impossibility of a "transparent" system of fundamental principles; but he faces it squarely, and it does not create for him a desperate predicament: the *fundamental* constitution of nature is simply not (directly) open to us; but we can nevertheless form perfectly clear conceptions of *what structures may underlie phenomena*; not *why* they do – nor even for certain *that* they do – but what structures *would suffice* as a basis for the constitution of the world we know, at the stage of knowledge we have reached. And what allows us to do this is a clear understanding of the *lawful relationships* that we have so far managed to discover among phenomena. Thus, first of all, we have "of extension an Idea the clearest of all." How did we obtain it? From experience – and, of course, *thought* (in particular, thought of the kind we call "mathematical") *based* upon experience: "geometry is founded in mechanical practice"; and "it is the glory of geometry that from [a] few principles, *brought from without*, it is able to produce so many things."[49] And in the second place, we have a perfectly clear conception of those attributes of bodies that the mechanical, corpuscular, philosophy has conceived as fundamental, including the laws governing the interactions of those bodies: the laws of impact. *That* means, in Newton's view, that we have a sufficiently clear conception of *what bodies are* if the mechanical philosophy is true.

To appreciate the clarifying power of this analysis, it is helpful to describe another perplexity in which Locke finds himself. In agreement with *both* the Aristotelian tradition *and* the Cartesian philosophy, Locke calls all "real existents" *substances*; and he asks what goes to make up our "*Ideas* of Substances."[50] His general answer is exemplified by one of his favorite examples: "the greatest part of the *Ideas*, that make up our complex *Idea* of *Gold*, are Yellowness, great Weight, Ductility, Fusibility, and Solubility in *Aqua Regia, etc.* all united together in an unknown *Substratum.*"[51] This "unknown substratum," the "idea" of which makes a part of *all* our ideas of particular substances according to Locke, he calls, simply, "substance" (or "substance in general"). At the same time, however, Locke tells us that we have of substance *no idea at all*:

> I confess, there is [an] *Idea*, which would be of general use for Mankind to have . . . and that is the *Idea of Substance*, which we neither have, nor

can have, by *Sensation* or *Reflection* . . . We have no such *clear Idea* at all, and therefore signify nothing by the word *Substance*, but only an uncertain supposition of we know not what . . . which we take to be the *substratum*, or support, of those *Ideas* we do know.[52]

There has been much discussion of the precise nature of Locke's dilemma here – that of holding both that we *require* a certain "idea," and that we do not *have* it. If we "do not have" the idea, how can it be an *idea* at all – how can we know what it *is* that we need but do not have? The following is a passage that helps to clarify the issue: "[I]n Substances, besides the several distinct simple *Ideas* that make them up, the confused one of Substance, or of an unknown Support and Cause of their Union, is always a part."[53] What this suggests we "need" is an *answer* to the twofold question: "(1) *In what* do the qualities we attribute to a substance *exist together*? (2) What is the *cause* of their existing thus together?"

Newton's analysis may be said to separate these two questions. To the first, his answer is that the qualities that fundamentally constitute a body can be coherently and clearly conceived to *exist in*, or to have as their "logical subject" or the metaphysical "support" of their "being," simply *extension*: regions or "parts" of space. In the language of later natural philosophy, the distribution of bodies through space can be described as a kind of *field* on space: the "field of impenetrability," characterized, at each point of space, by the simple indication "filled" or "not filled."[54] Newton's own comment upon this part of the question (in his summing-up, later in the piece) is illuminating, both of his own view and for the possible light it sheds on the perplexity Locke felt – since Newton (quite independently of Locke's thoughts on the matter) names a perplexity that his account *removes*:

> [F]or the existence of these beings [– that is, the beings whose creation by God he has imagined –] it is unnecessary to feign some unintelligible substance to be given in which as in a subject a substantial form should inhere: extension and an act of the divine will suffice. Extension takes the place of the substantial subject in which the form of the body is conserved by the divine will; and that effect of the divine will is the form or formal reason of the body, denominating as a body every region of space in which it is produced.

Newton goes on to assimilate the "unintelligible substance," the need for which he claims he has obviated, to the "materia prima" posited by the scholastics:[55] the notion of a totally "formless" ultimate

"support" of all forms or attributes; and says the following (Articles (3) and (4) of his summary):

> (3) Between extension and the form imposed upon it there is almost the same Analogy that the Aristotelians posit between the *materia prima* and substantial forms, namely when they say that the same matter is capable of assuming all forms, and borrows the denomination of numerical body from its form. For thus I suppose that any form may be transferred through any space, and everywhere denominate the same body.
>
> (4) They differ, however, in that extension . . . has more reality than *materia prima*, and also in that it is intelligible, as likewise is the form that I have assigned to bodies. For if there is any difficulty in this conception, it is not in the form that God imparts to space, but in the way in which he imparts it. But that is not to be taken for a difficulty, since the same [point] occurs with respect to the way we move our limbs, and nevertheless we do believe that we can move them. If that way were known to us, by parity of reason we should also know how God can move bodies, and expel them from a certain space terminated in a given figure, and prevent the expelled bodies or any others from entering into it again – that is, cause that space to be impenetrable and to assume the form of a body.

Here, then, we have Newton's answer (in effect) to the second part of the above-posed twofold Lockean question: what *causes* the *coexistence* of the basic qualities of his "new" or "quasi-"bodies, as well as *the laws of propagation and interaction*, which form a part of the essential character of these entities, is just "God's action" itself; or, in our neutral paraphrase, this coexistence and these laws just *are*, on this view, *the fundamental constitution of corporeal nature.* This may indeed be wrong – it is possible that the phenomena we know are produced in a different way; but *if* it is right, it is *enough*: the demand for a further "explanation" of this constitutional fact stems from the Cartesian illusion that we must in principle have a "clear and distinct" apprehension of the necessity of the basic constitution of nature – precisely the illusion that Locke on the one hand shares when he speaks of "impulse" as *the only way we can conceive bodies to act*, and that he on the other hand *explodes* when he asks: "Have we indeed a clear conception of this mode of transfer of motion?"

But there still remains a step to be taken in the creation of the "new" bodies. Why so? If the "beings" so far described have all the fundamental properties posited by the corpuscular philosophy, why is that not sufficient? The reason is this: we must ask, *would* these

beings have *all* the attributes required for us to take them for bodies of the sort we know? In particular, how could we detect the existence of these beings *at all*? So far, we have assumed that "*ordinary*" bodies *already* exist (including our own bodies!). Then we could detect the "new" bodies by the interaction of ordinary bodies with them: for instance, we should perceive that ordinary bodies bounce off the new ones, and so detect their presence; *light* might be reflected from them, so that we could *see* them; etc. But the metaphysical hypothesis Newton intends to suggest is that what we have been calling "new" or "quasi-"bodies are in fact just the bodies we know. And for *this*, he says, it is necessary to suppose that these beings are endowed, further, with the power to *interact with minds*: "[t]hat they be able to excite various perceptions in the senses and the fancy in created minds, and in turn to be moved by the latter" – most especially, that they are able, when they form part of what he calls our "sensorium" (the crucial region of our brain), to induce specific forms of *awareness* as a consequence of specific motions on their part; and, correspondingly, that our acts of will cause suitable motions in those that initiate activity in what we now call our motor neurons.

This is another rather original idea. Descartes placed the "essence" of bodies in extension alone; to this, Locke objects that impenetrability, which he calls "solidity," is equally essential to bodies;[56] and in an important summary passage, he suggests as the "primary and original" *ideas* we have of *anything* the following: "*Extension, Solidity, Mobility*, or Power of being moved; which by our Senses we receive from Body: *Perceptivity*, or the Power of perception, or thinking; *Motivity*, or the Power of moving: which by reflection we receive from our Minds."[57] But Newton points out (again, quite without any acquaintance with Locke's discussion) that just as "mobility" is correlative with "motivity," so must *perceptibility* be correlative with perceptivity; that, indeed, contrary to what the grammatical formation of the words might suggest, "perceptivity" is a *susceptibility* to being *affected*: a process in which it is *bodies* that "act on" *minds*. That such a power is essential to bodies is something he argues for rather strongly:

> But should anyone object that bodies not united to minds cannot directly arouse perceptions in minds, and that hence . . . this power is not essential to them: it should be noted that there is no question here of an actual union,

but only of a faculty in bodies by which they are capable of a union through the forces of nature. From the fact that the parts of the brain, especially the finer ones to which the mind is united, are in a continual flux, new ones succeeding to those which fly away, it is manifest that that faculty is in all bodies. And, whether you consider divine action or corporeal nature, to remove this is no less [a violation of the nature with which God has endowed bodies] than to remove that other faculty by which bodies are enabled to transfer mutual actions amongst one another[58] – that is, to reduce body to empty space.

Towards the end of this lengthy digression,[59] Newton makes the claim that "the usefulness of the described Idea of bodies shines forth most in that it clearly involves and best confirms and explicates the chief truths of Metaphysics." What he goes on to contend is that the conception of body in question provides a powerful argument against atheism. But the end of this passage has an importance beyond, and quite independent of, its theological claims. Having argued that the chief, or even the only, support of atheism is the "prejudice" or "notion" of bodies "as if having in themselves a complete absolute and independent reality," he adds:

Thus the prejudice just mentioned ought to be laid aside, and substantial reality rather ascribed to these kinds of Attributes which are real and intelligible in themselves and do not require a subject in which they inhere . . . And this we can manage without difficulty if (besides the Idea of body expounded above) we reflect that we can conceive of space existing without any subject, when we think of a vacuum . . . In the same way, if we should have an Idea of that Attribute or power by which God, through the sole action of his will, can create beings: we should perhaps conceive that Attribute as it were subsisting of itself, without any substantial subject, and involving his other attributes. But while we cannot form an Idea of this Attribute, nor even of our own power by which we move our bodies, it would be rash to say what is the substantial foundation of minds.

The boldness of this would be hard to exaggerate. In his rejection of the notion of "substance" as having reference to what he calls an "unintelligible" support or subject of attributes, in favor of a notion of "substantiality" *of the attributes themselves* (the criterion of substantiality being, as indicated by him earlier, the role played in *actions*), Newton goes so far as to suggest that even God might be conceived entirely in terms of his attributes, if only we could form

clear "Ideas" of these. It is well known that Newton's theologico-religious convictions (which he kept carefully concealed from all but a few very trusted contemporaries)[60] were unorthodox; in particular, that he rejected the doctrine of the Trinity. Well, of course the view of substantial reality described here would make not so much false, as entirely unintelligible, the proposition that God is "three persons, but one substance"!

However, as has been remarked, the reach of Newton's suggestion is by no means only theological; it bears explicitly upon the so-called "mind–body problem" – or, perhaps better put as Newton put it: upon the problem of understanding "the substantial foundation of minds." Just as in the theological case, the suggestion sets aside the distinction of "kinds of substance": mind–body dualism or monism, in favor of the program: *to seek to understand mental attributes and their relation to corporeal ones.* When these relations are sufficiently understood, Newton implies, we may expect to know all that there is to know about the "substantial foundation of minds"; *before* they are sufficiently understood,[61] "it would be rash to say what is the substantial foundation of minds."

It remains now to discuss what consequences for Newton's metaphysics resulted from his greatest discovery in natural philosophy: that of the law of universal gravitation.

The short answer is that this discovery led Newton to a quite new conception of the nature of what Descartes had called "a natural power in general"; that is, to a new conception of how it *may be fruitful* – not, as for Descartes, how *it is necessary* – to conceive of the "actions" that characterize nature, with a view to the deeper understanding of natural phenomena. In the Preface to the *Principia*, Newton formulates this conception in the following way: having first remarked that, whereas the ancients cultivated mechanics as the science of *machines* – that is, as the "art" of *moving weights* – his design in the present work concerns "not arts but philosophy," and his subject is "not manual but natural powers," he goes on:

> And therefore we offer this work as mathematical principles of philosophy. For all the difficulty of philosophy seems to consist in this, from the phaenomena of motions to investigate the forces of Nature, and then from these forces to demonstrate the other phaenomena . . . In the third book we give an example of this in the explication of the System of the World. For by the propositions mathematically demonstrated in the first books, we there

derive from the celestial phaenomena, the forces of Gravity with which bodies tend to the Sun and the several Planets. Then from these forces by other propositions, which are also mathematical, we deduce the motions of the Planets, the Comets, the Moon, and the Sea. I wish we could derive the rest of the phaenomena of Nature by the same kind of reasoning from mechanical principles. For I am induced by many reasons to suspect that they may all depend upon certain forces by which the particles of bodies, by some causes hitherto unknown, are either mutually impelled towards each other and cohere in regular figures, or are repelled and recede from each other; which forces being unknown, Philosophers have hitherto attempted the search of Nature in vain. But I hope the principles here laid down will afford some light either to that, or some truer, method of Philosophy.[62]

This is the new program for natural philosophy: deriving the phenomena of nature from "mechanical principles," not in the sense previously understood by the mechanical philosophy, but in the sense of *principles governing forces of attraction and repulsion* – themselves to be discovered by reasoning from the phenomena, as in Book 3 of the *Principia* itself. It is important to note that the program is put forward as *tentative* and *open to revision*. But what bearing does this change have on Newton's metaphysics?

For the answer to this, we must consider Newton's exposition of the general framework of his system of mechanical principles, both in the *Principia* and near the end of that thirty-first Query of the *Opticks* to which brief reference has already been made.

At the opening of the *Principia* we find first a section of "Definitions," and then one of "Axioms, or Laws of Motion." Among the eight definitions, six treat of concepts associated with the general notion of *force*. Definition 3 tells us that the "innate force of matter" is "a power of resisting, by which every body, as much as in it lies, endeavours to persevere in its present state, whether it be of rest, or of moving uniformly forward in a right line." The paragraph of discussion following this definition introduces the alternative expression *vis inertiae* – "force of inactivity" – for this same power; makes the important remark that this force is quantitatively measurable by "the [mass of the] body whose force it is"; and explains further that whenever a force is "impressed" upon one body, A, by another body, B, so as to tend to change the condition of A, the force of inactivity is *exercised* in a twofold way: (a) in the degree to which A "withstands" the force impressed – i.e., in the *smallness* of the change of velocity

that results; and (b) in that *A*, "by not easily giving way," reciprocally "endeavours to change the state" of *B*. Definition 4 is of a term already used in the passage just described: it says that an "impressed force" is an action exerted upon a body, tending to change its state of rest or motion. One might assume from this that "intrinsic force" and "impressed force" are, for Newton, correlative contrary terms; but as we shall see, this would be not quite correct. The paragraph of explanation following this definition remarks first that impressed force "consists in the action only; and remains no longer in the body, when the action is over." Thus, whereas the "force of inactivity" is a *permanent* attribute of a body – not always *exercised*, but always *present* – impressed force is by its nature *episodic*. The explanation ends with the remark, "Impressed forces are of different origins; as from percussion, from pressure, from centripetal force." The phraseology here – a force said to be "from" another (kind of) force as its "origin" – is rather odd. But the point is this: the "intrinsic force of matter" is, in Newton's terminology, one of the "natural powers" or forces of nature. The various "origins" of impressed forces, too, are natural powers: permanent features of material nature, not transient episodes. An *impressed* force is the *action* upon a body of one of these natural powers.

Of the three kinds of "origin" instanced by Newton, two – percussion and pressure – are recognizably the ones assumed by the mechanical philosophy. It is the third – "centripetal force" – that is the characteristic novelty of the *Principia*; and Definitions 5–8 are devoted to aspects of this notion.

Definition 5 tells us simply that a centripetal force is one directed towards a point as center. In the paragraph of discussion, Newton cites three characteristic examples – "Gravity by which bodies tend to the centre of the Earth; Magnetism, by which iron tends to the loadstone; and that force, whatever it is, by which the Planets are perpetually drawn aside from the rectilinear motions, which otherwise they wou'd pursue, and made to revolve in curvilinear orbits." These, it is clear, rightly count as "forces of nature"; and the main business of the *Principia* will be to establish that the first and third of them are the same, and to establish the fundamental law that characterizes this force. Unfortunately, with an uncharacteristic lapse in clarity, Newton adds a fourth example: that of the force by which a sling holds a stone in its orbit about the hand. In what sense this

example obscures the concept Newton has chiefly in view, we shall soon see.

The remaining three definitions concern three "quantities," or "measures," of a centripetal force, which Newton calls the *absolute*, the *accelerative*, and the *motive* quantities; and it is in his characterization of these three measures – above all, in the second paragraph of discussion following Definition 8, which paragraph is devoted to a fuller explication of all three measures – that Newton gives us the deepest information about his conception of a centripetal force itself as a natural power. Of the three definitions taken by themselves, the first two are, in different ways, a little puzzling. Definition 6 says that the absolute quantity of a centripetal force is the measure of that force "proportional to the efficacy of the cause that propagates it from the centre, through the spaces round about"; and Newton adds by way of example that "the magnetic force is greater in one load-stone and less in another, according to their sizes and strength." This makes clear the general idea of what it is that the absolute quantity is supposed to measure; however, it fails to tell us *how* this is to be measured: the phrase "proportional to the efficacy of the cause" presupposes that we know how to express the efficacy of the cause in a quantitative way.[63] But in spite of this, when the issue arises concretely, in the case of the force of gravity, the appropriate quantitative measure is entirely clear. With Definition 7, on the other hand, the quantity is explicitly named – the "accelerative quantity" of a centripetal force is its measure, "proportional to the velocity which it generates in a given time": in other words, the accelerative quantity is in effect just what we call the *acceleration* produced by the force; what is puzzling is Newton's remark in explanation of this notion: "Thus the force of the same loadstone is greater at less distance, and less at greater: also the force of gravity is greater in valleys, less on tops of exceeding high mountains; and yet less (as shall be hereafter shown) at greater distances from the body of the Earth; but at equal distances, it is the same everywhere . . . " The puzzle is, why choose *acceleration* as the measure that varies in this sort of fashion with distance? But here, the puzzle vanishes upon a little reflection. In the case of a magnet, acceleration is indeed *not* an appropriate choice for the measure Newton really has in mind; for it is by no means true (nor does Newton say it is) of the acceleration produced by a magnet that "at equal distances, it is the same everywhere." But that *is* true

of gravitational force. This is the centrifugal force Newton is chiefly concerned with in the *Principia*, and he has formulated his *general* definition in a way that strictly fits only this *special* case. Finally, Definition 8 presents us with the quantity that we normally associate with the word "force" in Newtonian mechanics: it defines the motive quantity of a centripetal force as its measure, "proportional to the motion which it generates in a given time." Since (1) according to Newton's Definition 2 the "quantity of motion" is jointly proportional to the mass and the velocity of a body, and since (2) the quantity generated "in a given time" means, in more modern language, the *rate, per unit time*, with which it is generated, the definition says that the motive quantity measures the force by the *rate of change of momentum* produced thereby; in other words, it measures the force impressed upon a body by the product of the mass of the body and the resulting acceleration.

Newton considers these interrelated notions important enough to devote a few paragraphs to their further clarification. Of these the most important part, for our concerns, is the following:

> These quantities of Forces, we may for brevity's sake call by the names of Motive, Accelerative, and Absolute forces; and for distinction sake consider them, with respect to the Bodies that tend to the centre; to the Places of those bodies; and to the Centre of force towards which they tend: That is to say, I refer the Motive force to the Body, as an endeavour and propensity of the whole towards a centre, arising from the propensities of the several parts taken together; the Accelerative force to the Place of the body, as a certain power or energy[64] diffused from the centre to all places around to move the bodies that are in them; and the Absolute force to the Centre, as indued with some cause, without which those motive forces would not be propagated through the spaces round about; whether that cause is some central body, (such as is the Load-stone, in the centre of the force of Magnetism, or the Earth in the centre of gravitating force) or any thing else that does not yet appear. For I here design to give a Mathematical notion of those forces, without considering their Physical causes and seats.

This passage describes the conception of what in a later terminology is called a *field of force*, distributed about – and everywhere tending towards – a center.[65] The "absolute quantity" of this force (this field) is meant to characterize the strength of the field *as a whole* – the "efficacy of the cause" by which it is produced, or "propagated through the spaces round about"; again, in later terms, it is the

"source-strength" at the center of the field. The "accelerative quantity" is *meant* to characterize the intensity of the field *at any given place* (and in the special case of gravitation, the "acceleration due to gravity" at the place in question successfully does so).[66] Finally, the "motive quantity" characterizes the action of the field upon an actual *body*: it measures, in other words, the force *impressed upon* a body by the field – the impressed force that has the given (field of) centripetal force as its "origin." In the case of gravity, the motive quantity of the force on a body is simply the *weight* of that body.[67]

When this array of concepts is juxtaposed with the passage quoted earlier from the preface to the *Principia*, in which the program is laid out of trying to account for the phenomena of nature as the effect of *forces of attraction and repulsion*, what emerges is the view that the natural powers – that of the *vis inertiae* of matter excepted – may all take the form of fields of force associated with the particles of matter; and, indeed, "central" fields (tending *either* toward *or away from* a center).[68]

One further essential point remains to be made – this derived from the Laws of Motion: namely, that the forces of nature constituted by the central fields are forces of *interaction*, governed by the third law of motion: that is, they produce *equal and opposite* motive forces between *pairs* of bodies. In Newton's argument in Book 3 culminating in the law of universal gravitation, this conception of a force of nature as an interaction subject to the third law plays a most crucial role.[69] Newton's awareness that there is in this a novel and important idea is clearly shown in a passage in the first version of Book 3, written (he tells us) "in a popular method,"[70] not published during his lifetime, but published both in Latin and in an English translation in 1728. The passage in question is striking in its iteration, which contrasts with Newton's usual conciseness of exposition (all emphases are added here, chiefly to highlight the main point – the one exception is explained in note 71):

> Since the action of the centripetal force upon a body attracted is, at equal distances, proportional to the matter in this body, it accords with reason that it should be proportional also to the matter in the body attracting. For action is mutual, and (by the third Law of Motion) makes bodies by a mutual tendency approach one another, and hence must be conformable with itself in each body. *One body may be considered as attracting, another as attracted; but this distinction is more mathematical than natural. The*

attraction really is of each body towards the other, and is thus of the same kind in each.

And hence it is that the attractive force is found in each. The Sun attracts Jupiter and the other Planets, Jupiter attracts the Satellites; and by parity of reason, the Satellites act among themselves reciprocally and upon Jupiter, and all the Planets mutually among themselves. *And though the mutual actions of two Planets may be distinguished from one another, and considered as two actions, by which each attracts the other: yet in so far as these* [*actions*] *are intermediate, they are not two, but a single operation between two terms.* By the contraction of a single interceding cord two bodies may be drawn each to the other. The cause of the action is twofold, indisputably [that cause is] the disposition of each body; the action is likewise twofold in so far as it is upon two bodies; but *as between two bodies it is sole and single. It is not one operation by which the Sun for instance attracts Jupiter, and another operation by which Jupiter attracts the Sun, but it is one operation by which the Sun and Jupiter mutually endeavor to approach one another.* By the action by which the Sun attracts Jupiter, Jupiter and the Sun endeavor to come nearer together (by the third Law of Motion) and, by the action by which Jupiter attracts the Sun, Jupiter and the Sun likewise endeavor to come nearer together: *but the Sun is not attracted towards Jupiter by a double action, nor Jupiter by a double action towards the Sun, but it is one intermediate action by which both approach nearer together*. Iron draws the loadstone as much as the loadstone draws the iron; for all iron in the neighborhood of the loadstone also draws other iron. *But the action between the loadstone and the iron is single, and is considered as single by the Philosophers* . . . Conceive a single operation arising from the conspiring nature of both to be exerted in this way between two Planets; and this will be disposed in the same way *towards* both: hence being manifestly proportional to the matter in one of them, it will be proportional to the matter in the other.[71]

To repeat, then: the almost obsessive iteration in this passage seems clear evidence of Newton's intention to bring emphatically forward a new notion of the *unity* of interaction as the form of a force of nature. In terms of the fields already referred to, this means that exactly those bodies that are susceptible to the action of a given interaction-field are also the *sources* of the field; and that the measures of susceptibility and of source-strength (the "absolute quantity" of the body's force) are the same.

If all this is brought into relation to the metaphysical analysis in "De gravitatione et aequipondio fluidorum," it implies that in creating a body, God (or in the "constitution" of a body, *nature*) must

impose, not only the field of impenetrability and the laws of motion appropriate thereto, but other fields as well, with their laws, characterizing forces of interaction of the kind that have been described – which fields, according to the Preface to the *Principia*, it becomes the presumed task of natural philosophy to discover.

And this is precisely the picture presented by Newton near the end of Query 31 of the *Opticks*. He there makes the explicit distinction, among natural powers or forces of nature, between the *vis inertiae*, as a "passive principle," and the other forces, which are "active principles"; but in both cases, he makes clear, what characterizes or identifies a particular such force is a *law* of nature (of the appropriate kind). Here are the principal relevant statements; they are preceded by a lengthy survey of physical and chemical phenomena, all tending to show that our understanding of nature depends upon the determination of forces of attraction and repulsion among particles:

> And thus Nature will be very conformable to herself and very simple, performing all the great Motions of the heavenly Bodies by the Attraction of Gravity which intercedes those Bodies, and almost all the small ones of their Particles by some other attractive and repelling Powers which intercede the Particles. The *Vis inertiae* is a passive Principle by which Bodies persist in their Motion or Rest, receive Motion in proportion to the Force impressing it, and resist as much as they are resisted.[72]

We see, then, that Newton regards as *the law or principle* characterizing the intrinsic force of matter as a natural power, not what *we* call the "law of inertia," but the *conjunction of all three Laws of Motion*. This is quite in accord with what he has said in his discussion of Definition 3 of the *Principia*, where he describes the twofold manifestation or "exercise" of the force of inertia: in reducing the acceleration of the body acted upon by an impressed force (Law 2), and in the reciprocal "endeavor to change the state" of the body responsible for that impressed force (Law 3).

After some further discussion, which culminates in the statement: "All these things being consider'd, it seems to me probable that God in the Beginning form'd Matter in solid, massy, hard, impenetrable, moveable Particles, [etc.],"[73] mentioned earlier – a statement that in itself can be regarded as a pretty close counterpart of the creation story of "De gravitatione et aequipondio fluidorum," but with its

deeper ontological analysis omitted – Newton goes on:

> It seems to me farther, that these Particles have not only a *Vis inertiae*, accompanied with such passive Laws of Motion as naturally result from that Force, but also that they are moved by certain active Principles, such as is that of Gravity, and that which causes Fermentation, and the Cohesion of Bodies. These Principles I consider, not as occult Qualities, supposed to result from the specifick Forms of Things, but as general Laws of Nature, by which the Things themselves are form'd; their Truth appearing to us by Phaenomena, though their Causes be not yet discover'd. For these are manifest Qualities, and their Causes only are occult.[74]

We have, then, once again, the explicit distinction of the one passive principle and the several active principles; the explicit identification of such a principle with a "general Law of Nature"; and further, the indication that these principles, forces, or laws, are taken not to *result from* something like Aristotelian "substantial forms," which are "occult Qualities," but to *replace* them: it is *by* these "general Laws of Nature" that "*the Things themselves are form'd*" – just as, in "De gravitatione et aequipondio fluidorum," the *clear* attributes of impenetrability and laws of transference of the fields of impenetrability through the parts of space *replaced* the obscure notions of substance and substantial forms. The contrast is further drawn – and the *tentative* character of Newton's philosophic program further emphasized – in these words:

> [O]ccult Qualities put a stop to the Improvement of natural Philosophy, and therefore of late Years have been rejected. To tell us that every Species of Things is endow'd with an occult specifick Quality by which it acts and produces manifest Effects, is to tell us nothing: But to derive two or three general Principles of Motion from Phaenomena, and afterwards to tell us how the Properties and Actions of all corporeal Things follow from those manifest Principles, would be a very great step in Philosophy, though the Causes of those Principles were not yet discover'd: And therefore I scruple not to propose the Principles of Motion above-mentioned, they being of very general Extent, and leave their Causes to be found out.[75]

Combining what Newton says here with the words previously quoted from the Preface to the *Principia*, one sees that – apart from the obvious openness to the future of a *program of investigation for physics* – the *metaphysics* that Newton presents is open and tentative in two respects: First, the words just cited imply that, although

we are asked to consider the active principles as *candidates* to replace the old substantial forms as fundamental constitutional elements of nature, we are *not* to suppose, dogmatically, that whatever principles we have managed to discover are *necessarily* "the" fundamental ones: it will be a question for the future whether (yet deeper) *causes* of these principles may remain to be found out. In particular, this explains why Newton never claimed – and strongly denied holding – that gravity is "essential" to bodies. In the *Principia*, in the General Scholium to that work (added in the second edition, 1713), he says in a very celebrated passage:

> Hitherto we have explain'd the phaenomena of the heavens and of our sea, by the power of Gravity, but have not yet assign'd the cause of this power. This is certain, that it must proceed from a cause that penetrates to the very centers of the Sun and Planets, without suffering the least diminution of its force . . . But hitherto I have not been able to discover the cause of those properties of gravity from phaenomena, and I feign no hypotheses. For whatever is not deduc'd from the phaenomena, is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy.[76]

And in the *Opticks* (in Query 21, added in its second edition, in 1717), Newton does actually sketch an hypothesis as to a possible "mechanical" cause of gravity by the action of a highly elastic aethereal medium (NB: a *possible* cause: one to be *considered*, not *adopted*; hence, although an hypothesis, not "feigned").

The second respect in which the metaphysics is left open to revision is more far-reaching (and commensurately vaguer). It is related to Newton's statement in "De gravitatione et aequipondio fluidorum" that we cannot know with certainty the ultimate constitution of things: namely, the general "probable" metaphysical conclusions Newton has reached on the basis of a comprehensive consideration of what has been discovered from phenomena are in the nature of the case open to possible *re*-consideration when *more* things have been learned; hence the form in which Newton expresses his hopes for the success of his program in the Preface to the *Principia*: "I hope the principles here laid down will afford some light either to that, or some truer, method of Philosophy."

In conclusion, it is worth considering briefly what the *actual* success has been of Newton's metaphysics, in the perspective of the

natural philosophy of the present time. Of course, in our own physics, *all* the foundations of Newtonian physics have been radically modified: space and time, since the work of Einstein, are not conceived as Newton conceived them; finitely extended rigid and impenetrable ultimate particles have been replaced by far more exotic beings; fields that are *not* rigidly associated with particle sources, as Newton's were, but that are capable of existing to some degree independently, and that have their own internal structure and interaction among their parts (as in the propagation of *waves*), have come to have an "ontological" standing no less fundamental than "fundamental particles" themselves; and – especially since the advent of quantum mechanics – we have even had to abandon the notion of particles as having, at each instant of time, definite locations in space, and as interacting through Newtonian "impressed motive forces." On the other hand, in the developments that have led to the present state of physics, the conceptions introduced by Newton have played an indispensable role. And what are arguably his two most characteristic – and in his own time most sharply controverted – basic conceptions remain, *although* radically modified, as basic characteristics of the structure envisaged by our own science. The first of these is the structure of space-time. It was once thought that the development of the general theory of relativity had decided the issue of "absolute" versus "relative" space and motion against Newton and in favor of his strongest contemporary critic in this matter, Leibniz; but more careful consideration has shown that in spite of the very far-reaching changes wrought by Einstein – in spite of the fact that absolute space and absolute time have been abandoned, and the geometric structure of space-time has proved to be *interdependent with* the distribution of matter (or, rather, of "energy-momentum") – it remains necessary to regard space-time and its geometry as having a status as "real" as that of matter: the program of "reducing" the properties of space-time to properties and interrelations of "bodies" has not succeeded. So on this *general* score – although certainly *not* in *detail* – Newton was, in the eyes of our own science, "right" to take space and time as fundamental entities.[77]

The other characteristic notion of Newton's that has proved quite remarkably durable is that of a natural power, or force of nature. This statement may seem as surprising as the claim that Newton was "right" in a general sense about space and time: for (a) as has

been already remarked, Newtonian "motive force" has disappeared from quantum mechanics, and (b) it *is* "motive force" – the "force" of Newton's second law, $f = ma$ – that is usually taken as the characteristic notion of "Newtonian mechanics." But as we have seen, as important as this concept is in Newton's *Principia*, it does not express his most basic notion; for instance, whereas an impressed force is not a natural power, the "force of inertia" – which is something entirely different from the force that is equal to ma – *is* one. Newton's basic notion of a force of nature is, however, so far from being antiquated that it is substantially the same – although again, as in the case of space and time, with profound modifications in detail – as the notion used when physicists today speak of the "four fundamental forces." Of these, the gravitational force is the first to have been discovered; it was, of course, a great discovery of Newton's – and, on the analysis here offered, provided the grounds on which Newton's general conception was based. Two of the four fundamental forces – the weak and the strong nuclear force – obviously could not have been foreseen in Newton's time. Of the remaining one – the electromagnetic force, whose classical definitive form was discovered by Maxwell in the 1860s – we find some traces in Newton's work. References to the loadstone have been quoted above. In the long closing query of the *Opticks*, from which material occurring near the end has been cited as illuminating Newton's general concept of a force of nature, there is also the following incidental speculation about electrical force, in the midst of a more general consideration (itself showing again exactly the *tentative* view of the "fundamental" that has been suggested as characteristic of Newton):

> What I call Attraction may be perform'd by impulse, or by some other means unknown to me. I use that Word here to signify only in general any Force by which Bodies tend towards one another, whatsoever be the Cause. For we must learn from the Phaenomena of Nature what Bodies attract one another, and what are the Laws and Properties of the Attraction, before we enquire the Cause by which the Attraction is perform'd. The Attractions of Gravity, Magnetism, and Electricity, reach to very sensible distances, and so have been observed by vulgar Eyes, and there may be others which reach to so small distances as hitherto escape Observation; and perhaps electrical Attraction may reach to such small distances, even without being excited by Friction.[78]

When we remember that electrical attractions, in Newton's time, constituted a rather isolated phenomenon, observed only when certain bodies were suitably rubbed – and when we recall that the "attractions [and repulsions as well] extending to small distances *within* bodies" that Newton had in mind were the ones that should eventually account for cohesion and for chemical processes – this glimmering of a suspicion that electricity might not be merely a special effect of rubbing, but might exist and be responsible for forces at short range as a general fact of nature surely deserves to be considered a remarkable one. In our own science, it is the electromagnetic force that is in fact seen to be responsible (but only in the light of quantum mechanics, not of Newtonian mechanics) for the physical and chemical properties of ordinary bodies.

"To derive *two or three* general Principles of Motion from Phaenomena, and afterwards to tell us how the Properties and Actions of all corporeal Things follow from those manifest Principles, would be a very great step in Philosophy, though the Causes of those Principles were not yet discover'd." Such is the great step in philosophy that Newton's metaphysics was conceived to facilitate: "I hope the principles here laid down will afford some light either to that, or some truer, method of philosophy." It seems fair to say that that hope has been amply realized.

NOTES

1 "The previous author" of a book with that title: for the title Newton used – *Philosophiae Naturalis Principia Mathematica* – is clearly a deliberate allusion to Descartes's work.

2 René Descartes, *Principles of Philosophy*, trans. Valentine Rodger Miller and Reese P. Miller (Dordrecht: D. Reidel Publishing Company, 1983), p. xxiv (in the "Letter from the Author to the Translator of this Book [into French], which can serve here as a Preface").

3 *Encyclopaedia Britannica*, 11th edn, vol. 18, p. 253.

4 Descartes hoped that his goals for a new science would be achieved *entirely* in his *own lifetime*, and indeed by his own efforts – aided only by the work of artisans and trained technicians he needed to construct equipment for experiments and to help in carrying out the experiments. The most ambitious of these goals was the establishment, on sound principles, of a science of medicine that should succeed in prolonging human life to a term measured in centuries.

5 The guarantee, that is, of what we should call the "objective validity" of those principles that carry complete "subjective" conviction. (Descartes's terminology, following that of the medieval philosophers, is the reverse: for him, "subjective" means what characterizes the proper *subject of knowledge* – the "real things"; whereas "objective" means characteristic of the "object of the mind," *as* mental object, whatever it may be in reality – or indeed whether or not it exists in reality.) The guarantee of truth is obtained by the famous argument of Descartes's *Meditations*, a crucial turn in which is the (alleged) demonstration (a) of the existence of God as a "perfect being," and (b) of the consequence that, since a perfect being cannot be a deceiver, everything we perceive as true beyond the possibility of doubt must be true in reality.

6 That is, the *Dialogue concerning the Two Chief World Systems.*

7 *Principles of Philosophy*, Part 2, §24.

8 *Ibid.*, §13.

9 *Ibid.*, §15. In the *Rules for the Direction of the Mind*, in stark contrast, "place" is offered as an example of those "simple natures" which are self-evident in themselves, and cannot be defined or "explained" in terms of something even more evident; and Descartes adds: "And when told that 'place' is the surface of the surrounding body, would anyone conceive of the matter in the same way? For the surface of the 'surrounding body' can change, even though I do not move or change my place; conversely, it may move along with me, so that, although it still surrounds me, I am no longer in the same place." (Quoted from *The Philosophical Writings of Descartes*, ed. John Cottingham, Robert Stoothoff, and Dugald Murdoch, vol. 1 [Cambridge: Cambridge University Press, 1985], p. 45.) So here Descartes has ridiculed, as a bizarre doctrine of the scholastic philosophy he is attacking, the very notion he puts forward in his *Principles* as the scientifically "correct" one. (We shall later see that Newton makes mincemeat of this way of conceiving place and motion.)

10 "*Semi-*"relativist, because some bodies are singled out – or *partially* singled out – as the ones to which motion *in the strict sense* should be referred; but only partially singled out because of the arbitrariness implied by "and which are regarded as being at rest."

11 Both in his *Meditations on First Philosophy* and in his *Principles of Philosophy*, what Descartes claims to establish by thought without the aid of sensation is the *essential attribute* of material things, in the sense of "what they would be if they *did* exist"; then sensory experience is called upon to show that such things *do* exist.

12 Quoted from the fourth paragraph in the discussion of *Rule Eight*; edition of Cottingham *et al.*, p. 29.

13 In the *Rules for the Direction of the Mind*, Descartes deprecates in the strongest terms any reliance upon hypotheses ("conjectures") and any "merely probable cognition"; and at least as late as 1637, in replying to an objection of Fermat to the argumentation of Descartes's *Dioptrics* (which was published in that year in the same volume as his *Discourse on the Method of Rightly Conducting One's Reason and Seeking the Truth in the Sciences*), he says "I consider almost as false whatever is only a matter of probability" (letter of 5 October 1637, to Mersenne). At the end of his *Principles of Philosophy* (1644), he says, in contrast to that: "With regard to the things which cannot be perceived by the senses, it is enough to explain their possible nature, even though their actual nature may be different" (Part 4, §204) – certainly an endorsement of the value of "hypotheses," even of ones that may in the end not be true. He goes on, however (in the next two articles), to claim (a) that his explanations "appear to be at least morally certain"; and (b) that his explanations possess "more than moral certainty"; indeed that "perhaps even these results of mine will be allowed into the class of *absolute* certainties" (emphasis added).

14 It is of course possible to maintain proposition (a) while rejecting (b); but hardly the reverse: for if space is *full* of *rigid, indivisible* bodies, the possibilities for motion are extremely restricted – the kinds of motion we encounter in the world would be quite impossible on such an assumption. It should be added that one important philosopher, slightly younger than Newton, who came to reject Descartes's metaphysical characterization of matter, nevertheless *also* rejected *both* (a) and (b): namely, Leibniz, in whose view empty space was not a *contradictory* notion, but who claimed to derive the proposition that the world is a plenum from his metaphysical principle of "sufficient reason."

15 A characteristic expression of this view, late in the century, by a philosopher who was certainly *not* a Cartesian, is to be found in Locke; cf. his *Essay concerning Human Understanding*, Book 2, ch. viii, §11, which reads as follows in the first edition (1690): "The next thing to be consider'd, is how *Bodies operate* one upon another, and that is manifestly *by impulse*, and nothing else. It being impossible to conceive, that Body should operate on what it does not touch, (which is all one as to imagine it can operate where it is not) or when it does touch, operate any other way than by Motion." Quoted from John Locke, *An Essay concerning Human Understanding*, ed. Peter H. Nidditch (Oxford: Clarendon Press, 1979), p. 135 *(via* the apparatus at the foot of the page – the passage having been drastically revised in the fourth edition).

16 This, as is well known, is the origin of the very word "metaphysics" (which is quite foreign to Aristotle himself): the collection of Aristotle's treatises on first philosophy was labeled – as if by a call-number – τὰ μετὰ τὰ φυσικά: "the [writings] after the physical [ones]."

17 The point needs to be emphasized, because there is a tradition that sees the basic conceptions of Newton's natural philosophy, most especially his conceptions of space and time, as derivative from, or grounded in, his theology. Thus, J. E. McGuire claims "that the basic concepts of Newton's natural philosophy can be ultimately clarified only in terms of the theological framework which guided so much of his thought" (see his "Force, Active Principles, and Newton's Invisible Realm," *Ambix* 15 [1968], 154). McGuire goes on to remark that the thesis is not original with him, and gives the following citations:

> See the fundamental studies of H. Metzger, *Attraction universelle et religion naturelle chez quelques commentateurs anglais de Newton*, Paris, 1938, and A. Koyré, *From the Closed World to the Infinite Universe*, Harper edition, 1958. Also see H. Guerlac, "Newton et Epicure," *Conf[é]rences du palais de la découverte*, no. 91, Paris, 1963: an excellent study by David Kubrin, "Newton and the Cyclical Cosmos: Providence and the Mechanical Philosophy," *J.H.I.*, 1967, XXVIII, 325–46; J. E. McGuire and P. M. Rattansi, "Newton and the Pipes of Pan," *Notes and Records of the Royal Society of London*, 1966, 21, 108–43; J. E. McGuire, "Body and Void and Newton's *De Mundi Systemate*: some new sources," *Archive for History of Exact Sciences*, 1966, 3, 206–48; an important lengthy study by A. Koyré and I. B. Cohen, "Newton and the Leibniz–Clarke correspondence," *Archive[s] Internationales d'histoire des Sciences*, 1962, 15, 63–126; and A. R. and M. B. Hall, *Unpublished Scientific Papers of Isaac Newton*, Cambridge, 1962, part 3.

The evidence cited in the text above, preceding and immediately following the place to which this note is attached, does not show that this opinion is wrong, so far as concerns either the psychological connections of Newton's thought or the logical or conceptual connections among his principles; but it does at least strongly suggest that the opinion is at variance with what Newton himself thought about these connections, and therefore at variance with at least the epistemological side of Newton's own metaphysics. To discuss the controversy implied with any pretence to thoroughness is beyond the scope of a chapter like the present one; but further evidence will be given, tending to show that on the objective or ontological side, too, Newton's doctrine about space and time, in the light of his explicit statements, did not teach that space and time *per se*, or their attributes, depend upon the nature of God.

On the degree of confidence attached by Newton to his main results in physics, in both his optical work and that on the solar system and the theory of gravity, cf. Shapiro's and Smith's chapters in this volume.

18 This rule, with the statement referred to in the text above, first appeared in the second edition of the *Principia*, 1713.

19 To avoid a possible wrong inference, it should be added that besides knowledge of God "from the appearances of things," which "belongs to Natural Philosophy," Newton holds that there is knowledge of God through *revelation.* This, too, of course, would be through *experience*; and what is more important so far as concerns Newton's own efforts in the domain of "revealed" theology (efforts that occupied no small part of his whole intellectual career), the deliverances of revelation are, for Newton, accessible *only through historical documents* (Newton does not subscribe to any claim of immediate religious authority – nor does he claim access to revelation through personal inspiration), and therefore demand a very arduous historical-critical investigation of such documents. In any event, there is nowhere in Newton a suggestion that our knowledge of anything pertaining to *natural philosophy* can be derived from revealed truths. (He does *relate* some aspects of his views about space, for example, to passages in ancient writings, both pagan and Judeo-Christian; but this is far from ascribing evidentiary or conceptually binding force to such relations.)

20 See the specimens given in John Herivel, *The Background to Newton's* Principia: *A Study of Newton's Dynamical Researches in the Years 1664–84* (Oxford: Clarendon Press, 1965).

21 Herivel, *Background to Newton's* Principia, p. 123.

22 *Ibid.*, p. 124.

23 *Ibid.*, p. 125.

24 *Ibid.*, p. 136.

25 *Ibid.*, p. 138.

26 See A. Rupert Hall and Marie Boas Hall (eds.), *Unpublished Scientific Papers of Isaac Newton* (Cambridge: Cambridge University Press, 1962), pp. 89–121 (Latin), 121–56 (English). In the present text, translations from this work are my own.

27 Mistranslation begins with this first sentence, which the Halls render as: "It is proper to treat the science of gravity and of the equilibrium of fluid and solid bodies in fluids by two methods." This version has been used as the basis of a claim that the manuscript actually represents an abortive draft of an introduction to Newton's *Principia*, "[s]ince the two studies mentioned – of gravitation and of the equilibrium of fluids and of solid bodies in fluids – bear a strong resemblance to Books I and II of the published *Principia*," and since the two methods Newton describes

also have a correspondence to the *Principia.* (See Betty Jo Teeter Dobbs, *The Janus Faces of Genius: The Role of Alchemy in Newton's Thought* [Cambridge: Cambridge University Press, 1991], p. 141.) But Newton's phrase has nothing to do with a "science of gravity": he is speaking of the *weight* of fluids and of solids in fluids, which is the exact subject of the classic treatise "On Floating Bodies" of Archimedes; and, on the other hand, Book 2 of the *Principia* is concerned with the *motions*, not the *equilibrium*, of fluids and of solids in fluids – an entirely *new* subject at the time of its publication.

28 For these statements, see Descartes, *Principles of Philosophy*, Part 3, §27.

29 It is important to bear in mind that for Newton – and for *all* seventeenth-century thinkers – the word "philosophy" was used for all *systematic knowledge* or *systematic inquiry.* Thus, when Newton speaks of "philosophical" usage, he means *exact*, or *systematic*, or *technical* usage; and so does Descartes. So Newton's criticism is that *in Descartes's technical discussion of motion, he does not use that conception of motion which he had put forward as technically correct*; and so he has implicitly acknowledged that the conception he calls "proper" is in fact unsuitable for technical purposes.

30 On the particular issue of the "straightness" of the path, an important argument of Galileo's is relevant, and may be clarifying. Galileo considered an object dropped from high up on the mast of a ship that is sailing, in a smooth sea, with uniform speed. To an observer on shipboard, the object will appear to fall vertically downward – that is, in a straight line – alongside the mast, with a speed that increases proportionally to the time of fall. To an observer on the shore – who of course also sees the object as falling directly alongside the mast, but who also sees the mast itself as moving uniformly forward – the object will appear to traverse a parabolic arc. Therefore – even setting aside the issue of the *dispersal* of surrounding bodies – whether, in general, a path is straight or not will depend upon *which* bodies one chooses to "regard as at rest."

31 The force of Newton's argument is great. In a famous polemic that came to a head late in the lives of both men, Leibniz took up the cudgels against Newton on behalf of a "relational" view of space and motion – not, indeed, that of Descartes, but one that was still open to Newton's criticism that on that view neither straightness of a path of motion nor constancy of speed is a concept that makes sense. Yet Leibniz – in the same polemic – in arguing against Newton's theory of gravitation, says that for one body to move in a *curved line* about the other without something that *pushes* on the first "could not be done without a miracle; since it cannot be explained by the nature of bodies" (because

a body of itself tends to move uniformly in a straight line) (Leibniz's third letter, in his correspondence with Samuel Clarke of 1715–16, §17; in, e.g., H. G. Alexander [ed.], *The Leibniz–Clarke Correspondence* [Manchester: Manchester University Press, 1956], p. 30.) It is unfortunate that Clarke – Newton's representative in this discussion – did not point out to Leibniz the incoherence that Newton had long ago noted in a position that simultaneously maintains that principle about the motion of bodies and regards motion as having a meaning *only* as "relative," *among bodies.* This *might* have led to a clarification by Leibniz of his own relational theory. For further discussion of the issues involved, in which Newton's own position – although much stronger than it was once thought to be among philosophers – is by no means the last word (so far as the foundations of "Newtonian mechanics" itself are concerned), see Howard Stein, "Newtonian Space-Time," *The Texas Quarterly* 10 (1967), 174–200; also (with correction of an important typesetting error in a quotation) in Robert Palter (ed.), *The* Annus Mirabilis *of Sir Isaac Newton* 1666–1966 (Cambridge, MA: MIT Press, 1970), pp. 258–84. For further discussion of the views of Leibniz, and also those of Huygens, on the relativity of motion, see also Howard Stein, "Some Philosophical Prehistory of General Relativity," in John Earman, Clark Glymour, and John Stachel (eds.), *Foundations of Space-Time Theories*, Minnesota Studies in the Philosophy of Science 8 (Minneapolis: University of Minnesota Press, 1977), pp. 3–49 (§§1 and 2, with relevant Notes, and Appendix). Cf. also DiSalle's chapter in the present volume.

32 Newton's words here – quite scholastic in cast – are: "it does not stand under the kind of characteristic affections that denominate substance, namely actions, such as are thoughts in a mind and motions in a body."

33 The use of the word "idea" – unusual for Newton – is striking; and so is its capitalization (here, and in similar contexts later in the piece). One is reminded of Locke's *Essay concerning Human Understanding*, in which the word is also uniformly capitalized (and italicized as well). There can be no question of influence, in either direction: whatever the date of this fragmentary piece of Newton's, it certainly antedates Locke's *Essay*; and, as certainly, Locke had never seen it when he wrote the *Essay.*

34 Some words are necessary here concerning the translation, since this passage is one of those in which the published version is badly at fault. There, the first sentence reads: "Space is a disposition of being *qua* being." Newton's Latin is: "Spatium est entis quatenus ens affectio." Now, the word *affectio* is standard in philosophical Latin, and is regularly translated by its English cognate, "affection"; "disposition" has a rather different connotation. But this is a minor point. The major one is how

to translate – and how to understand – the phrase *entis quatenus ens.* Latin "ens" and English "being" are precisely synonymous; and "entis" is the genitive of "ens"; so "an affection of being as being" – or "of being *qua* being" – that is, "of being as such" – is linguistically warranted. Further, the phrase is borrowed directly from the Aristotelian tradition, in which "being *qua* being" is the standard definition of the subject-matter of first philosophy or metaphysics. So far, therefore, the Halls' rendering seems justified. However, one must also note two things: first, that the Latin word "ens" like the English word "being" is susceptible of a concrete meaning (as when we call *ourselves* "human beings") as well as an abstract one; second, that in Latin there are no articles, definite or indefinite; and therefore the reading given in the text above is, on purely linguistic grounds, equally eligible. Two considerations may be thought to favor the Halls: first, the point just made about the formula in the Aristotelian tradition; second, the fact that the phrase "being *qua* being," understood to mean "being *in the highest sense*," had the special connotation of "*[the] divine Being*" (cf. God's answer to Moses, Exodus 3.14, in response to the question what Moses shall tell the people is the name of the one who has sent him: "I AM THAT I AM"); this would seem to agree with Newton's former statement that space is an emanative effect of God. However, these considerations are clearly overborne by what follows – in particular, by Newton's statement, "*If I posit any being whatever, I posit space.*" The word "being" – *ens* – in *this* assertion can only be taken in its concrete sense. And since this statement is given to ground the clause immediately preceding it, there too "being" must be used in the concrete sense; indeed, in any case, only the concrete sense – "the first-existing *thing* – or *entity*" – fits that clause at all. (The translation of that phrase by the Halls – "the first existence of being," rather than "the first-existent being" – not only makes its sense obscure, but is incompatible with the grammar of the Latin. To discuss this in detail here would take us too far into purely linguistic matters.)

35 Newton, of course, under the rubric "all minds," would have included the minds of *angels*.

36 On this point it is instructive to compare what Locke says about the relation of mind ("spirit" or "soul") to place and motion: "[F]inding that Spirits, as well as Bodies, cannot operate, but where they are; and that Spirits do operate at several times in several places, I cannot but attribute change of place to all finite Spirits . . . Every one finds in himself, that his Soul can think, will, and operate on his Body, in the place where that is; but cannot operate on a Body, or in a place, an hundred Miles distant from it. No Body can imagine, that his Soul can think, or move a Body

at *Oxford*, whilst he is at *London*; and cannot but know, [*sic*] that being united to his Body, it constantly changes place all the whole Journey, between *Oxford* and *London*, as the Coach, or Horse does, that carries him [etc.]."

37 The qualification, "ordinary," is needed to distinguish the case from the special one of an *atom*, which on Newton's (and the traditional) conception is precisely an *indivisible* body.

38 Another case of mistranslation in the published version: the latter reads, not "and therefore we are able [etc.]," but (emphasis added): "and so *in some circumstances* it *would be possible* for us to conceive of extension while imagining the non-existence of God." This suggests that only on Descartes's conception would we be able – "in some circumstances" – to conceive extension while "imagining the non-existence of God." But this is not what Newton says: (1) There is nothing in the Latin that corresponds to the phrase "in some circumstances." (2) The verb is *possumus*: indicative – "*we are able*"; not the subjunctive *possimus*: "*we should be able.*" Newton asserts unqualifiedly that we *are* able to conceive of space without any reference to God ("we have an absolute Idea of it without any relationship to God"); his point against Descartes is that on the identification of extension with body the same thing would hold of body: (a) it would be uncreated; (b) we could conceive of it "*as existent*" while "feigning" the non-existence of God. (This criticism would of course be rejected by Descartes; the point here is merely to be clear about what Newton's doctrine is.)

39 The Halls, in first publishing "De gravitatione et aequipondio fluidorum," expressed uncertainty about its date, but described the handwriting as characteristic of Newton's youth, and – although they noted the important fact that it has affinities with the General Scholium to Newton's *Principia* (introduced in the second edition of that work, thus in 1713, when Newton was seventy years old) – they characterized its general style as labored, and some of its thought as immature (see *Unpublished Scientific Papers*, pp. 89–90); on these grounds, they leaned toward an early date. The present writer, in a paper presented at a conference in 1969 and published in 1970, while not contesting the early date assigned, suggested two reasons for caution about it: first, a disagreement with the Halls' assessment of the thought; second, the testimony of Coste about to be discussed in the text of the chapter (see Howard Stein, "On the Notion of Field in Newton, Maxwell, and Beyond," in Roger H. Stuewer (ed.), *Historical and Philosophical Perspectives of Science*, Minnesota Studies in the Philosophy of Science 5 [Minneapolis: University of Minnesota Press, 1970], p. 274, n. 11). More recently, Dobbs, who gives a survey of opinions on the question (Dobbs, *The Janus*

Faces of Genius, pp. 139–40), has argued for a date close to that of the *Principia* – namely, late in 1684 or early in 1685; but it must be noted that an important part of her case rests upon the mistakes noted earlier (note 27 above). It seems fair to say that uncertainty remains about the date of "De gravitatione," and evidence based upon handwriting may after all be decisive.

40 Gottfried Wilhelm Leibniz, *New Essays on Human Understanding*, trans. Peter Remnant and Jonathan Bennett (Cambridge: Cambridge University Press, 1981), p. 442.

41 Coste's account is quoted in A. C. Fraser's edition of Locke's *Essay*; see Locke, *An Essay concerning Human Understanding*, ed. Alexander Campbell Fraser (reprinted New York: Dover Publications, 1959), vol. 2, pp. 321–2.

42 In their edition of Leibniz's *New Essays*, Remnant and Bennett cite a letter from Leibniz to Locke's friend Lady Masham in 1704, containing "an urgent request that she ask Locke to elucidate"; but it arrived after Locke's death. (See Leibniz, *New Essays*, ed. Remnant and Bennett, p. xxxix, near the end of the volume.)

43 Latin, *arbitrarius*: "depending on the will."

44 Newton's repeated use of the expression "let us feign" – Latin, *fingamus*: the same verb that occurs in Newton's famous declaration, in the General Scholium to the *Principia*, "Hypotheses non fingo": "I do not feign hypotheses" – is reminiscent of language used by Descartes in his own "creation fable," both in *The World* and in his *Principles of Philosophy*. For the former, see René Descartes, *Le Monde, ou Traité de la lumière*, parallel edition (French and English), trans. Michael Sean Mahoney (New York: Abaris Books, 1979), pp. 50 (French), 51 (English); the phrase in French is "Or puisque nous prenons la liberté de *feindre* cette matière à nostre fantaisie . . ." (emphasis added) – "Now since we are taking the liberty of feigning this matter to our fancy . . ."; "la liberté de feindre" is rendered by Mahoney as "the liberty of imagining." As to the *Principles*, the verb *fingere* occurs in Part 4, §2: "Fingamus itaque Terram hanc [etc]" – "Let us therefore feign this earth [etc]." (Again, in the translation by Miller and Miller cited earlier, the verb is translated "Let us imagine.") The phrase "fingamus itaque," in this last place, is exactly the same as that used by Newton in the opening sentence of *his* creation story: "Fingamus itaque spatia vacua . . . " – "Let us therefore feign empty spaces . . . " In view of the fact that this whole metaphysical discussion has the character of an anti-Cartesian polemic, the parody of Descartes is most probably intentional.

45 See note 18 above.

46 Cf. note 15 above.

47 Locke, *Essay concerning Human Understanding*, Book 2, ch. xxiii, §28; Nidditch edition, pp. 311–12.

48 These pessimistic views about the possibility of systematic science were strikingly ameliorated by Locke's reflections on what Newton had achieved, but he did not allow his changed assessment to have any effect on the later editions of the *Essay*. The point is discussed in Howard Stein, "On Locke, 'the Great Huygenius, and the incomparable Mr. Newton'," in Phillip Bricker and R. I. G. Hughes (eds.), *Philosophical Perspectives on Newtonian Science* (Cambridge, MA: MIT Press, 1990), pp. 17–47; see esp. pp. 30–3.

49 Both quotations are from the Author's Preface to the first edition of the *Principia*. They are quoted in an order the reverse to that in which they occur there; and the emphasis (in the second passage) is added here.

50 The subject of Book 2, ch. xxiii of the *Essay concerning Human Understanding*.

51 *Ibid.*, §37; Nidditch edn, p. 317.

52 *Ibid.*, Book 1, ch. iv, §18; Nidditch edn, p. 95.

53 *Ibid.*, Book 3, ch. vi, §21; Nidditch edn, p. 450.

54 This characterization of Newton's theory of bodies as a theory of *fields of impenetrability* was first given in Stein, "On the Notion of Field in Newton, Maxwell, and Beyond" (cited in note 39 above); there follow immediately in the same volume some critical comments by Gerd Buchdahl and by Mary Hesse, with responses by the author defending his view.

55 Whether Aristotle himself believed in such a thing is a debatable question.

56 See *Essay concerning Human Understanding*, Book 2, ch. iv.

57 *Ibid.*, ch. xxi, §73; Nidditch edn, pp. 286–7.

58 Newton's wording is a little odd, in its reference to "removing" the power in question; he has in mind Descartes's famous thought-experiment with a lump of wax, of which he attempts to strip away, in thought, whatever properties can be removed from the wax without destroying its "essential" character as bodily substance. Descartes concluded that only extension cannot be removed; Newton argues that to remove impenetrability, and the laws of transfer of motion, from his mobile impenetrable regions would be to reduce them to empty space; and he adds, here, that to remove the power to produce perceptions in minds would be an equally serious derogation from their substantial nature.

59 (But before the passage quoted immediately above.)

60 (Locke was prominent among these.)

61 (A condition in which it would seem we remain to this day.)

62 This and subsequent passages are quoted from the (unemended!) translation of Andrew Motte: Isaac Newton, *The Mathematical Principles of Natural Philosophy*, trans. Andrew Motte (1729) (reprinted in two volumes, London: Dawsons of Pall Mall, 1968). See "The Author's Preface" (prefatory material is on unnumbered pages).

63 More precisely, for the expression "proportional to the efficacy of the cause" to have a well-defined meaning, one would have to have the conception of the *ratio* of the efficacy of one cause to that of another.

64 The Latin phrase here rendered as "a certain power or energy" is *efficaciam quandam*: that is, simply, "a certain efficacy."

65 Again, cf. Stein, "On the Notion of Field in Newton, Maxwell, and Beyond," cited in note 39 above.

66 For other fields, quite different measures of the field intensity are appropriate: e.g., for magnetism, the "force per unit pole"; for electricity, the "force per unit charge." (For a fuller discussion of the role of the concept of field in Newton's investigation, see Stein, "On the Notion of Field in Newton, Maxwell, and Beyond," cited in note 39 above.)

67 One sees, then, how far the example of the sling is from illustrating the intended pattern: here, there is indeed an impressed motive force toward the hand as a center; but no good sense can be made of the conception of "a certain efficacy diffused from the center *to all the places around*," with a definite magnitude or measure *at each point* (whether or not there is an actual body there to be acted upon).

68 In the *Opticks*, on the basis of a wide survey of phenomena – both optical and *chemical* phenomena figuring largely among them – Newton concludes that there must be some forces that are *attractive at certain distances, repulsive at others.* See Isaac Newton, *Opticks* ("based on the fourth edition, London, 1730"; New York: Dover Publications, 1952), pp. 395ff.

69 That Newton's special use of the third law, crucial to his argument, involves a risky assumption, was briefly mentioned in Stein, "On the Notion of Field in Newton, Maxwell, and Beyond" (cited in note 39 above), p. 269; the point is discussed more fully in Howard Stein, "'From the Phenomena of Motions to the Forces of Nature': Hypothesis or Deduction?" *PSA 1990* 2 (1991), 209–22, and also in Dana Densmore, *Newton's* Principia: *The Central Argument* (Santa Fe: Green Lion Press, 1995), p. 353.

70 See *Principia*, introductory paragraph to Book 3.

71 Translated by the present author from Newton, *De Mundi Systemate Liber* (London, 1728), pp. 24–6. Matter in square brackets has been added to help to show in clear English the sense of the Latin. Besides the emphases added to highlight the main point, the word "towards"

in the last sentence has been italicized; this has been done to indicate a contrast Newton is making, perhaps somewhat subtly, by the way he manages his prepositions: that between how the "operation" arises *from* the bodies, on the one hand, and how it "behaves *towards* them" on the other (if it arises from them in the same way, it will affect them in the same way).

The author has had the advantage of consulting both the excellent English translation of 1728 (anonymous, but presumably by Andrew Motte, whose translation of the *Principia* was published the following year) *A Treatise of the System of the World* (London, 1728), and a draft of a forthcoming translation by I. B. Cohen and Anne Whitman. The old translation was reissued with revisions in the volume: *Sir Isaac Newton's Mathematical Principles of Natural Philosophy and his System of the World*. Translated into English by Andrew Motte in 1729. The translations revised . . . by Florian Cajori. (2nd printing; Berkeley: University of California Press, 1946). In that edition the sections (distinguished in the original Latin publication and in the 1728 English version by marginal section-headings) are numbered (these numbers do not appear in the 1728 English or in the 1728 or 1731 Latin editions); the paragraphs quoted are, with a small elision, §§20–21 there (pp. 568–9). Unfortunately, the revisions made in that publication introduce a serious error into the text of §21; the author is therefore particularly grateful to Benjamin Weiss, Curator of Rare Books at the Burndy Library of the Dibner Institute for the History of Science and Technology at the Massachusetts Institute of Technology, for making available photostatic copies of the 1728 English and Latin versions of those sections (and of the 1731 Latin edition as well); and to George Smith for obtaining those copies, as well as a copy of the Cohen and Whitman draft mentioned above. (See editors' additional note, p. 307.)

72 *Opticks* (Dover edn), p. 397.

73 *Ibid.*, p. 400.

74 *Ibid.*, p. 401.

75 *Ibid.*, pp. 401–2.

76 *Principia* (edition cited in note 62 above), vol. 2, p. 392. (One emendation has been made of the Motte translation: "I feign no hypotheses" for "I frame no hypotheses." It was pointed out by Alexandre Koyré – cited in I. Bernard Cohen, *Introduction to Newton's "Principia"* [Cambridge, MA: Harvard University Press, 1978], p. 241, n. 9 – that this is the English version of his Latin phrase "hypotheses non fingo" used by Newton himself in the *Opticks*, in Query 28; see Dover edn, p. 369.)

77 Cf., for fuller discussion of these matters, Stein, "Newtonian Space-Time" and "Some Philosophical Prehistory of General Relativity" (sections 1–3), both cited in note 31 above.

78 *Opticks* (Dover edn), p. 376.

Editors' note. In note 71 above, Professor Stein calls attention to the section numbers in Cajori's version of the English translation of *A Treatise of the System of the World* and their absence in both the English and Latin editions of 1728. The history of these section numbers is complicated. The manuscript from which the Latin edition was printed, entitled "De motu corporum liber secundus," is in the hand of Humphrey Newton (Isaac's amanuensis at the time), with modifications in Isaac's hand. This manuscript contains eighty section-headings in the margins, with the first twenty-eight numbered in Roman numerals, precisely in the manner of Descartes's published *Principia*; the remaining fifty-two sections, however, are not numbered. In every edition of the English translation before Cajori's, and in all Latin editions save one, the section-headings are placed in the margin without numbers. The exception is Samuel Horsley's Latin edition in his *Isaaci Newtoni Opera Quae Exstant Omnia* of 1779–85. Horsley, who had gained access to the "De motu corporum liber secundus" manuscripts, kept the eighty section-headings in the margins, but placed Arabic numerals at the beginning of the text of seventy-eight of the sections, electing to omit a number in the case of the seventy-fifth section-heading (introducing Table II) and the eightieth (introducing the lemmata near the end). In his German translation, attached to his 1872 translation of Newton's *Principia*, Jakob Phillipp Wolfers put numbered section-headings in the text rather than the margins, and he dropped the seventy-fifth and eightieth section-headings entirely. Cajori, who acknowledged his use of this German translation, followed Wolfers save for putting the numbers in brackets, presumably to signify their absence in the English translation that he was modifying.

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