INTERPRETING NEWTON

Critical Essays

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Newton's law-constitutive approach to bodies

a response to Descartes

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1.1 Introduction

In his *Principia* Newton offers us a science of bodies in motion. Such a science has bodies as its subject-matter, but what are these bodies? If Newton's three laws of motion are to say anything, then there must be bodies for them to refer to. I shall label this the 'problem of bodies'. In this chapter I outline the 'problem of bodies' as Newton finds it in Descartes's *Principles of Philosophy*. I claim that while there is no obvious solution *explicit* in Descartes's writings, an implicit solution is strongly suggested. I argue that Newton was acutely aware of the problem, and addressed it explicitly by adopting the strategy implicit in Descartes. My claim is that Newton offers a *law-constitutive* solution to the problem of bodies, according to which the definition of bodies is *incomplete* prior to the specification of the laws of nature, and *completed by* those laws of nature.

1.2 Descartes and the problem of bodies

Taken together, Descartes's laws of nature concern the behaviour of 'bodies'.[1] Here are the laws as he stated them in his *Principles of Philosophy* (Part II, paragraphs 37, 39, and 40):[2]

> The first law of nature: that each thing, as far as is in its power, always remains in the same state; and that consequently, when it is once moved, it always continues to move.
>
> The second law of nature: that all movement is, of itself, along straight lines; and consequently, bodies which are moving in a circle always tend to move away from the center of the circle which they are describing.

1 The first law has a more general scope, concerning 'things' in general. I am grateful to Eric Schliesser for drawing my attention to this.

2 Quotations are from Descartes (1991), the Miller and Miller translation of the *Principles of Philosophy*. The *Principles* was first published in Latin in 1644.

> The third law: that a body, on coming in contact with a stronger one, loses none of its motion; but that, upon coming in contact with a weaker one, it loses as much as it transfers to that weaker body.

The 'problem of bodies' is this: what are the 'bodies' to which these laws apply? For Descartes, the answer is 'parts of matter'. Famously, however, this answer masks a difficulty that Descartes never satisfactorily resolved, and which arises as follows.

1.2.1 Descartes on matter and its parts

In Part I of the *Principles*, Descartes argues that extension is the sole principal attribute of material substance, and Part II opens with an argument that leads from extended matter (mass noun) to bodies plural (count noun), repeating essentially the same argument as in the *Meditations*.[3] He writes (Descartes, *Principles of Philosophy*, II.1) that we

> clearly and distinctly perceive, a certain matter which is extended in length, breadth and depth; the diverse parts of which are endowed with various shapes and subject to various movements, and which also cause us to have sensations of color, odor, pain, etc.

Then, since God is not a deceiver, we are entitled to conclude that extended matter is indeed divided into parts of various shapes and movements, affecting our senses in this way. However, while Descartes has argued earlier for the claim that matter is extended, he offers no argument in support of the claim that we clearly and distinctly perceive *parts* of matter that are endowed with various shapes and subject to various movements, and also affect our senses. This knowledge of bodies plural is dependent on what comes to us through our senses, and the faculty of the imagination; whenever Descartes considers the nature of the bodies that affect our senses, he takes us back to the sole principal attribute of body, pure extension, and to a conception of body in general[4] that contains nothing corresponding to a division of extended matter into parts.[5] There is therefore an apparent gap between what is known via the

3 Descartes (1985), Meditation VI. The *Meditations* were first published in 1641.

4 The term 'body in general' should be understood to refer to the nature of any body (that it is extended), and need not refer to the entirety of Descartes's indefinite extension (see Kaufman, 2008; Schmaltz, 2008b). However, the conception of 'body in general' understood as referring to a part of matter (a body, any body), presupposes that Descartes's extended matter is divided into parts (bodies). The slide from extended matter to bodies plural (a body or any body) via 'the nature of body in general' is vividly seen in the *Principles* II.1&4. Just how the division into parts is achieved is the issue we are interested in here.

5 The claim that our knowledge of bodies plural is located only in the imagination and not the intellect might seem in conflict with the wax example of Meditation II. However, in the wax example bodies plural are presupposed as given, and the issue is our knowledge of these bodies.

intellect (the nature of body in general, as extended), and what is known via the senses (that extended matter is divided into parts, having various shapes and motions, and that these parts correlate with our experience of bodies (plural) and their various sensory properties). To close this gap, Descartes must explain in virtue of what extended matter is divided into parts *such that* we can clearly and distinctly perceive that it is indeed so divided. If Descartes is to solve the 'problem of bodies', he must provide within his metaphysical system the resources for this division.[6]

After several passages discussing matter as extension, Descartes returns to the topic of the *parts* of matter in motion in paragraph 23, where he writes:

> all the properties which we clearly perceive in it [that is, in extended matter] are reducible to the sole fact that it is divisible and its parts movable . . . all the variation of matter, or all the diversity of its forms, depends on motion.

There are two possibilities here: either motion is the principle by which matter is divided into parts, or matter is divided into parts by some other principle and then the motions of the parts account for the 'diversity of its forms'.

This paragraph leads naturally into a discussion of motion, in which Descartes famously distinguishes between 'What movement is in the ordinary sense' (paragraph 24) and 'What movement properly speaking is' (paragraph 25). Newton's vehement criticisms of Descartes's 'proper definition of motion' in 'De Gravitatione'[7] are now legendary, and I will have reason to return to them later. The definition offered in the paragraph reads as follows (emphasis in the original):

> it is *the transference of one part of matter or of one body, from the vicinity of those bodies immediately contiguous to it and considered as at rest, into the vicinity of some others.*

There are two points here that are important for my argument. First, the motion of a given body is defined with respect to other (special) bodies. For a body to move *is* for it to move with respect to these other special bodies. Second, Descartes clearly equates 'one part of matter' with 'one body'. He immediately goes on to say more about this second point:

> By *one body*, or *one part of matter*, I here understand everything which is simultaneously transported; even though this may be composed of many parts which have other movements among themselves.[8]

6 Descartes's God is so powerful that he could divide matter into parts in ways incomprehensible to us, presumably, but that won't do here because Descartes requires that we clearly and distinctly perceive that matter is so divided. Therefore, on Descartes's own terms, God must be dividing matter into parts in a way that is intelligible to us and can be accounted for within Descartes's metaphysical system.

7 Newton (2004).

8 Note that Descartes also emphasizes at this point that motion is a mode of a body, just as is shape.

Here, Descartes offers an account of the division of indefinite extension into parts or bodies *through* motion: one body, or one part of matter, is everything that is 'simultaneously transported'. Thus, it seems that motion is the principle by which matter is divided into parts. The resulting view is that, in short, motion is defined in terms of bodies, but the division of indefinite extension into bodies is achieved through their relative motions. This is, at best, a rather tight circle.[9]

1.2.2 Strategies for solving the 'problem of bodies'

The question we are trying to address is this: Given Descartes's laws of nature, what are the 'things' and 'bodies' to which these laws apply?

Here is one way to understand Descartes's general strategy: first, provide a metaphysical account of bodies, and then provide the laws of nature governing the behaviour of these bodies, consistent with

(a) various principles, including God not being a deceiver and God acting constantly in the world, and
(b) our experience of change.

Construed this way, one understanding of his proposed solution is that there is a substance, body, and this is divided into individual bodies (the term 'individual body' is used in paragraph 31) by its *modes* (especially shape and motion). In other words, on this interpretation Descartes seeks to provide a solution to the problems of individuation and identity of bodies, following which he sets out the laws of nature applying to those bodies.

What exactly are we looking for, when we ask Descartes for his solution to the problems of individuation and identity of bodies?[10] The following

9 The ensuing paragraphs (26–35) elaborate on this definition of motion, emphasizing that true motion is reciprocal (paragraph 29) – hence why, when we are asking about the motion of a single body, we must consider the reciprocal bodies to be at rest – and that there is only one true motion associated with each body. Thus, paragraph 31 begins 'Each individual body has only one movement which is peculiar to it . . .' Notice the term 'Each individual body'. The remainder of Part II of the *Principles* continues to make reference to bodies, and no further explicit information is given concerning how the division of indefinite extension into parts is achieved. Paragraph 36 turns our attention to the causes of motion, the primary cause being God, and the secondary cause being the laws of nature.

10 In his introduction to the collection *Individuation and Identity in Early Modern Philosophy* (Barber and Gracia 1994), Barber notes that in Cartesian philosophy the problem of individuation loses the prominence it had enjoyed in much medieval philosophy, but writes that (p. 2) 'since philosophers in the early modern period were for the most part systematic, presenting ontologies rivalling their medieval counterparts in comprehensiveness if not in detail, one can ask how within their systems the problem of individuation could or should have been resolved even where explicit discussion of the issue is minimal'.

distinctions will be helpful in thinking about what might constitute such a solution. First, there is the metaphysical problem of individuation, and here we should distinguish between necessary and sufficient conditions of individuality, and a principle of individuation. For example, one might subscribe to the view that the necessary and sufficient condition of individuality is being distinct from all other individuals, and that the principle of individuation that grounds this is being distinct *in virtue of* being a unique bundle of properties. (Other conditions that might be thought to be necessary and/or sufficient include indivisibility, noninstantiability, and ontological independence. Other principles of individuation include haecceities, or essence, or Aristotelian prime matter, and so forth.) The problem of individuation is to be distinguished from the problem of identity over time, where we ask *in virtue of what* is this individual the very same individual at another time. These metaphysical problems have epistemological counterparts, where we ask about our access to the individuating features of these metaphysical individuals (how we distinguish them from one another), and our warrant for according them the status of individuality.[11]

What does Descartes offer us, as regards physical bodies? Let's begin with the problem of individuation. I think that we can offer the following interpretation. The necessary and sufficient condition of individuality for physical bodies is being a part of matter that is divided from the rest of matter. In virtue of what is a region of matter so divided? Answer: in virtue of being in motion from

11 Barber (1994, p. 5) discusses the relationship between the metaphysical and epistemological problems, noting that they are often in tension:

> the epistemologist complains about the cavalier attitude of his ontologically inclined brethren who generate entities and distinctions in an unconscionable manner, while the ontologist in turn dismisses the epistemologist as one blinded to the richness of the universe through a neurotic fixation on a few favorite sense organs.

He distinguishes between a 'strong model', whereby 'epistemological considerations serve as criteria for the adequacy of an ontological system: putative candidates for inclusion in the catalogue of existents must first pass a test for knowability and, once included, their classification in terms of categorical features must again meet the same rigorous standard', and a 'weak model', which distinguishes between the ontological question of 'what it is *in objects* that *individuates* those objects' versus the epistemological questions of how we can differentiate among objects through our experience of them, but requires only that these should be compatible – neither has a veto over the other. Barber goes on to say that, 'broadly speaking, the weak model is dominant in medieval philosophy', but that 'By 1641, however [the year Descartes published his *Meditations*], the strong model has replaced its weaker medieval counterpart.' He writes (p. 6): 'the epistemological turn is significant for its effect on the *content* of those discussions [i.e. of individuation and identity]. What could possibly count as solutions to those problems is restricted by the imposition of new criteria; solutions formerly held to be uncontroversial are rendered puzzling, incomprehensible, or in conflict with newly discovered "truths" about the world.'

the vicinity of immediately contiguous bodies considered to be at rest into the vicinity of some others.

This account faces immediate challenges as to its adequacy, both as a proposed solution to the problem of individuation, and with respect to providing bodies that are suitable as the subject of Descartes's laws of nature. First, it is not clear that Descartes's definition of motion, without parts of matter that are prior to motion, is coherent. Second, even if it is, we have as Garber (1992, pp. 178–179) puts it 'a rather unwelcome consequence' that rules out the possibility of two bodies being at rest with respect to one another,[12] and therefore of any body ever being at rest. This leads directly to problems when we attempt to apply Descartes's laws of nature, most obviously in his rules of collision that supplement his third law. As Garber goes on to discuss (1992, pp. 179–180), the rules rely crucially on the distinction between bodies at rest and in motion.[13]

Turning now to the problem of identity over time, the only remaining resource seemingly available is shape. The shape of a part of matter would help in giving identity over time, but isn't enough, unless every part of matter has a different shape from every other part.

It seems to me that the strategy of *first* providing a metaphysical account of bodies (i.e. a solution to the problems of individuation and identity of bodies), and *then* providing the laws of nature governing the behaviour of these bodies, does not succeed given the resources that Descartes provides.

Suppose we agree that in the first half of Part II of the *Principles* Descartes does not solve the problem of individuation for the bodies that are the subject-matter of his physics. Nevertheless, the second half of Part II proceeds as if the problem has been solved – it assumes that there are individual bodies that satisfy the laws of nature. But if there *are* no bodies in Descartes's system, then there is nothing for his physics to be about, which to me at least casts something of a shadow over the entire exercise.[14]

Fortunately, there is a very different way to read what happens in Part II of the *Principles*. I am not advocating it as an exegesis of what Descartes took himself to be doing, but I do think the strategy I outline is implicit in the text, I think it is broadly successful, and I will argue below that it is a strategy that

12 Thus, Descartes's discussion (paragraph 55) of the cohesion of the parts of solid bodies in terms of their being at rest relative to one another is, strictly speaking, nonsense: solid bodies cannot have any parts.

13 Garber further notes that Descartes was aware of this difficulty, and yet failed to recognize how problematic it is, merely saying that a body at rest is a 'part' of a larger body.

14 Garber (1992, p. 181) concludes his discussion of motion and individuation and Descartes writing, 'I shall continue to talk as if Descartes is dealing with a world of individual bodies, colliding with one another, at motion and at rest with respect to one another. But, in the end, I suspect that this is something that he is not entitled to, and this is something that, if true, would seriously undermine his whole program.'

Newton explicitly takes up. The strongest, and most straightforward, version of the solution is this:

> The necessary and sufficient condition for the individuality and identity of physical bodies is that they satisfy the laws of nature.

So: instead of *first* solving the problem of generating bodies, and *then* applying the laws of nature to those bodies, physical bodies *are* whatever satisfy the laws.[15] We expand that rather tight circle where motion and body are inter-defined, and thereby hope to create a virtuous circle.[16]

A weaker version of the solution would drop the claim to sufficiency, as follows:

> A necessary condition for the individuality and identity of physical bodies is that they satisfy the laws of nature.

Even on this weaker version, one consequence is that the account of bodies has no wider applicability than that of the laws. That is, an account of bodies is available to us at best only in those circumstances where the laws are applicable; if there are circumstances for which it is inappropriate to apply the laws, then we will also lack an account of bodies in those circumstances. What we have is *a law-constitutive solution to the problem of bodies.*

Notice also that we have limited our goal to giving an account of *physical bodies*, rather than *bodies considered in general.* This is consistent with Garber's point (1992, pp. 176–177) that Descartes's definition of 'one body' in paragraph 25 has a restricted application. He writes (p. 176): 'it is important to note, first of all, that this definition should be understood as limited to a special kind of individuality, that which pertains to body as such, what we might call physical individuality, to distinguish it from a broader notion of individuality'. He emphasizes that this notion is not appropriate for other fields of interest (such as 'morality, property law, medicine, animal husbandry, agriculture, etc.', p. 177), and states (p. 177): 'The notion of an individual body he is concerned to define there is concerned with the notion of a physical individual, the sort of thing that can enter into the basic laws of nature.'

15 Notice the change that this makes to the problem of individuation. Traditionally, the challenge is to specify one constituent of an individual that is not present in any other individual. In this way, the world can be created one individual at a time. But on the approach I have outlined here, the challenge is to carve the given undifferentiated world up into individuals 'all at once', and the resulting account of individuality does not include the resources for creating the world one individual at a time. But this is not to say that it is not a coherent strategy for creating individuals (*pace* Leibniz).

16 I will discuss the principle of individuation below.

I want to push this further, by arguing that the definition of physical bodies is *incomplete* prior to the specification of the laws of nature, and *completed by* those laws of nature.

In my opinion, this way of proceeding is strongly suggested by the text of the *Principles*, because of the failure (arguably) of Paragraphs 1–35 to provide a complete solution to the problem of bodies, combined with the fact that Descartes's next move is to introduce his laws of nature. Paragraphs 36 onwards present the laws of nature for bodies and concern their elaboration and consequences: these contain additional resources for individuating bodies, including the laws themselves and refinements of the concept of motion (introducing 'determination', for example). If we accept that Paragraphs 1–35 are insufficient by themselves, and we are seeking a solution to the problem of bodies using the resources Descartes offers, then a natural move is to make use of the laws in attempting to complete the solution. This is a law-constitutive approach to the problem of bodies.

I have talked about necessary and sufficient conditions for a region of matter to be a physical body, and I have talked about identity over time, but I have said nothing about the principle of individuation. On this account, a principle of individuation would tell us *in virtue of what* a body satisfies the laws of nature. It seems that either there is no further question here (and principles of individuation are dispensed with), or the only possible further response is 'God'. It is consistent with Descartes's philosophy that the principle of individuation is, indeed, God. But the other option is also available: the above approach to solving the 'problem of bodies' makes philosophically viable the abandonment of principles of individuation for physical bodies.

1.3 Newton and the 'problem of bodies'

We know from Newton's early writings that he also asked about the division of uniform matter into parts (McGuire and Tamny, 1983, p. 339): 'Suppose the first matter one uniform mass without parts; how should that body be divided into parts, as we see it now is, without admission of a vacuum?' Of course, the central topic here is the discussion of atoms and the void. But rather than following this line of Newton's thinking, my interest is in how the problem of bodies shows up in other writings, specifically in the manuscript generally referred to as 'De Gravitatione' and in the *Principia*.

In his *Principia* Newton, like Descartes, offers us a science of bodies in motion, with laws that apply to those bodies. What are these bodies? To answer this question, I will begin by looking at 'De Gravitatione', and I will argue that in this text Newton criticizes Descartes's account of body *as a solution to* the 'problem of bodies', that he offers his own solution to the problem, and that this solution is explicitly *law-constitutive* (in the sense explained above). I will then argue that we should understand this solution as being

present in the *Principia*, and I will do this by looking at the text, but also primarily at some draft revisions. My overall message is that in Newton's work we can find a powerful philosophical solution to the 'problem of bodies'.[17]

On the account offered so far, a necessary condition for the individuality and identity of physical bodies is that they satisfy the laws of nature. This is the weak version of the law-constitutive solution. The strong version asserts that *the* necessary *and sufficient* conditions are satisfaction of the laws of nature. My claim is that the weak version of the solution is explicit in Newton, and that, in stating what the physical bodies are that are the subject-matter of his laws, criteria additional to satisfaction of the laws are to be given. I am also willing to argue that the strong version is implicit (although I will say little to support this here), and that it offers important insights into the notion of body at work in physics.

1.3.1 Newton's criticisms of Descartes's account of bodies, in 'De Gravitatione'

The Newton manuscript 'De Gravitatione' contains explicit criticisms of Descartes's account of bodies in motion, as he understood it from reading Descartes's *Principles of Philosophy*. Within the current philosophy of physics literature, a great deal of attention has been paid to Newton's criticisms of Descartes's definition of motion.[18] However, the paragraph that introduces these criticisms makes clear that the target is also *the account of body* along with the definition of motion. Newton writes (2004, p. 14, my emphasis):

> when I suppose in these definitions that *space is distinct from body*, and when I determine that *motion is with respect to the parts of that space, and not with respect to the position of neighboring bodies*, lest this should be taken as gratuitously contrary to the Cartesians, I shall venture to dispose of his fictions.

The two things (the account of body, and the definition of motion) are intimately tied together. What I want to place centre stage is this: Newton's diagnosis of the reason why 'Cartesian motion is not motion' (2004, p. 20) is that

17 When discussing Newton on body, the main focus of interest has been on Newton's matter theory, but my interest is different from this. As with Descartes, Newton offers us laws that apply to bodies, and our question is: what are the bodies to which these laws apply? Supplying a theory of matter could indeed answer this question, but – as I have argued – that is not the type of solution that Descartes ended up offering, and nor – as I shall now argue – is it the solution that Newton offers in his *Principia*. Nevertheless, it is a genuine solution, and one which is (in an important way) *complete* even in the absence of a theory of matter.

18 See Slowik (2002, chapter 1) for example.

Descartes has offered an inadequate account of *body*, where 'inadequate' means 'inadequate for the purposes of a science of bodies in motion'.

There's a lot bundled up there, and I want to unpack it. Before discussing Newton's criticisms of Descartes's account of body, let me first review the familiar criticisms Newton makes of Descartes's definition of motion. The standard philosophy of physics story about 'De Gravtitatione' focuses on Descartes's relational definition of motion. Newton offers several criticisms of this definition, many of which are united by a central theme that, according to Newton, we should be looking for a systematic connection between the presence of forces and changes in states of motion, and that Descartes's account fails to offer this.[19] However, the argument that has received the most attention is one that doesn't rely on appeal to the presence or absence of forces, and the conclusion Newton draws is much stronger. He argues *not* that Descartes has given a definition of motion that fails when we try to apply it, but that *he has failed to give a definition of motion at all* (Newton 2004, p. 20):

> Now since it is impossible to pick out the place in which a motion began – that is, the beginning of the space traversed – for this place no longer exists after the motion is completed, that the traversed space, having no beginning, can have no length; and since velocity depends upon the length of the space passed over in a given time, it follows that the moving body can have no velocity, just as I wished to show at first. Moreover, what was said regarding the beginning of the space passed over should be understood concerning all the intermediate places; and thus, as the space has no beginning nor intermediate parts, it follows there was no space passed over and thus no determinate motion, which was my second point. It follows indubitably that Cartesian motion is not motion, for it has no velocity, no determination, and there is no space or distance traversed by it.

I don't want to dwell on this argument against the Cartesian definition of motion. Instead, I want to shift attention to the very next sentence, which is this (Newton 2004, pp. 20–21):

> So it is necessary that the definition of places, and hence of local motion, be referred to some motionless being such as extension alone or space in so far as it is seen to be truly distinct from bodies.

So, there is a criticism of Descartes's account of body here, and the thrust of it is this: Descartes's account of body is inadequate *in the sense that* it is inadequate to the purposes of a science of bodies in motion. Why? Because if body is

19 For example, Newton points out apparent problems with reconciling in a consistent manner when a body has a 'tendency to recede' and when it is in motion or at rest (2004, p. 15), and that we can have changes in motion of a body even when there are no forces acting on that body, and vice versa (2004, p. 18).

identified with extension, then we can't give an adequate account of what it is for a body to move. Thus, the 'problem of bodies' – of specifying a concept of body that is adequate to the purposes of a science of bodies in motion – is explicitly at stake in Newton's criticisms of Descartes on body and motion.

There is also strong evidence that this is exactly one of the problems that Newton is trying to solve in 'De Gravitatione'. Prior to the attack on Descartes's definition of motion, Newton states four definitions of his own (Newton 2004, p. 13), the second of which is a definition of body. It reads: 'Body is that which fills place.' Newton further elaborates on this as follows (my emphasis added): 'Note. I said that body fills place, that is, so completely fills it that it wholly excludes other things of the same kind or other bodies, *as if* it were an impenetrable being.' He then goes on to state the purpose that this notion of body is intended to fulfil, writing that 'body is here proposed for investigation not in so far as it is a physical substance endowed with sensible qualities, but only in so far as it is extended, mobile, and impenetrable'. That is, the notion of body is intended to be 'adequate to' the task Newton has in mind: he writes that he has 'postulated only the properties required for local motion' (Newton 2004, p. 13).

In conclusion, the main content of this first part of 'De Gravitatione' is Newton's detailed arguments as to why space and body must be distinct from one another: body cannot be merely extension because then we cannot give a satisfactory account of what it would be for bodies to move. Descartes's account of body is inappropriate for the purposes of a theory of bodies in motion.

1.3.2 Newton's solution to the 'problem of bodies' in 'De Gravitatione'

In the second part of 'De Gravitatione' (beginning towards the end of p. 21 of Newton, 2004), Newton offers his positive account of space and body, the most familiar aspect of which is Newton's insistence that space and body are distinct, having a very different ontological status from one another. In addition to a rich account of space,[20] these passages are where we find evidence that Newton's solution to the 'problem of bodies' is a law-constitutive solution of exactly the kind found implicitly in Descartes. Newton does not *first* give a general account of bodies, and *then* show that it is satisfactory for the purposes of a science of bodies in motion (among other things). Rather, a necessary condition for something to be a body is that it satisfy certain laws. The textual evidence for this claim is as follows.

Two properties that Newton attributes to bodies are mobility and impenetrability (see Newton 2004, p. 27). A region of space that is impenetrable will be 'impervious to bodies', and 'by hypothesis' the implication of this is that it will

20 For discussion see DiSalle (2006), McGuire (1978), Stein (2002).

'assume all the properties of a corporeal particle, except that it will be regarded as motionless' (Newton 2004, p. 28) Crucially, this includes being sensible, or 'tangible' (Newton 2004, p. 28). Newton then goes on to introduce what he means by mobility (Newton 2004, p. 28, my emphasis):

> If we should suppose that that impenetrability is not always maintained in the same part of space but can be transferred here and there *according to certain laws*, yet so that the quantity and shape of that impenetrable space are not changed, there will be no property of body which it does not possess.

Newton sums up his position (p. 28) by saying that 'these beings will either be bodies, or very similar to bodies', and if they are bodies then we can define them as 'determined quantities of extension' that are (1) mobile, (2) impenetrable, such that they reflect off one another '*in accord with certain laws*', (3) sensible, and movable by us. The appeal to laws is emphasized by Janiak (2006), where he notes that 'in a clever and crucial twist, Newton adds that the region's mobility would be lawlike'. Newton is explicit that a necessary condition for something to be a body is that it move in accordance with the laws.[21]

In sum, I have shown that in 'De Gravitatione' Newton's criticism of Descartes's concept of body claims that it is inadequate to the purposes of a science of bodies in motion, and I have argued that he offers an explicitly law-constitutive solution to this problem (the 'problem of bodies'). In the following section I will argue that this same solution is also at work in the *Principia*. Before doing so, however, I will address a criticism of Newton's account of body, as offered in 'De Gravitatione', made by Bennett and Remnant (1978).

In their paper 'How matter might at first be made', Bennett and Remnant (1978) argue that the account of body offered by Newton in 'De Gravitatione' is a failure. They focus on the criterion of impenetrability, and object that Newton does not have the resources to say what he means by impenetrability.[22]

21 There is a subtlety here. In a clear jibe at Descartes, Newton is cautious about saying 'positively what the nature of bodies is' since he has 'no clear and distinct perception of this matter': he leaves open the possiblity that God could create bodies that appeared to us in every way as Newton has described them and yet differ in nature from those Newton describes (see Newton, 2004, p. 27). This could be read as casting doubt on the law-constitutive approach as providing necessary conditions, but I think that this isn't right. In 'De Gravitatione', space and body differ in their epistemic status. The exclusively a posteriori character of our enquiries into the nature of body render the results less certain, and this includes the possibility that God has created bodies with a nature different from that described by Newton. Nevertheless, Newton ends the relevant paragraph by concluding that his description of body will be such that 'we can hardly say that it is not body'. It seems to me that the necessary conditions should be understood as inheriting this modest epistemic status.

22 I am grateful to Eric Schliesser for suggesting that I revisit Bennett and Remnant's position in the light of my reading of 'De Gravitatione'.

There are many issues raised by their discussion, and I will pick up only one thread that relates directly to the law-constitutive interpretation I have been advocating here. According to Bennett and Remnant, impenetrability can do the job of ensuring that two shapes, once delineated and distinguished from space (such that they can move around with respect to space) never overlap. What impenetrability cannot do, they say, is delineate a shape (so that it is distinct from space such that it has the possibility of being mobile with respect to space) in the first place. They claim that impenetrability is the only resource that Newton has to delineate shapes, and that his account is therefore a failure.

This criticism rests on the requirement that Newton's account of bodies as regions of impenetrable space underwrites *in virtue of what* bodies are mobile. However, on the view I propose, it is a condition on being a body that – in addition to being impenetrable and sensible – it be mobile. Mobility is itself one of the criteria that Newton stipulates, independently of impenetrability, so impenetrability was never intended to confer mobility. The condition of mobility is itself a stipulation, and Newton is not attempting to explain in virtue of what a shape is delineated in space such that it has the possibility of being mobile. As Newton himself says, body is that which *fills* place; a portion of matter, or a body, is not identified as an impenetrable region of space. It is, rather, a perceptible shape that in fact moves around according to certain laws. So we can grant Bennett and Remnant this much: Newton has not given an account of how matter might at first be made in the sense that he has not given an account of what makes possible the mobility of an impenetrable and sensible region. Nevertheless, Newton has given a clear set of conditions that, if satisfied in the making of matter, would deliver a world such that 'if all of this world were constituted out of these beings, it would hardly seem to be inhabited differently'.[23] And this is all that the law-constitutive approach requires.

1.3.3 The 'problem of bodies' in Principia

Definition 1 of Newton's *Principia* is famous:[24]

> Definition 1: Quantity of matter is a measure of matter that arises from its density and volume jointly.

In elaborating on the definition, Newton says: 'I mean this quantity whenever I use the term "body" or "mass".' So 'body' is a 'quantity of matter', and the first part of the definition tells us that this quantity is a measure of matter. The first part of the definition introduces a new quantity into physics, and the second part relates this newly introduced concept to the pre-existing concepts

23 Newton, 'De Gravitatione', p. 28.

24 Quotations are from Newton (1999), the Cohen and Whitman translation of the *Principia*.

of density and volume. But still, this isn't hugely informative. What else does Newton give us? Definition 3 attributes a property to bodies, inertia,[25] and in the Scholium to Definition 8, Newton repeats an assertion familiar from 'De Gravitatione': 'Place is the part of space that a body occupies.' And, of course, we have Newton's laws of motion:

Axioms, or the Laws of Motion

Law 1: Every body perserveres in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by forces impressed.

Law 2: A change in motion is proportional to the motive force impressed and takes place along the straight line in which that force is impressed.

Law 3: To any action there is always an opposite and equal reaction; in other words, the actions of two bodies upon each other are always equal and always opposite in direction.

What Newton is doing in these opening sections of the *Principia* is specifying the notion of body that is needed for his project, his science of bodies in motion, to get off the ground. But the question I am interested in is the same as the one I discussed with respect to Descartes. Does Newton intend to offer an account of body that is independent of the laws, or is the account of body *incomplete* prior to the specification of the laws, and *completed by* those laws? I think the latter. The material from 'De Gravitatione' discussed above, and which pre-dates the *Principia*, points in this direction, and material from after the *Principia* also points the same way, or so I will now argue.

The relevant later materials are drafts published by McGuire in 1966.[26] McGuire dates the drafts at 'some time towards the end of 1716', but in any case, they were done in preparation for the third edition of the *Principia*, which came out in 1726. According to McGuire (p. 115) the intended positioning in the third edition is just after the Rules of Reasoning, and indeed much of what is at stake in the drafts for Newton concerns his claim that he is 'arguing from the phenomena'. But for our purposes I want to highlight the following aspects:

From Draft 1 (McGuire, p. 113):[27]

> thus body and vacuum are here defined [*not in order that we deny that other bodies exist but in order that we may show in what sense these words are to be*

25 Definition 3: 'Inherent force of matter is the power of resisting by which every body, so far as it is able, perseveres in its state either of resting or of moving uniformly straight forward.'

26 Page references are to the reprinted version, McGuire (1995).

27 Square brackets were used by Newton to indicate passages that were to be omitted when the document was copied. Italics indicate passages Newton crossed out. I have used underlining to add my own emphasis.

understood in what follows. The propositions which follow are understood of bodies of this kind. About other bodies let authors in other sciences dispute.]

From Draft 2 (McGuire, p. 114):

> **Definition I** Body I call everything tangible in which there is resistance to tangible things, and whose action *resistance*, if it is great enough, can be perceived.
>
> It is indeed in this sense that the common people always accept the word body. And of this sort are The Earth, Planets, Comets, metals, stones, sand, clay . . . These emit and reflect light and are weighed down by their constituent parts *and are numbered among the phenomena and in their motions observe the laws of bodies*. [Mathematical solids are not perceived by touching nor cause a resistance nor are they usually called bodies.] Vapours and exhalations on account of Their rarity lose almost all perceptible resistance, and in the common acceptance often lose even the name of bodies and are called spirits. And yet they can be called bodies in so far as *they are the effluvia of bodies* and have a resistance proportional to density. [But if the effluvia of bodies were to change thus in respect of their forms so that they are to lose *all* power of resisting, *and cease to be numbered among the phenomena*, these I would no longer call bodies: for I speak with the common people.]

From Draft 3 (McGuire, p. 115):

> **Definition II** Body I call everything which can be moved and touched, in which there is resistance to tangible things, and its resistance, if it is great enough, can be perceived.
>
> It is indeed in this sense that the common people always accept the word body. And of this sort are The Earth, Planets, Comets, metals, stones, sand, clay . . . I add the heavenly bodies. These emit and reflect light . . . and in their motions observe the laws of bodies. Mathematical solids are not *perceived* do not move by touching nor cause a resistance, nor are they usually called bodies . . . . At the beginning of the first book I have defined the quantity of matter so that it may be treated in mathematical terms; here I have defined body composed of such matter in order that it may be treated in physical terms.

I think there is clear evidence in these drafts of two things:

(1) The definition of body is intended for the specific purposes of Newton's project.
(2) The definition includes the requirement that for something to *be* a body of this kind it move according to the laws.

This is a law-constitutive solution to the 'problem of bodies'. I think that the solution is deliberate on Newton's part, and that it is already present in the first edition of the *Principia*.[28]

The conclusion we should draw is this: it is explicit in Newton's writings, from 'De Gravitatione' through the *Principia*, that a necessary condition for the individuality and identity of physical bodies is that they satisfy the laws of nature: in answering the question 'What are the bodies that are the subject-matter of Newton's laws?', we must make reference to those laws.

1.3.4 An interpretative consequence: transmutation

I believe that this approach to bodies is explicit in Newton's writings, and I am proposing it as an interpretation of one (very small) aspect of what Newton took himself to be doing. If we accept this then, even though the topic itself is narrow, there will be wider implications through its connections to other areas of Newton's work, including his views on atoms and the void, and the divisibility of matter, and on universal and essential properties and the distinction between them. Another example is his views on transformation and transmutation, and how we should understand Rule 3 of his Rules of Reasoning (in the second edition, 1713) and the abandoned Hypothesis 3 (of the first edition). Hypothesis 3 reads as follows:[29]

> Hypothesis 3. Every body can be transformed into a body of any other kind and successively take on all the intermediate degrees of qualities.

The apparent problem is that Hypothesis 3 allows the degree of a quality to vary, which entails, in the extreme, that the quality might disappear altogether.

28 One might object that – being later – these drafts are irrelevant to the claim that the solution is already present in the first edition, leaving open the possibility that this view is a post-hoc rationalization. I have already urged that 'De Gravitatione' provides evidence that the position I am advocating on body was already in place prior to publication of the *Principia*. I also suggest that this law-constitutive view of bodies is what Newton relies on when, after the publication of the first edition of the *Principia*, the controversy over the reality of the void gets going, but I will not argue for this here. It is also interesting to note that Newton's definition of motion as being with respect to space appears to long pre-date his offering a definition of bodies, and indeed Newton doesn't include any definition of bodies in his manuscripts until quite close to the time of writing the *Principia*. The first time it appears seems to be in 'On the Motion of Bodies in uniformly yielding media', which Herivel dates to the 1680s. Here, Newton defines absolute and relative time and space and then states (Herivel 1965a, pp. 309–310): 'Definition 5 By common consent bodies are movable things unable to penetrate each other.' The next definition of body to appear is one that is a clear pre-cursor to Definition 1 of the *Principia*. For those interested in the dating of 'De Gravitatione', the presence of a definition of body in this manuscript might add credence to the 1680s dating.

29 See Newton (1999, p. 198) for this translation of Hypothesis 3.

And this seems to allow that we might transform a body into something that is not a body. McMullin (1978, p. 7) puts the point as follows:

> Newton gradually came to believe that he would have to limit his original transformation hypothesis in order that mechanical properties remain invariant. After all, if solidity could be 'remitted' (decreased) at all, it was conceivable that it could be 'taken away' entirely, yet this must clearly be excluded, since it would entail that a body could cease to be subject to mechanics, that is, could cease to be a body.

I agree with the consequences McMullin states here: if solidity could be taken away entirely, then the body would cease to be subject to the laws of motion, and this implies that it would cease to be a body. But I don't agree that Newton gradually came to believe that he would have to limit his transformation hypothesis. Rather, I think that what happens is that Newton makes precise and explicit a view he was already committed to, in particular that things have to have certain features in order to count as bodies. In his revisions, he adds a new hypothesis about qualities which cannot be intended or remitted, but for a while he retains the old Hypothesis 3 alongside this new one. I agree with McGuire (1967) that this is because Newton saw no conflict between the two.[30]

1.4 Solving the 'problem of bodies'

I have argued that in the work of Newton we find a solution to the 'problem of bodies' according to which a necessary condition for the individuation and identity of physical bodies is that they satisfy the laws. This is the weak version of the 'law-constitutive' solution that I have been advocating, and it allows that the sufficient conditions can be completed from resources outside the laws themselves. The strong version states that the necessary *and sufficient* condition for the individuation and identity of physical bodies is that they satisfy the laws. Both the weak and strong versions are limited in the same way: they provide a solution to the 'problem of bodies' for *physical bodies* rather than *bodies in general*; that is, in each case the solution picks out bodies of a certain kind, while leaving open the possibility that there may be other kinds of bodies that are of relevance for other interests.

This solution to the philosophical problem leaves us with a research programme: to fill out the details of the laws, and of any additional conditions, and

30 I am also sympathetic to McGuire's position that the reason Newton eventually abandoned Hypothesis 3 during his revisions of the *Principia* was because he didn't want to have to explain the compatibility and the details of his atomism and transformation thesis, partly because it would have been a distraction from his main point, which was to argue for the universality of gravitation as a quality of bodies.

to demonstrate that the resulting package is indeed a complete and coherent account of the physical bodies that are the subject-matter of the laws.

One way to interpret the *Principia* would be that the definition of mass and the three laws of motion complete the task of filling out these details. We might read Stein (2002) as endorsing the weak version of the law-constitutive solution, and as viewing Newton as having completed the filling out of the details, when he writes (p. 275),

> we have a perfectly clear conception of these attributes of bodies that the mechanical, corpuscular, philosophy has conceived as fundamental, including 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.

Be that as it may regarding the interpretation of Newton's own position, implicit in the *Principia* is a strategy for filling out the details that is very different, and which shifts us from the weak to the strong solution (although I am definitely not advocating this as an interpretation of Newton's own position). According to this approach, Newton's three laws of motion begin the project but do not complete it. The left-hand side of Newton's second law is a place-holder for force-functions associated with whatever forces there happen to be in the world. Completing our account of physical bodies requires the specification of all these force-functions. Newton's law of universal gravitation provides one such force-function, and thereby moves us closer to an account of physical bodies. Newton believed that there were more force-functions to be found (associated with electrical phenomena, for example), but he did not know what they were or how many more remained to be found. Filling in the details of our solution to the 'problem of bodies' will be complete only when all the force-functions have been found. The strong version of the law-constitutive approach maintains that the laws are both necessary and sufficient, and – with this as a guiding heuristic – the research programme it engenders is the search for the specific forms of the laws that provide the details of this solution to the 'problem of bodies'.[31]

There are no guarantees that a research programme guided by the strong version of the law-constitutive approach will succeed: perhaps we will always be left with some additional features of bodies that need to be specified antecedently to the laws, in order for the laws to have bodies that can serve as their subject-matter. Furthermore, there is no guarantee that this strategy will generate one

31 This approach appears to ride roughshod over Newton's distinction between universal and essential qualities; I think that the distinction can be maintained even while pursuing the strong programme (McMullin 1978, for example, argues that the role of *universal* qualities is to ensure that the bodies that are the subject-matter of Newton's mechanics *remain* bodies (by remaining solid, etc.)), but in any case I am not advocating the strong programme as an interpretation of Newton's own thinking.

unified kind of physical body: perhaps the bodies that serve as the subject-matter of the laws when gravitation is included will turn out not to be identical to those that serve as the subject-matter of the laws when electrical phenomena are at issue. Thirdly, there is no guarantee that the law-constitutive approach to physical bodies will deliver *individuals*. While I have formulated the law-constitutive approach offered in this chapter in terms of necessary and sufficient conditions for the individuation and identity of physical bodies, a more general formulation of the law-constitutive approach (in its strong version) says that the necessary and sufficient condition for some region of a world to be a physical body is that it satisfy the laws of that physical theory. This formulation is neutral as to whether the bodies to which the laws of a given theory apply will turn out to be individuals. Finally, there is no guarantee that the 'bodies' that we end up with are sufficiently close to our pre-theoretic account of bodies that we will be willing to call them bodies: a generalization to the 'entities' that are the subject-matter of a given theory is therefore natural. All these become matters that can be decided only by including the details of a particular physics, and not in advance.

When we see this, we realize just how radical is this solution (in its weak or strong version) to the 'problem of bodies'. Metaphysics and physics become entangled: not all metaphysical questions about what bodies are can be settled prior to doing physics, and that doesn't mean 'physics in general', it means that some metaphysical questions are not independent of a specific and *specified* physical theory (and which questions are independent and which are not depends on the specific theory in question).[32]

My claim is that the law-constitutive approach (weak or strong) is successful as a philosophical solution to the problem of bodies. I have argued that there is no guarantee of success when we work out the details with the specific laws we find in this, the actual, world. But that is a different matter from its philosophical viability as a candidate generic solution. Thus, independently of whether we accept my account as an interpretation of what Newton took himself to be doing, one of the implications of his work for philosophy is that it offers a solution to a problem found in Cartesian philosophy.

The philosophical consequences of this solution should be taken seriously. One motivation for contemporary structural realism stems from the fact that quantum mechanics fails to determine whether its particles are individuals or non-individuals. According to French and Ladyman, if quantum mechanics is interpreted as being about objects (rather than about structure), then it fails to adequately specify the entities that are its subject-matter. This is because, according to French and Ladyman, objects must be determinately individuals or

32 In Brading (2011) I further explore the metaphysical ramifications of the law-constitutive approach, treating composite systems, their unity, and the actual/potential parts debate.

non-individuals.[33] Clearly, this includes in the necessary conditions of quantum object-hood a requirement that goes beyond being an entity that satisfies the laws of quantum mechanics. Thus, how we respond to their challenge will depend in part on the extent to which we are willing to say: to be an entity that serves as the subject-matter of a theory *is* to satisfy the laws of that theory; no less, and also no more.

1.5 Conclusions

I have drawn conclusions of increasing strength during the course of this paper, and there are various points at which one might want to get off the boat. However, there are some key claims that I would press for, as follows.

Descartes fails to offer an adequate account of the bodies that are the subject-matter of his laws. This is by his own criteria: there are not the resources within his metaphysics to underwrite his claim that we have a clear and distinct idea of bodies (plural) as opposed to body (Cartesian indefinite extension). It is also by Newton's criteria: Descartes fails to specify a concept of body that allows him to go on and provide an account of what it is for a body to move. In these ways, Descartes fails to solve the 'problem of bodies'. Newton's solution to the problem involves distinguishing body from space, and stating that a necessary condition for something to be a physical body is that it move according to certain laws. It is this latter claim that I have focused on, arguing that while this law-constitutive account of body can be read implicitly in Descartes, it is explicit in Newton.

I have also gone on to claim that this is a powerful and effective solution to the 'problem of bodies', one which challenges the need for a principle of individuation distinct from necessary and sufficient conditions, and which has significance for discussions of the entities that are the subject-matter of contemporary physics. About these latter claims, there are surely more arguments to be made.

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33 See Ladyman (1998) for the first statement of this position. See French and Ladyman (2003) for further elaboration. Brading and Skiles (forthcoming) appeals to the law-constitutive approach in responding to French and Ladyman's argument.