

Unity and change in Newton's physics

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Abstract

Here is a problem at the heart of the metaphysics of the natural world: *How, if at all, can a unity undergo change?* This problem incorporates two questions. First, in virtue of what is a thing a *genuine unity*? And second, the issue that's more obvious in the formulation of the question: how, if at all, can such a unity undergo change?

There are two basic approaches to this problem present in Newton's physics. The more familiar grounds unity and change in space and time, the second in the laws of nature. The latter approach is set out in this paper. I argue that a law-constitutive approach to the entities that are the subject-matter of Newton's physics offers a principle of unity for things, be they simple or composite, and for the parts of composites, such that we also gain an account of what it is for a genuine unity to undergo change in its properties whilst retaining its numerical identity. I end by arguing that the law-constitutive approach favors endurantism over perdurantism.

This paper is intended as an example of a particular approach to the relationship between metaphysics and philosophy of physics, according to which, as a philosopher, one engages with physics as a part of the history of philosophy, beginning with our deepest philosophical questions and using the development of physics *read as a contribution to philosophy* to explore how these questions are transformed, re-worked, addressed, and sometimes rendered non-questions.

1. Introduction

Here is a problem at the heart of the metaphysics of the natural world: *How, if at all, can a unity undergo change?* That is, how can a thing which is *one*, a genuine unity, remain the very same thing, whilst also changing? This problem incorporates two questions. First, in virtue of what is a thing a genuine unity? What is it to be *one*? And second, the issue that's more obvious in the formulation of the question: how, if at all, can such a unity undergo change?

There are two basic approaches to this problem present in Newton's physics. The more familiar one grounds unity and change in space and time, and I'll give a brief overview of this in a minute. The second grounds unity and change in the laws of nature, and this is the approach I'm going to explore in this paper. These two approaches persist into contemporary physics, and are changed in important ways

by that physics, but in order to understand these changes it is important to understand the basic positions as they are found in Newton's physics, so we'll begin there.

2. Space and time as the ground of unity and change

A familiar picture from the "new philosophy" of the seventeenth century is the idea that all change is spatial re-arrangement of the parts of matter by means of local motion. So the parts of matter move around from place to place and all change is reduced to matter in local motion. This, of course, was Descartes's project and, in different versions with various different methods for pursuing the project, it took deep hold in the seventeenth century and has remained with us (bracket all sorts of caveats and revisions) up to the present.

What of unity in this picture? Well, here are the basic ingredients of one approach in which space and time play a crucial role (this will be a rough caricature, and is intended simply to remind you of some familiar features of the approach and some familiar problems that it faces).

Given a thing – an object, a body, or whatever – an account of identity over time can be offered by appeal to spatio-temporal trajectories; thus the unity and structure of space and time (the continuity of the spatiotemporal trajectory etc.) can be used to ground the unity over time and through change of spatial location of a material body. But I said "given a thing" – i.e. given a genuine unity to start with. In virtue of what is that initial "thing" a genuine unity? This is a notorious problem for the "matter in motion" picture. Should we start with spatially extended (and therefore conceptually divisible) yet metaphysically indivisible "atoms" and declare these our basic, ungrounded, genuine unities? Is there anything that could stick these together into larger genuine unities? Should a "mechanical philosophy" be supplemented by non-mechanical principles of unity? We're familiar with this problem from Leibniz, Spinoza, Locke, and so on.

The problems for unity and change on this view accumulate. Can there be change at the level of the "genuine unities", or is it perhaps the case that all change is re-arrangement of unchanging unities, and at the basic metaphysical level nothing that is a unity undergoes change? But if there are all these unchanging unities, in virtue of what is the universe, as a composite of these unities, itself a genuine unity? Or is the universe a mere heap, an aggregate that lacks genuine unity? What sense could it make to say that the universe is not genuinely *one*? Here space and time can be invoked again in providing metaphysical unity, this time for the universe as a whole. Space and time provide the framework within which everything that is material exists, and they are the ground of the unity of the universe: what makes

this material universe *one* universe is the unity of the space and time framework within which the matter is located.

In Newton's physics, space and time can be understood as playing just such a role. In Newton's *Principia*, absolute space and absolute time are the framework within which all material bodies exist, and if we turn our attention to the manuscript 'De Gravitatione',¹ we can flesh out the picture. Here, space and time are emanations of God. Every created being is somewhere in space, and is created at some time. So space and time ground the unity of the universe as a whole. Moreover, this space is geometrically rich, already containing all the shapes that bodies might have, all the trajectories along which they might move, and so forth. Newton offers a proposal according to which bodies are regions of space that God endows with various conditions, including impenetrability, mobility, and sensibility. In this way, the structure of space and time underwrites the unity of the material objects created in them. Thus, there is a strong sense in which space and time are the metaphysical ground of the unity of each material thing in the world, and also of the world as a whole.

So much for the first approach to unity and change, in which *unity* is grounded in space and time, and *change* is reduced to local motion with respect to space and time. I know it's been rough and ready, and my only purpose was to take it out of the box and set it on the table, so that it can sit there during the rest of my paper. There is, in Newton, a second approach to unity and change, and it is this that I really want to talk about.

3. The law-constitutive approach to unity and change

In the manuscript 'De Gravitatione', Newton sums up his tentative account of bodies by saying that 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', and (3) sensible, and movable by us. This account of bodies is offered in direct and explicit engagement with Descartes, and should be understood as offering a solution to a problem that Newton and others found in Descartes's "physics". The crucial move that Newton makes concerns the role of the laws of nature in the account of bodies, and it leads to a second account of unity and change (*not* grounded in space and time). On this approach, the questions "What is it to be an object, a genuine unity?", "What is it to be that very same object at a different time?", "What is it for a unity to persist through change?" are answered by appeal to the laws of nature in a very specific way. My claim is that this offers an important alternative approach to the metaphysical

¹ This Newton manuscript was re-discovered in the mid-twentieth century and has now become very famous. Although untitled it is commonly referred to as 'De Gravitatione'. See Janiak (2004).

problem “How, if at all, can a unity undergo change?” Once I’ve developed the approach, so that you can see what it is, I’ll try to make good on this claim.

So let me begin at the beginning with the relevant problem in Descartes’s work that Newton solves.²

3.1 Descartes and the ‘problem of bodies’

In his *Principles of Philosophy*, Descartes offers his three laws of nature, concerning the behaviour of ‘things’ and of ‘bodies’. Here they are (*Principles of Philosophy*, Part II, paragraphs 37, 39, and 40):³

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.

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.

But what are the ‘things’ and ‘bodies’ to which these laws apply? If Descartes’s laws are to say anything, then there must be bodies for them to refer to. Call this the ‘problem of bodies’. For Descartes, the answer is ‘parts of matter’. Famously, however, this answer masks a difficulty that Descartes never satisfactorily resolved, which is as follows.

According to Descartes, on the one hand we have a clear and distinct idea of matter as extended, and on the other hand experience teaches us that this extension is divided into parts, having various shapes and motions. If our metaphysics is to be founded on clear and distinct ideas *and* to include parts of matter, then we’d better have a clear and distinct idea of those parts. For *this* to be possible, Descartes must provide *within his metaphysical system* the resources for dividing matter into parts *such that we*

² The following material is from Brading (2011a) and (2011b), where the arguments for the law-constitutive approach are developed in more detail.

³ Quotations are from Descartes (1991), the Miller and Miller translation of the *Principles of Philosophy*.

can clearly and distinctly perceive that it is so divided.⁴ The answer that Descartes appears to give is that *motion* is the principle by which matter is divided into parts. In the *Principles* II.25 Descartes gives his definition of ‘What movement properly speaking is’, and then 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. However, motion is itself defined by appeal to the parts of matter. The resulting view is that 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. Whatever you might think about this, Descartes’s next move is to present his laws of motion and, as we have seen, these refer to bodies. The difficulty we are faced with is that we have laws that refer to bodies while not yet having in hand a completed account of bodies.

There are two ways to respond to this difficulty. On the one hand, you might attempt to ‘complete’ the metaphysical account of bodies, providing additional criteria that enable a solution to the ‘problem of bodies’ prior to the specification of the laws of nature. On the other hand, you might suggest that the laws themselves contribute to the solution of the ‘problem of bodies’, such that bodies *are*, in part, whatever satisfy the laws. We expand the rather tight circle where motion and body are inter-defined, and thereby hope to turn a vicious circle into a virtuous one. This is what I call a ‘law-constitutive’ approach to the problem of bodies. It says that *to be* a physical body *is* (at least in part) to satisfy the laws. This might be a necessary condition on what it is to be a physical body, with other conditions also being specified. Or, on the stronger view, it would be both necessary and sufficient.

3.2 Newton and the ‘problem of bodies’

Newton explicitly adopts a law-constitutive approach to the problem of bodies. Recall the conclusion of his account of bodies in ‘De Gravitatione’: 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*’, and (3) sensible, and movable by us. The inclusion of the clause ‘in accord with certain laws’ is not casual.⁵ It occurs earlier in the account, as he is developing it, and persists through his later writings. In ‘De Gravitatione’ he begins his account by supposing that regions of space are endowed with

⁴ 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.

⁵ 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’.

impenetrability and then goes on to introduce what he means by mobility (Janiak, 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 is explicit here that a necessary condition for something to *be a body* is that it move in accordance with the laws. He makes the same claim in draft revisions for the third edition of the *Principia*, where he is working on a definition of physical body. In each version of the definition, Newton repeats the stipulation that such bodies “in their motions observe the laws of bodies”. This is part of *what it is* to be a physical body.

So the first claim in the story I want to tell is this: In answering the question “What is a body?”, there is no complete account available prior to specification of Newton’s laws. By body here we mean, quite generally, “physical thing”. The claim is that there is no prior account of physical things available, which we can help ourselves to and then ask “Do such things satisfy Newton’s laws?” I want to emphasize the strength of this claim. I am not saying “Given a physical thing, whether it is an electron or an up-quark depends on which particular laws it satisfies.” That is about the division of things into kinds, and is a much weaker claim than the one I am making. My claim is that the very constitution of the thing as a thing, *in the most generic sense*, depends on the laws: what makes it a physical thing *at all* is, at least in part, that it satisfies Newton’s laws.⁶

It is, of course, an open question whether the laws in this world in fact suffice to constitute physical bodies: it might turn out that they don’t. But that is irrelevant to the question of whether the law-constitutive approach offers a philosophically viable solution to the problem of bodies, and my purpose here is to put *that* question on the table for philosophical consideration.

Let’s suppose that it’s philosophically viable (as I think it is). With this law-constitutive solution to the problem of bodies in hand, I want to move us on towards considerations of unity and change.

3.3 Unity and change in Descartes⁷

⁶I am also claiming that this view is explicit in Newton, and is developed as a direct response to a philosophical problem found in Descartes’s work. I have made this case in detail elsewhere, see Brading (2011a).

⁷The argument of this section is made in detail in Brading (2011b).

Consider the structure of Descartes's three laws (quoted above), viewed from a law-constitutive perspective. The first two laws tell us, of a single body, what that thing will do when it does not interact with any other things: it will stay in the same state. If we know what properties constitute the state of a thing, we know necessary (and sufficient, on the strong version) conditions on what it is for that thing *to remain the same thing over time*, provided that it does not interact with any other things. In this case, the properties of a thing (although not its spatial location) remain the same.

The role of the third law is to extend the account from single things to composite systems. It is a law of conservation for the total quantity of motion of a composite system, and it extends the first law from the single thing case to the case of a pair of things, and provides us with a law for a composite system of colliding things considered as isolated from all other things. It's perhaps not obvious that this is a conservation law, but the earlier version in *The World* (where it appears as the "second rule") makes clear that this is its genesis (see Descartes, 1998):

I suppose as a second rule that when one body pushes another it cannot give the other any motion unless it loses as much of its own motion at the same time; nor can it take away any of the other's motion unless its own is increased by as much.

Adopting the law-constitutive approach, satisfaction of this law is (partially) constitutive of what it is to be a composite system: when it is free from outside collisions, it conserves its total quantity of motion. We know it is a composite, because we start with two things, and we know it is a whole, because the composite satisfies the conservation law. Thus, the second law provides a *principle of unity* in virtue of which the composite is a genuine whole.

The Principles attempts a significant step forward beyond *The World*: in addition to providing a principle of unity for composite systems free from outside collisions, the third law and the rules of collision can also be used to try to determine the behaviour of the components. Viewed from the law-constitutive perspective, it provides a necessary condition for something to *be* a component of a composite system: it must move according to the third law and the rules of collision. Moreover, if the laws determine the behavior of the components, they determine the *changes* that a thing undergoes whilst remaining that very same thing. In fact, Descartes fails to solve the problem of collisions, but the strategy is clear.

The key message at this point is as follows:

(1) In Descartes's work, we have available a criterion for answering the metaphysical question 'In virtue of what is a given entity a genuine unity?' for isolated things and for composite systems (up to and including the universe as a whole), and that answer is 'in virtue of possessing a constant total quantity of motion'.

(2) We also have available an account of change: the laws specify what it is for a genuine unity to stay in the same state, and also what it is for that unity to undergo change.

These points will become clearer, I hope, when we consider the same issues in Newton's physics.

3.4 Unity and change in Newton⁸

With the Cartesian background in mind, we are now well placed to understand the law-constitutive accounts of unity and change present in Newton's physics. Here are Newton's laws:⁹

Law 1: Every body perseveres 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.

Newton's general strategy towards composite systems is exactly that found in Descartes: we proceed by construction from the behaviour of a single isolated thing, to the behaviour of composite systems, via conservation laws. But, whereas Descartes failed to solve the problem of collisions with his third law and his rules of collision in the *Principles*, and thereby failed to provide determinate parts of his composite systems, in Newton the strategy is implemented with clear success when it comes to the component parts of composite systems. The role of the third law is to determine the behaviour of components of a system, behaviour that must be consistent with the first law continuing to hold for the composite interacting system as a whole. Two things are important here. First, an analogous principle of unity for composite systems that we drew from Descartes's system is also available in Newton's system:

⁸ The argument of this section is made in detail in Brading (2011b).

⁹ The laws remain incomplete until the forces are specified: they are a research program, not a complete physics, but that is not to the point here.

conservation of quantity and direction of motion of the whole, when free from external interactions. Second, the laws uniquely and quantifiably determine the outcome of interactions between two things. From the law-constitutive perspective, this is important not just because it solves a problem in mechanics, the problem of collisions, but – more fundamentally – because it extends the law-constitutive approach to the *component parts* of a composite system. Putting the point more dramatically: it gives necessary conditions for something to *be* a part of a composite system, and sufficient conditions for those parts to be determinate. We are being offered a principle of unity that applies across the board to simple things, composite systems, and component parts of those systems. Moreover, the changes in the state of a component are determined by the laws; that is, the laws provide an account of what it is for a genuine unity to undergo change whilst remaining the very same thing.

Aside: My goal is not Descartes or Newton exegesis but rather the question of how best to think about physical things and composite systems in the light of the legacy left to us by Descartes and Newton. But let me be clear about how far I am willing to support what I have said as exegetical. First, I *do* think that the law-constitutive approach to bodies is explicit in Newton. Second, I *do* think the constructional strategy for how to build composite systems out of bodies is explicit in Newton, both with respect to how he presents his theoretical system and also with respect to how he applies it. Finally, while I do *not* think that the law-constitutive approach to composite systems is explicit in Newton, I *do* think it follows very naturally from the conjunction of the law-constitutive approach to bodies with the constructional strategy, both of which I maintain are explicit in Newton.

I will summarize the position that I have presented. My claim is that the law-constitutive approach to the construction of composite systems from bodies leads to important metaphysical results. First, it provides a principle of unity in virtue of which a composite system constitutes a genuine whole rather than a mere collection. This principle of unity is not about merely *physical* unity. It is not, for example, about the glue that binds a composite system together (for this, in the Newtonian picture, we need specific force laws). Moreover, the unity of the things from which the composite is made is itself grounded in the very same principle. The conservation of quantity of motion by a thing, or by a composite system, should be read as a *metaphysical* principle, the necessary and sufficient ground of the unity of the thing or system. This proposal for a principle of unity can be challenged, of course, but it should be challenged as a metaphysical claim, and thus duly recognized as such. In addition, the laws provide an account of what it is for such a unity to persist through change: that is, to retain its numerical identity whilst not its qualitative identity, without appeal to either essential properties or to haecceities. This issue is the last thing that I will talk about today.

4. Back to the basic puzzle

What is it for an object to persist through change? The *prima facie* puzzle here is as old as it is familiar. How can a thing – by which we mean a genuine unity – remain the very same thing and yet undergo change? In particular, if F and G are inconsistent properties (e.g. being 5 inches long and being 7 inches long), then (1) Fa, (2) Gb, and (3) a=b cannot all be true. How might one respond?

On the one hand, one might hold fast to the principle that no genuine unity can have inconsistent properties, and conclude that no genuine unity in fact persists through change at all. No numerical identity without qualitative identity. Thus, we make the distinction between enduring unities and perduring unities, and insist that objects persist in virtue of perduring (through a succession of momentary genuine unities appropriately related to one another), not in virtue of enduring.

On the other hand, we might take seriously the idea that time is doing some important work here, and allow that while a genuine unity cannot have inconsistent properties at any one time, having inconsistent properties at different times might be tolerated somehow (in a way that is to be explicitly specified). Thus, we allow for the possibility of numerical identity in the absence of qualitative identity. Since numerical unity cannot be grounded in qualitative identity on this route, we must ground it in something else, and there are two prominent options. One might restrict the class of properties that are required to remain the same in order for the numerical identity of the thing to be preserved: the essential properties do not change, no object has associated with it a set of inconsistent essential properties, not even over time. As for the accidental properties, we require that these are consistent at any one time, but we do not care whether they contain inconsistencies over time. Alternatively, one might claim that numerical identity over time is *independent* of sameness of properties over time: we appeal to haecceities to ground numerical identity over time, and we don't care about inconsistencies in properties over time (although we continue to require that an object's properties be consistent at any one time). This allows for genuine unities which persist in virtue of *enduring*.

There are good reasons for philosophers of physics to be sceptical about both essentialism and haecceitism, which appears to leave “no numerical identity without qualitative identity” as a feature of our account of unity, and consequently perdurantism as our account of change, as the only option. But the law-constitutive approach reveals an alternative. The law-constitutive approach offers a principle of unity in virtue of which a thing remains the very same thing over time and through change of properties. It does so not by appeal to haecceities, nor by appeal to essential properties, but by specifying the relations that must hold between the states of the thing at different times.

It might be thought that this view is compatible with both perdurantism and endurantism, with the laws specifying the relationship between the successive momentary genuine unities for the perdurantist and the successive states of a single genuine unity for the endurantist, but this is not the case. For, what are these “momentary genuine unities” that are tied together by the laws according to the perdurantist? *In virtue of what* are they *genuine unities*? If the genuine unity is grounded in qualitative identity, give me an argument why I should accept this view. If in something else, tell me what. It seems to me that the law-constitutive approach offers an argument in favor of endurantism as against perdurantism, because according to this approach the very principle that grounds the unity of a thing has *as one of its consequences* rules by which such a unity can undergo qualitative change.

Let me press on the key point a little more. In generating the *prima facie* puzzle above, we had to write down “ $a=b$ ”. But in order to write this down, we have to presuppose that our things labelled by “a” and “b” are genuine unities, and we need an account of what grounds that unity. We cannot take unity as brute, at least not without saying why the worries of the seventeenth century philosophers were misplaced.¹⁰ So, in the absence of a principle of unity, suitably argued for, the perdurantist is at a disadvantage as compared to the endurantist. The law-constitutive approach offers a principle of unity which provides numerical identity without qualitative identity, and provides an account of what it is for a genuine unity to undergo change. It is an approach that arose within attempts to construct a physics and a metaphysics of things by two giants of this enterprise: Descartes and Newton.

A final remark about the conclusion in favor of endurantism, arising as it does from thinking about physics. This might seem in conflict with considerations arising out of space-time theory, and in particular with the view that taking special relativity seriously demands a commitment to four-dimensionalism. While both endurantism and perdurantism are compatible with both presentism and four-dimensionalism, many contemporary metaphysicians think there is a more natural fit between endurantism and presentism and between perdurantism and four-dimensionalism. Physics might seem to be pulling towards endurantism on the basis of the argument I have given, and towards perdurantism on the basis of space-time theory. But a great deal here hinges on the status we attribute to space and time.

¹⁰ In our theorizing about the world, *objects* should not be taken as primitives. As Saunders (2003) argues, we have access (at least in physics) first of all not to objects, but to their properties and relations, and (for the purposes of physics at least) identity of objects needs to be defined in these terms, not taken as primitive. For example, Della Rocca (forthcoming) diagnoses an apparent stand-off between endurantism and perdurantism, and then argues against endurantism on the grounds that the endurantist must take persistence as primitive. The implicit assumption Della Rocca makes is that objects are to be taken as primitives: in the law-constitutive approach, objects are not primitive, and neither is persistence. Thus, endurantism escapes Della Rocca’s argument.

If they do not play the metaphysical role of grounding the unity of what there is, then “taking special relativity seriously” might look rather different than it does in many contemporary metaphysical discussions. But that is a story for another day.

The official part of my paper ends there, but given the title and stated goals of this conference, I cannot resist a comment on the manner in which philosophers should engage with physics. Very often, philosophers of physics work on “interpretations” of theories in physics, and work their way back from these towards philosophical questions. Here is an example of a philosopher of physics describing this work:¹¹

Physics provides theories which typically consist of a mathematical formalism and some procedures for applying that formalism to particular concrete situations. But both the formalism and the procedures may admit of alternative ontological interpretations. It may not be clear, for example, which part of the mathematics corresponds to real physical magnitudes and which is an artefact of arbitrary choices of units of gauges. It may not be clear which mathematical models represent real physical possibilities, and which do not. And it may not be clear which pairs of mathematical models represent the same physical situation. All of these problems confront even the philosopher who tries to take, for example, the Theory of Relativity ‘at face value’.

This is one possible approach, of course, and there is important conceptual work to be done here, but I do not think it is the most profound philosophically. An alternative is to begin with the deepest of our philosophical questions, and to use the development of physics *read as a contribution to philosophy* to explore how these questions are transformed, re-worked, addressed, and sometimes rendered non-questions. One does not “help oneself” to a philosophically shallow formalism, and then attempt to do philosophy: *one sees physics as a part of the history of philosophy*, and engages it on those terms. That is what I have tried to do here.

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¹¹Maudlin, in Loux and Zimmerman (eds.), 2003, pp. 461-2. I quote Maudlin here not as an example of a philosopher of physics who endorses this approach, but because of the clear description he gives of the approach, and the fact that his description appears in a metaphysics handbook.

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