PART TWO

Newton and "Empiricist" Philosophers

4

LOCKE'S METAPHYSICS AND NEWTONIAN METAPHYSICS

Lisa Downing

4.1 INTRODUCTION

I begin just with two passages, both well known to Locke scholars, one from Locke's correspondence with Stillingfleet and the other from the *Essay*. The first is the section of the correspondence with Stillingfleet (1697–1699) where Locke admits that the *Essay* needs some amendment to accommodate Newton's astounding success in the *Principia*:

> It is true, I say [in the *Essay*], "that bodies operate by impulse, and nothing else." And so I thought when I writ it, and can yet conceive no other way of their operation. But I am since convinced by the judicious Mr. Newton's incomparable book, that it is too bold a presumption to limit God's power, in this point, by my narrow conceptions. The gravitation of matter towards matter, by ways inconceivable to me, is not only a demonstration that God can, if he pleases, put into bodies powers and ways of operation above what can be derived from our idea of body, or can be explained by what we know of matter, but also an unquestionable and every where visible instance, that he has done so. And therefore in the next edition of my book I shall take care to have that passage rectified. (*W*, IV, pp. 467–468)[1]

The second, concerning the creation of matter, dates from the second edition of the *Essay* (1694):[2]

[1] *The Works of John Locke* (Locke 1823) are referred to as *W*, followed by volume and page number.

[2] Locke's *Essay Concerning Human Understanding* (Locke 1975) is simply referred to by book, chapter, and section numbers.

> … if we would emancipate our selves from vulgar Notions, and raise our Thoughts, as far as they would reach, to a closer contemplation of things, we might be able to aim at some dim and seeming conception how Matter might at first be made, and begin to exist by the power of that eternal first being: But to give beginning and being to a Spirit, would be found a more inconceivable effect of omnipotent Power. But this being what would perhaps lead us too far from the Notions, on which the Philosophy now in the World is built, it would not be pardonable to deviate so far from them; or to enquire, so far as Grammar it self would authorize, if the common setled Opinion opposes it: Especially in this place, where the received Doctrine serves well enough to our present purpose, and leaves this past doubt, that the Creation or Beginning of any one SUBSTANCE out of nothing being once admitted, the Creation of all other, but the CREATOR himself, may, with the same ease, be supposed. (4.10.18)

These two passages have several connected things in common:

(1) They are places where Locke is directly responding to Newton. (This isn't obvious in the second passage, however, but a little background makes it plain. As I will detail at greater length below, Locke's translator Pierre Coste famously claimed that Newton identified himself as the source of this hypothesis about how matter might at first be made, and it is evident that the hypothesis is, at least roughly, the one Newton sketched in his unpublished manuscript "De gravitatione et aequipondio fluidorum.")[3]
(2) They are places where prominent scholars[4] have thought that Locke's response to Newton leads him into inconsistency with his official position in the *Essay*.
(3) They are places where Leibniz pricks up his ears, usually a sign that something interesting is going on. (He reacts to the first passage with condemnation, and to the second with enthusiastic interest.)

In this paper, I focus on these two passages in turn and some issues radiating from them. The central questions are these: How does Locke's response to Newton influence his thought, what tensions does it produce, and does inconsistency result? I will contend that the first passage, Locke's discussion of gravity in the correspondence with

[3] As is typically done, I will refer to this manuscript of Newton's as *De Grav*. Page references are first to Christian Johnson's translation in Newton (2004), and second to the Latin original in Newton (1962), separated by a semicolon. Quotations are from Newton 2004, though I have occasionally departed from it.

[4] As for the first passage, Margaret Wilson (1979) identified the tension in Locke, which many scholars have since sought to resolve. The second passage is less discussed, but Stein (1990, p. 36) suggests some concerns.

Stillingfleet, reveals no inconsistency in Locke's position and, rather, points us toward a deeper understanding of Locke's mature metaphysics as well as his considered view of corpuscularianism. The second passage, Locke's allusion to Newton's hypothesis from "De gravitatione" about the creation of matter, presents a number of puzzles. In the end, I conclude that the *De Grav* hypothesis would represent a significant revision to the background metaphysical picture of the *Essay*, but that nevertheless its attractions to Locke are intelligible and illuminating. Along the way, I also argue that both Leibniz's reactions turn out to be misplaced: the first passage does not contradict his own views in the way that he imagines, so he ought not to condemn it, but the second passage hints at a view that is unacceptable to him. This examination should contribute toward a better understanding of Locke's *Essay*, of the evolution of his thought, and, ultimately, of Locke's place in the historical transition from Boylean mechanism to Newtonianism.

4.2 GRAVITY, SUPERADDITION, AND MERE MECHANISM

The question presented by our first target passage is whether Locke here does what Ayers (1975, p. 22) warns against, namely, "let[s] in the possibility that powers or phenomenal properties should belong to things as a matter of brute or miraculous fact not naturally intelligible," with the result that his "whole carefully constructed philosophy of science and his support for the corpuscularian case against the Aristotelians" must "collapse."[5]

Leibniz clearly thinks that Locke is admitting inexplicable powers or miracles, with disastrous consequences. His response is to give Locke a rather patronizing lecture about how to do metaphysics responsibly:[6]

> …it must be borne in mind above all that the modifications which can occur to a single subject naturally and without miracles must arise from limitations and variations of a real genus, i.e. of a constant and absolute inherent nature.

[5] Ayers holds that Locke does *not* do this, but Stein (1990, p. 33) maintains that he does. Margaret Wilson (1979) suggests a similar concern, though she presents it as Locke's holding that some properties cannot be natural consequences of Boylean corpuscles.

[6] See also:

> I cannot but praise our renowned author's modest piety here, when he acknowledges that God can do what is beyond our understanding and hence that there may be inconceivable mysteries among the articles of faith. But I would not like to be compelled to resort to miracles in the ordinary course of nature, or to admit absolutely inexplicable powers and operations. For, with the aid of 'what God can do', we may give too much leeway to bad philosophy by admitting these 'centripetal powers' and 'immediate attractions' at a distance,

> For that is how philosophers distinguish the modes of an absolute being from that being itself; just as we know that size, shape and motion are obviously limitations and variations of corporeal nature (for it is plain how a limited extension yields shapes, and that changes occurring in it are nothing but motion). Whenever we find some quality in a subject, we ought to believe that if we understood the nature of both the subject and the quality we would conceive how the quality could arise from it. So within the order of nature (miracles apart) it is not at God's arbitrary discretion to attach this or that quality haphazardly to substances. He will never give them any which are not natural to them, that is, which cannot arise from their nature as explicable modifications. So we may take it that matter will not naturally possess the attractive power referred to above, and that it will not of itself move in a curved path, because it is impossible to conceive how this could happen—that is, to explain it mechanically—whereas what is natural must be such as could become distinctly conceivable by anyone admitted into the secrets of things. This distinction between what is natural and explicable and what is miraculous and inexplicable removes all the difficulties. (Leibniz 1996, p. 65)

Leibniz supposes that Locke has responded to Newton's success by amending his matter theory in an ad hoc and unacceptable way. He assumes that Locke's matter theory is, in effect, the corpuscularianism of Robert Boyle, which seems ensconced in Locke's doctrine of primary qualities. (I will refer to this Boylean view as a corpuscularianism, strict mechanism, or sometimes simply a mechanism. It is the view that the nature of bodies is exhausted by size, shape, motion/rest, and solidity, and that as such they can interact only at contact by impact.) Because *Newtonian* gravity cannot, it seems, arise from corpuscularian real essences, Locke, on this interpretation, is forced to appeal to God's arbitrarily attaching powers to bodies not otherwise capable of them, but this is perpetual miracle, or, more neutrally, it is in violation of Locke's position that the powers and behavior of bodies flow deductively from their real essences (plus spatial arrangements among bodies). It's this latter position that I call Locke's essentialism.

Here, I think Locke can be cleared of charges of inconsistency[7] and of Leibniz's accusation of metaphysical muddle. Indeed, I think Locke disagrees with very little

> without being able to make them intelligible; I do not see what is to prevent our Scholastics from saying that everything simply comes about through 'faculties', and from promoting their 'intentional species' which travel from objects to us and find their way into our souls. If that is acceptable, 'Everything will now happen whose possibility I used to deny' [Ovid]. (Leibniz 1996, p. 61)

[7] Leveled by Wilson (1979) and Stein (1990).

in Leibniz's paragraph. The key claims in my defense are two.[8] First, Locke is not as attached to corpuscularian mechanism as is often thought. Second, Lockean superaddition is not the attaching of extrinsic or ungrounded powers, but rather the bestowing or configuring of more than merely mechanical real essences.

I contend that what Locke's response to Newton has driven him to here is not to abandon his essentialism, but rather his strict corpuscularianism. And, moreover, this is not an ad hoc response but a well-motivated step down a route Locke was already travelling. As I have suggested elsewhere,[9] Locke held consistently that mechanism might not be the right theory of body, though it is peculiarly natural and intelligible to us; he also held that the explanatory gaps in mechanism (namely, that it can't explain impulse, cohesion, or body-mind interaction) give us reason to back away from our natural commitment to it. His appreciation of Newton's success in the *Principia* is, in effect, the last straw: Locke now holds that strict mechanism cannot be the complete and correct account of the nature of body.

And this is exactly what Locke is saying in our target passage:[10] Newton has shown that there is something *in* bodies that we do not understand.[11] God has put something in bodies that goes beyond our idea of body (that is, goes beyond the nominal essence of body as something extended, solid, etc.), but not beyond the nature of body. Similarly, he writes:

> If it be asked, why they limit the omnipotency of God, in reference to the one rather than the other of these substances; all that can be said to it is, that they cannot conceive how the solid substance should ever be able to move itself. And as little, say I, are they able to conceive how a created unsolid substance should move itself; but there may be something in an immaterial substance, that you do not know. I grant it; and in a material one too: for example, gravitation of matter towards matter, and in the several proportions observable, inevitably shows, that there is something in matter that we do not understand, unless we can conceive self-motion in matter; or an inexplicable and inconceivable attraction in matter, at immense and almost incomprehensible distances: it

[8] For a tour through the logic of the interpretive possibilities here, see Downing (2013).

[9] Downing (1998, 2008).

[10] *W,* IV, pp. 467–468.

[11] Andrew Janiak suggests (2008, pp. 120–123), in effect, that Locke should have concluded from the *Principia* that there is something more-than-merely-mechanical in bodies that we *do* understand, namely, mass. I think it is true that Locke missed this (as Stein 1990, p. 36 observes as well), but it wouldn't suffice by his lights, since he holds that there must be something in bodies that grounds a causal explanation of gravitational interaction.

> must therefore be confessed, that there is something in solid, as well as unsolid substances, that we do not understand. (*W*, IV, pp. 464–465)

Locke takes it, rightly, that Newton has shown that universal gravitation is actual and that it cannot be accounted for mechanically, in terms of the impacts of bodies possessing only size, shape, solidity, and motion/rest. If Locke is an essentialist, this implies that strict Boylean mechanism is a false or incomplete account of the natures of bodies. But this is exactly what Locke acknowledges in stating that Newton has shown that there *is* something in solid substances that we do not understand.

Most tellingly, if the Leibnizian interpretation of Locke (according to which Locke is not an essentialist and holds that God can add powers arbitrarily to things) were right, Locke should have no problem at all with gravity; it would pose no *challenge* to his understanding of how the world works. One thing that is clear is that this is not Locke's response to Newton: he thinks Newton forces us to acknowledge that the physical world is deeply different from what we had thought.

Leibniz goes wrong in his Locke interpretation by supposing that Locke agrees with him in holding that intelligibility considerations allow us to definitively characterize the natures of bodies, and to do so along corpuscularian lines. Although Locke is tempted in this direction around the time of "Draft C" and the first edition of the *Essay*, the correspondence with Stillingfleet marks an official repudiation of that temptation.[12] This mistake leads Leibniz to misinterpret Locke's talk of "superaddition" as the attaching of ungrounded powers, a mistake in which he has been followed by many commentators.[13]

Admittedly, this mistake, as I regard it, is encouraged by some of Locke's formulations, and especially by the fact that Locke writes of the possibility of God's superadding thought to matter, while apparently arguing in 4.10.14–17 that matter is not naturally capable of thought. The "ungrounded powers" reading of superaddition solves this problem by holding that matter on its own cannot think, but that matter plus an extrinsic power supplied by God might do so. By maintaining as I do (along with Michael Ayers) that Locke does not contradict his essentialism in the correspondence with Stillingfleet, and does not commit himself to ungrounded powers, I am forced to resolve this apparent tension differently.[14] I think what Locke aims to establish at 4.10 is that *mere* matter cannot think; that is, matter as characterized by strict mechanism, matter whose nature is exhausted by extension plus solidity, is not capable of thought.

[12] For more on the evolution of Locke's thought on this issue, see Downing (2008).

[13] Including Stein (1990), McCann (1994), Stuart (1998). Although I hold that it is incorrect, the ungrounded powers reading has nontrivial textual support, as briefly discussed below.

[14] For a more detailed treatment, see Downing (2007).

This does not rule out that something material might think, that is, something that manifests extension and solidity and thus satisfies the nominal essence of matter (and so *is* matter). Thus the hypothesis that God might superadd thought to matter is the hypothesis that he might have configured some more than merely mechanical real essences, so as to allow them to think. (This is what I call essentialist superaddition.)[15]

A further consideration in favor of essentialist superaddition over the ungrounded powers view is that Locke thinks he's shown that its *unlikely* that matter thinks, though possible. But on the ungrounded powers view this is completely mysterious—God has already added one ungrounded power, attraction; how could it be difficult for him to add a second, thought? On the essentialist superaddition interpretation, Locke could imagine that it is unlikely for there to be one real essence that grounds both solidity and thought, though we are not in a position to rule this out.

I conclude that the central conclusion that Locke took from Newton's *Principia* was the straightforward one that strict mechanism could not be a correct and complete account of the nature of body, and that this conclusion did not threaten his core commitments.

One might well wonder here: what about Locke's core commitments to the primary/secondary quality distinction? Doesn't the refutation of Boylean mechanism threaten them? Here, my central claim is that the primary/secondary quality distinction is first and foremost an abstract metaphysical distinction between the intrinsic and irreduceable qualities of bodies, on the one hand, and sensible qualities that aren't intrinsic and irrreduceable.[16] Locke's usual list of primary qualities—size, shape, solidity, motion/rest—represents our natural view, as well as the view of the most intelligible scientific theory going, about what those intrinsic and irreduceable qualities of bodies are. Ultimately, however, the list represents an illustration of what the primary qualities of bodies *could be*, not a final account of what they are. Newtonianism then, on Locke's view, doesn't threaten the primary/secondary quality distinction, it merely threatens a corpuscularian's claim to have correctly and completely answered the question: what are the primary qualities?

A further question one might ask at this point is why Locke took Newton's conclusions so seriously given that by Locke's lights, the *Principia* was founded not on knowledge but on probable opinion.[17] This deserves more argument than I can give

[15] In what sense is this *super*addition? First, in the (epistemological) sense that, with regard to our conceptions of body, these are extra qualities. Secondly, Locke might imagine that what explains the difference between thinking and unthinking bodies is a matter of how God has set up or "configured" the real essences.

[16] For an elaboration and defense of this claim, see Downing (1998).

[17] This question too is raised by Stein (1990, pp. 31, 33).

it here,[18] but I contend that Locke is basically consistent here too: He regards the *Principia* as the outstanding example of what can be achieved in experimental natural philosophy, here extended in its reach by the astonishingly powerful use of mathematics.[19] As he writes in *Some Thoughts Concerning Education*:

> Though the Systems of *Physicks*, that I have met with, afford little encouragement to look for Certainty or Science in any Treatise, which shall pretend to give us a body of *Natural Philosophy* from the first Principles of Bodies in general, yet the incomparable Mr. *Newton* has shewn, how far Mathematicks, applied to some Parts of Nature, may, upon Principles that Matter of Fact justifie, carry us in the knowledge of some, as I may so call them, particular Provinces of the Incomprehensible Universe. (Locke [1693] 1989, 248–249)

And so to put the point more precisely, Locke understood that Newton had shown it to be extremely improbable that strict mechanism could be a complete and correct account of the nature of body, although Newton himself did not, in the *Principia*, substitute another such account. In the next section, we will consider the manuscript in which Newton famously did speculate on the ultimate nature of body.

It is worth noting, in concluding this section, that a traditional picture of Locke as failing to come to grips with Newton's *Principia* is mistaken, or at least misleading. That picture is perhaps mostly based on Desaguliers' (1734, Preface) famous anecdote asserting that Locke had to ask Huygens whether the mathematical propositions in the *Principia* were true. More significantly, Locke wrote an early (1688) review of the *Principia* for the *Bibliothèque universelle et historique* that suggests that at that stage, he was missing the radical implications of Newton's theory.[20] Nevertheless, I have argued that he eventually came to an acute assessment of its significance for his philosophical project.

4.3 "HOW MATTER MIGHT AT FIRST BE MADE"

Our second passage requires some stage setting: In the context of his proof of God's existence in 4.10, Locke attacks in passing the view that matter must be eternal and

[18] For more, see Downing (1997). But see Winkler (2008) for an enlightening attempt to provide a Lockean demonstration of the falsity of Cartesian mechanism.

[19] There are casual contexts, such as *Some Thoughts Concerning Education*, where Locke describes Newton's results as certain, but I think this is best explained by the context.

[20] Winkler (2008) contains a nice discussion of the historical evidence about the relations between Newton and Locke, including Desaguliers' anecdote and the early review.

uncreated because its creation ex nihilo is inconceivable. While in the first edition Locke merely argues that the creation of spirit is just as difficult to conceive as that of matter, in the second edition he adds our passage, suggesting that the creation of *matter* might be *more* easily conceived, if we emancipate ourselves from vulgar notions, etc.

Pierre Coste, who knew both Locke and Newton well, provides the key to Locke's cagey passage in a footnote in the second edition of his French translation of the *Essay* (1729):

> Here Mr. Locke arouses our curiosity but is unwilling to satisfy it. Within a short time after my translation appeared, many people who supposed that he had told me this way of explaining the creation of matter asked me to divulge it to them; but I had to confess to them that Mr. Locke had kept it a secret even from me. Eventually, long after his death, the whole mystery was revealed to me by Sir Isaac Newton, to whom I happened to mention this part of Mr. Locke's book. Smiling, he told me firstly that it was he himself who had devised this way of explaining the creation of matter, the thought of it having come to him one day when he happened to touch on this question in company with Mr. Locke and an English lord who is full of life and is as distinguished for his breadth of understanding as by his birth.[21] Here is how he expounded the thought to them. *One could* (he said) *in some fashion form an idea of the creation of matter by supposing that God could through his power prevent everything from entering a certain portion of pure space, space being by its nature penetrable, eternal, necessary, infinite; for thereafter that portion of space would possess impenetrability, which is one of the essential qualities of matter. And as pure space is absolutely uniform, we have only to suppose God to have communicated this kind of impenetrability to another similar portion of space, and that would give us some sort of idea of the mobility of matter, another quality which is also utterly essential to it.* So now we are freed from the search for what Locke had thought fit to hide from his readers. (Bennett and Remnant 1978, p. 5)[22]

As many have observed,[23] the hypothesis sketched here about matter's creation seems very similar to the one that Newton elaborates in his manuscript, "De gravitatione et aequipondio fluidorum."[24]

[21] Bennett and Remnant (1978, p. 5) identify him as Thomas Herbert, the eighth Earl of Pembroke, to whom Locke dedicated the *Essay*.

[22] For Coste's note in the original French, see Locke (1729, p. xliv).

[23] E.g., Koyré (1965, p. 92), Bennett and Remnant (1978), Tamny (1979), Woolhouse (1982), and Stein (1990, p. 35).

[24] I will not here address the vexed question of the dating of *De Grav*. Most who have commented on the question think that Newton would have written *De Grav* considerably earlier than this reported conversation, but Stein suggests (1970, p. 275) that we can't rule out the truth of the Coste/Newton report.

Before worrying about whether Locke can consistently endorse this hypothesis, I would like to address a worry raised by Bennett and Remnant about whether there is a coherent hypothesis there to be endorsed. Doing so will begin to fill out an account of how Newton understands the hypothesis. In *De Grav*, the hypothesis is first sketched as follows: after an extended attack on Descartes' account of space and the laying out of his own account (some details of which will concern us shortly), Newton makes a proposal about body/matter. This proposal is uncertain, he tells us, because matter is a production of the divine *will*, as opposed to space, which is a necessary consequence of the first-existing being. The hypothesis is introduced as follows: we can move bodies, so God can move bodies. But if God can move bodies, he can prevent bodies from entering a certain space, defined by certain limits. That space is now impenetrable, Newton suggests. Further, God could transfer the area of impenetrability according to certain laws. Note that this is not to transfer the portion of space; Newton emphasizes that the parts of space are immoveable. What is transferred (through different parts of space) is rather the impenetrability, "so that the quantity and shape of that impenetrable space are not changed" (*De Grav,* pp. 28; 106). A world composed of bodies like this, Newton asserts, would be indistinguishable from our world.

This corresponds quite closely to Coste's sketch in the footnote. Coste himself undertakes to criticize it as follows: he argues that merely preventing other bodies from entering a portion of space does not change the nature of the space, and thus does not succeed in bestowing the quality of impenetrability. I admit to some initial sympathy with Coste's point, but it is subject to an easy response. Newton can reply: if you like, you may say that my bodies lack true impenetrability. They have impenetrability* however, which is indistinguishable from it, and quite sufficient to account for experience. In missing this easy reply, it seems that Coste has missed Newton's point entirely.

A considerably more telling point is made by Bennett and Remnant against the hypothesis:[25] The germ of their objection is that Newton is trying to get his ontology off the ground with one relational property: "A portion of space is to be rendered 'impenetrable'—but impenetrable *to what*? The answer must be 'impenetrable to *matter*', and then the trouble starts" (1978, p. 7). Newton's initial description makes sense because there are already other bodies, but if *all* matter is supposed to be created in this way, as he goes on to suggest, it doesn't get off the ground.

Bennett and Remnant hold that the difficulty could be addressed either by employing two qualities, e.g. redness and warmth, to characterize bodies, or by one non-relational quality that admits degrees of intensity. This seems slightly too

[25] It is worth emphasizing that this is an objection that applies against both Newton's *initial* sketch of his hypothesis in *De Grav* and against the hypothesis Coste describes. As discussed below, Newton's hypothesis in *De Grav* contains crucial further elaborations.

demanding: surely just one positive quality could suffice. If bodies are green and unoccupied space is not-green, then the impenetrability can consist in God's never moving green-volumes so as to "overlap" (so, no decrease permitted in the amount of greenness). For they get things exactly right when they observe:

> Our objection to Newton's account is that he attempts to make the 'quality' of impenetrability do both the jobs just described: mark off one or more portions of space, as suffused by a property not possessed by pure space; and express his resolve never to move two suffusions into the same portion of space. But impenetrability can only do the second job—unless of course God also provides bits of matter of some other sort to bounce off regions suffused by impenetrability. (Bennett and Remnant 1978, p. 7)

But can't it do both jobs? Why not suppose that, in creating matter, God scatters throughout space a dispositional property, call it "Disposition-To-Deflect," or DTD.[26] DTD now purportedly characterizes many, but not all, volumes of space. The question is how we are to make sense of these dispositions. A region characterized by this property is such that, if another such property-area approaches, one or the other will be "deflected." But what is "approaching" and what is "deflected"? No parts of space approach, nor are deflected, for those are immobile (and impenetrable by other parts of space!). Rather, a spatially distributed counterfactually characterized property instantiation must approach and be deflected. And the instantiated property in question is the disposition to deflect other such instantiated properties. But what is the difference between this property instantiation being deflected and not being deflected? Between the property instantiations overlapping and their not overlapping? There is no such difference. And if there is no such difference, then we cannot make sense of the disposition in the first place.[27] And we certainly don't have an impenetrability*, sufficient to account for experience.

[26] I have heard versions of this response from more than one audience, but most forcefully from some audience members at the University of Connecticut's Department of Philosophy.

[27] Bennett and Remnant (1978, p. 7): "… when in this account any region of space is rendered impenetrable, what happens is that it is made invulnerable to invasion *by other impenetrable regions of space*. But this is a vacuous exercise of God's power—a purely idle exercise—because on any tolerable theory and certainly on Newton's it is of the essence of space that no part of it can overlap or intrude into any *other* part of it. So the alleged making-impenetrable has no effect at all; we are left with nothing but 'pure space'; and so the endeavor to describe a creation of matter has failed." See also Gorham 2011 (p. 23), who endorses their conclusions: "… impenetrability alone is inadequate to distinguish bodies from the unfavored portions of absolute space. And without this distinction, the condition of mobility (1) cannot get hold since Newton insists the parts of space are absolutely immobile in themselves."

Few commentators explicitly address this issue on Newton's behalf,[28] but one might locate replies in a couple of prominent treatments. In his discussion in the *Stanford Encyclopedia*, Andrew Janiak (2009) reads Newton as having God endow the region of space with a repulsive force. If one understands this as a positive quality, it would suffice to solve the problem, but if the repulsion is supposed to be understood purely relationally, as the ability to exclude other bodies, the problem remains.[29] Similarly, Stein, in the *Cambridge Companion to Newton* (2002, p. 278), describes impenetrability as though it were a positive quality, "filled," which would solve the problem unless "filled" is supposed to be glossed *simply* as "excludes other bodies."

A different solution seems to be suggested by Stein's noting (2002, p. 280), in relation to the point that Newton's initial account presupposes the existence of other bodies, that in the end Newton characterizes bodies as follows:

> … we can define bodies as determined quantities of extension which omnipresent God endows with certain conditions. These conditions are: (1) that they be mobile, and therefore I did not say that they are numerical parts of space which are absolutely immobile, but only definite quantities which may be transferred from space to space; (2) that two of this kind cannot coincide anywhere, that is, that they may be impenetrable, and hence that oppositions obstruct their mutual motions and they are reflected in accord with certain laws; (3) that they excite various perceptions of the senses and the imagination in created minds, and conversely be moved by them… (*De Grav*, pp. 28–29; 106)

Thus, in what seems to be Newton's *official* account in *De Grav*, there is in effect an *additional* quality, namely, the ability to affect and be affected by minds.[30] This, importantly, also suffices to solve the problem.[31] For now we have a quality, the ability to affect and be affected by minds, that suffuses some portions of space. And impenetrability can be God's policy of not allowing such suffusions of mind-affectingness to overlap. Note that if two areas of mind-affectingness approach one another, there is a difference between those

[28] An exception is Gorham (2011). See also Brading (2012, p. 24–25).

[29] One might think that Janiak, in effect, treats it as a positive quality, though the contrast he draws with Locke's attributing a "primitive quality" of solidity to bodies casts doubt on that.

[30] This, of course, is a relational quality, but if the relation holds between parts of space and an independent set of things, minds, there is no special problem about its doing the work of distinguishing bodies from empty space.

[31] Stein describes the third condition as solving an epistemological problem about the detection of bodies. But arguably it is needed to solve an ontological problem, as Gorham (2011) nicely brings out. It thus seems that condition (3) is prior to conditions (1) and (2). Recall, though, that this additional quality is not represented in Coste's account, leaving it unclear whether or not it was specified as part of the hypothesis as Locke heard it from Newton.

areas being deflected (as they will be, per (2)) as opposed to merging, and that difference has consequences.

Bodies, then, on the *De Grav* hypothesis, are determined quantities of space endowed with three conditions. These conditions, or qualities, are "dispositional characteristics of the spatial region," Stein suggests (1970, p. 276). But now we are in a position to appreciate the tensions created by Locke's friendliness to the hypothesis: (A) It looks as though the hypothesis posits bare powers, undermining my interpretation of superaddition and justifying Leibniz's criticism. (B) Newton's hypothesis aims to do without the idea of substance. Indeed, Newton emphasizes this fact as a virtue of and primary motivation for his account, as well as an advantage of his account over the Cartesian view:

> That for the existence of these beings it is not necessary that we imagine that some unintelligible substance is given in which, as a subject, a substantial form inheres; extension and an act of the divine will are enough. Extension serves in place of the substantial subject in which the form of the body is conserved by divine will; and that effect of divine will is the form or formal ratio denominating all the dimensions of space in which the body's being is produced. (*De Grav*, pp. 29; 106–107)

Locke, however, despite his famous disdain for our obscure and confused idea of substance in general (or substance as substratum), commits himself firmly to our need for it. In the third letter of the correspondence with Stillingfleet, moreover, he seems to go further by indicating that substance as substratum exists, on his view.[32] If, à la Newton, we can simply use extension and discard unintelligible substance, why all the angst and spilled ink, and doesn't this go against Locke's commitment to substance in general?

Two ways of dismissing both these worries too easily can themselves be dismissed: First, one might suppose that Locke understood the hypothesis as merely concerning the *creation* of bodies rather than their nature once created. That thought is easily ruled out, for it would be dim not to see that the hypothesis entails a view about the nature of bodies, and it seems unlikely that Newton would not have emphasized those implications, and the fact that Locke describes this hypothesis as a radical departure from "vulgar Notions" and "received Doctrine" tells us that he sees those implications. Secondly, one might emphasize (as does Benjamin Hill in his 2003 work) the fact

[32] See *W*, IV, p. 445:

> Your lordship then, if I understand your reasoning here, concludes that there is substance, "because it is a repugnancy to our conceptions of things" (for whether that repugnancy be to our first or second conceptions, I think that is all one) "that modes or accidents should subsist by themselves;" and I conclude the same thing, because we cannot conceive how sensible qualities should subsist by themselves.

that Locke is using the *De Grav* hypothesis for a particular *end*, namely, arguing that the creation of matter ex nihilo is *conceivable*. For this, of course, he does not need to be committed to the hypothesis' truth. Hill (2003, p. 315) adds that he needn't be committed even to its plausibility, just its possibility. All of this is true, but mere commitment to the hypothesis' *possibility* still raises the above worries. Further, the passage strongly suggests that Locke finds the hypothesis *attractive*; surely it's the fact that he describes it in such tantalizing terms that provoked the curiosity that Coste recounts. I conclude that Locke *approves* of the hypothesis, though he may not adopt it as his settled view.[33] Accordingly, although the hypothesis need not fit with every turn of phrase in the *Essay*, it ought not to contradict his mostly deeply held or seriously argued-for views.

I think the hypothesis' appeal for Locke is in fact readily intelligible from the perspective of the *Essay*'s core doctrines. For Locke, objects as *known to us through sensory experience* are (bundles) of powers; it is powers to which our sensory ideas are adequate:

> … all the notion we have of substance amounting at last to noe more then the Ideas of certain powers i.e either of susteining in its self several simple Ideas or else altering or produceing other simple Ideas in other Beings. (Locke 1990, p. 20)

Locke contrasts this known object with what he calls in the *Drafts* (1990, pp. 32) the uncertain philosophical cause of our sensations. Newton's hypothesis suggests a collapsing of the distinction between the two, converting the uncertain philosophical cause into a knowable bundle of powers.[34]

This seems just to return us to our problem, however, for Locke's position by the time of the published *Essay* is that the notion of a bundle of powers is conceptually problematic. The idea of power that we glean from experience is a relative one, linking an item regarded as producing change to one regarded as receiving change. The idea of substance, by giving us a terminus for the power relation, allows us to think in terms of *things with* powers and thus unifies the bundle.[35] It is this extra content that the general

[33] Indeed, I conclude below that the evidence is against his having adopted it.

[34] Though this may be too quick for Newton if, as Zvi Biener has suggested to me, Newton allows for an explanatory gap between the general ability to affect minds and the specific abilities to cause various sensory experiences.

[35] This is the point one is left with, if, following Locke's instructions, one substitutes "qualities" for "ideas" in the otherwise perplexing 2.23.1:

> … not imagining how these simple *Ideas* can subsist by themselves, we accustom our selves, to suppose some *Substratum*, wherein they do subsist, and from which they do result, which therefore we call *Substance*.

idea of substance supplies for us. Locke gives his best, most developed account of the content and origin of this idea in the correspondence with Stillingfleet:[36]

> … all the ideas of all the sensible qualities of a cherry come into my mind by sensation; the ideas of perceiving, thinking, reasoning, knowing, &c. come into my mind by reflection: the ideas of these qualities and actions, or powers, are perceived by the mind to be by themselves inconsistent with existence; … i. e. that they cannot exist or subsist of themselves. Hence the mind perceives their necessary connexion with inherence or being supported; which being a relative idea superadded to the red colour in a cherry, or to thinking in a man, the mind frames the correlative idea of a support. For I never denied, that the mind could frame to itself ideas of relation, but have showed the quite contrary in my chapters about relation. But because a relation cannot be founded in nothing, or be the relation of nothing, and the thing here related as a supporter or support is not represented to the mind by any clear and distinct idea; therefore the obscure, indistinct, vague idea of thing or something, is all that is left to be the positive idea, which has the relation of a support or substratum to modes or accidents; and that general indetermined idea of something, is, by the abstraction of the mind, derived also from the simple ideas of sensation and reflection: and thus the mind, from the positive, simple ideas got by sensation or reflection, comes to the general relative idea of substance; which, without the positive simple ideas, it would never have (*W*, IV, pp. 21–22, my emphasis).

But this very *thin* account of the idea of substance, as the idea of a thing with powers, promises to dissolve our problem, for a bit of Newtonian space, it would seem, could serve as the terminus of the power relation, could be that to which we attribute the powers,[37] and thus could meet the diagnosed need and satisfy Locke's idea of substance as substratum.

Still, questions remain. An initial (rather vague) question is this: How well does space fit this idea, i.e., how thing-like is space? If the *De Grav* hypothesis were correct, would it be true to say that substance-in-general exists and it is space?[38] Newton's views about this in *De Grav* are subtle, and perhaps not fully worked out.[39] Fortunately, our

[36] See McCann (2001).

[37] Note, though, that if we are concerned with a moving object, we attribute the powers to different parts of space, over time.

[38] I neglect here Benjamin Hill's intriguing suggestion (2003, p. 321), that Newton distinguishes between extension and space, that extension is something like an incomplete substance, pure potentia, which is a metaphysical constituent of both body and space. As he notes, Newton does not consistently observe this distinction in *De Grav*.

[39] For discussions of some of the subtleties, see Janiak (2008, pp. 130–162) and Schliesser (2012).

central question concerns how *Locke* would have viewed space's suitability as a substratum. His own views on space are broadly Newtonian, but considerably less subtle, and there is no reason to suppose that he would have seen the need to refine them in considering the hypothesis about matter's creation. He holds that space is clearly something, not nothing, though a something distinct from both body and mind. Like Newton, he resists and mocks the question: Is it a substance or an accident? He gives more than one response to it, in effect. One is to wave the question off as not worth addressing until it can be more clearly formulated. The second is to suggest that if one is willing to call body, spirit, and God all substances, nothing prevents one from regarding space as a fourth kind of substance: "And if they can thus make three distinct *Ideas* of *Substance*, what hinders, why another may not make a fourth?" (2.13.18). That space fits awkwardly into traditional ontological categories, but is none the worse for that, is a view that Locke shares with Newton (as we have seen) and also Gassendi.[40]

It might seem that this already tells us what we need to know: space is (or could be)[41] thing-like, it suffices to unite the powers, so it satisfies the minimal idea of substance in general and counts as a substratum. But there is reason to resist this answer as overly quick. Surely, one might say, the co-location of powers in space is obvious from experience; if co-location were enough, we wouldn't *need* the idea of substance; what we are positing with the idea of substance must be more than mere co-location. What Locke wants is for the powers to be grounded and explained, which merely attaching them to space doesn't do. As Stein rightly observes (2002, p. 278), Locke seeks "an *answer* to the twofold question: '(1) *In what* do the qualities we attribute to a substance *exist together*? (2) What is the *cause* of their existing thus together?' "

This is to return us to the other diagnosed tension, A (the worry about bare powers) and to reveal its connection to B (the worry about substance): these co-located powers constituting body still seem to be bare, ungrounded powers, in conflict with what I have called Locke's essentialism. The answer to this worry is that the powers *are* in a certain way ungrounded, but they are not unexplained. They are not grounded in

[40] In effect, Locke returns to this question later in 2.13, suggesting (at 2.13.26) that one might consider space either as a relation between existing things or as attributable to God in some fashion. And this latter thought, that God "fills Immensity" is repeated prominently at 2.15.3. Of course, this latter thought is also a broadly Newtonian one. In *De Grav* (pp. 25; 103), Newton calls space an "emanative effect" of God. He also calls it an affection of every kind of being, but nonetheless holds that it is more like a substance than an accident (22; 99).

[41] Of course, if space were merely a relation between existing things, it would not be thing-like, nor could it play the role of constituting things. Thus, Newton's hypothesis about matter's creation rules out the relational account of space to which Locke no longer seems particularly inclined. (And, of course, it is hardly a surprise that Newton's hypothesis should be inconsistent with a relational account of space.)

natured physical stuff, contrary to Locke's standard assumption in the *Essay*, the standard assumption of "the Philosophy now in the World." That's what makes this a radical doctrine. They are however, explained by divine will, divine activity.[42] Newton's answer to the second part of the twofold question is God. That is, it is God that causes the co-location of the powers. Locke can follow Newton in separating these questions and in giving these answers,[43] though it does represent a departure from the background metaphysics of the *Essay*. It is worth observing, though, that, as this is an account of the *nature* of bodies and not just of how they are created, the appeal to divine activity does not cease. That is to say, what the hypothesis must posit, if it is to satisfy Locke's demand that powers be explained, is God's continual activity.[44]

This does seem to be what Newton had in mind in *De Grav*.[45] The evidence of the text might seem to be conflicting: the description of how God adds mobility to bodies clearly suggests continual activity, but other passages might seem to imply that God could just bestow these powers and be done:

> For it is certain that God can stimulate our perception by means of his own will, and thence apply such power to the effects of his will. (*De Grav*, pp. 28; 106)

But strong evidence for the continual action thesis is provided by Newton's discussion of the world soul:

> And so some may perhaps prefer to posit a soul of the world created by God, upon which he imposes the law that definite spaces are endowed with corporeal properties, rather than to believe that this function is directly discharged by God. To be sure, the world should not be called the creature of that soul but of God alone, who creates it by constituting the soul of such a nature that the world necessarily emanates. But I do not see why God himself does not directly inform space with bodies . . . . (*De Grav*, pp. 30–31; 108)

[42] Further, the powers are interconnected, not arbitrarily conjoined, as is arguably also true of mechanism.

[43] Though the answers may not stay separate in the end. That is, God may be the ultimate answer to the "in what" question as well, given Locke's friendliness, noted above, to the view that God "fills Immensity" (2.15.3) and that this might provide an ontology of space (2.13.26).

[44] Specifically, on the full *De Grav* account, God's continual activity in bestowing the power to cause ideas in minds upon bits of otherwise empty space. (Here I agree with Gorham 2011.)

[45] Though this is not much noted in the literature. But see Gorham, cited above, and the Halls (Newton 1962, p. 81), and Woolhouse 1982, who argues continual action "follows from Newton's comparison of God's ability to endow portions of space with impenetrability and mobility to our ability to move our bodies" (pp. 88–89).

It seems here that the posited world soul would be continually carrying out some function that, instead, God might directly (and continually) perform. And further evidence may be located in the contrast that Newton draws between his ontology and the Cartesian ontology:[46]

> Further, they attribute no less reality in concept (though less in words) to this corporeal substance regarded as being without qualities and forms, than they do to the substance of God… . And hence it is not surprising that atheists arise ascribing to corporeal substances that which solely belongs to the divine. Indeed, however we cast about we find almost no other reason for atheism than this notion of bodies having, as it were, a complete, absolute, and independent reality in themselves, such as almost all of us, through negligence, are accustomed to have in our minds from childhood (unless I am mistaken), so that it is only verbally that we call bodies created and dependent. (*De Grav*, pp. 32; 110)

I conclude that the dependence Newton highlights in his own system of "corporeal substance" is a continual dependence.

I had promised, or threatened, to bring in Leibniz here as well, so here is Leibniz's response to our second passage:

> You have given me real pleasure, sir, by recounting something of a profound thought of your able author, which his over-scrupulous caution has stopped him from offering in its entirety. It would be a great pity if he suppressed it and, having brought us to a certain point with our mouths watering, left us standing there. I assure you, sir, that I believe there is something fine and important hidden under this rather enigmatic passage. The word 'substance' in capital letters might make one suspect that he conceives the production of matter in the manner of the production of accidents; there is not thought to be any problem about *their* being derived from nothing. And when he distinguishes his personal thought from 'the philosophy which is now established in the world' or in 'this place on the earth', I suspect that he has the Platonists in mind: they took matter to be something fleeting and transitory, in the way accidents are, and had an entirely different idea of minds and souls. (Leibniz 1996, p. 442)

I suggested in the introduction that Leibniz's enthusiasm here is misplaced, but that turns out to be a fairly subtle issue. What Leibniz approves of is the apparent demotion

[46] But then Stein's "neutral paraphrase" (2002, p. 279) is not really a paraphrase at all, for it eliminates the explanation for something that on Newton and Locke's view still needs explanation.

of matter to some sort of accident, dependent on substance. Something like this is true in his own metaphysics, of course, with the substance in question being monads, in the plural. Now, I have argued that for both Newton and Locke, the hypothesis makes matter continually dependent on God, so continually dependent on mind. This much, I suppose, Leibniz could endorse. However, by Leibniz's lights, the hypothesis ascribes entirely too much reality to extension.[47] On the hypothesis, matter is dependent on God's volitional efficient causal powers, but space itself is not.

It might look like Leibniz's disapproval should go further, that his concern about attraction applies here even more strongly, and he should accuse Locke and Newton of resorting to perpetual miracle. But by no means. For Leibniz himself adheres to continuous creation,[48] holding that God continually produces the natures of things, and those natures then explain their behavior. The *De Grav* hypothesis (unlike superadded attractive powers) arguably conforms to this model, and thus should not be classed as perpetual miracle by Leibniz's lights. Leibniz's difference in attitude, I suggest, highlights the difference between (on the one hand) the *De Grav* hypothesis about the manner in which the nature of bodies are continually generated and (on the other) the arbitrary attaching of powers to bodies so natured, thus legitimating Locke's approval of the former.

Nevertheless, I think the balance of the evidence suggests that while Locke *approved* of the hypothesis, he did not adopt it as his considered and settled view of the metaphysics of bodies. First, there is the historical evidence, or lack thereof. As Benjamin Hill (2003, pp. 311–312) has pointed out, there is no discussion of the *De Grav* hypothesis in any of Locke's correspondence, and no trace of any further conversations about it. Second, an argument that I used earlier against ungrounded powers superaddition also applies here: if Locke had adopted the *De Grav* hypothesis, he ought to have found the problem of gravity much more tractable than it seems that he did, for the inverse square law could simply be one more principle according to which God transfers corporeal powers through space.[49] That Locke gives no indication that he sees

[47] As Bennett and Remnant point out (1978, p. 6).

[48] See Leibniz's *Theodicy*, sections 382 and following (Leibniz 1985, pp. 354–356). See also Lee (2004).

[49] One might think that some version of the hypothesis promises to explain thinking matter as well, especially if all thinking matter requires is that the ability to think be located in the same region of space as the powers that constitute bodies. But this turns out to be a tricky issue. If thinking matter requires, more strictly, that the powers that are constitutive of matter/body give rise to thought, then a new circularity worry looms, since one of the fundamental powers, on the expanded *De Grav* account, is the ability to cause perceptions in mind. And there is a strong reason to think that Locke must not have supposed that minds can readily be understood as the power to think produced by God in some region of space. For if he thought that, it appears that

this problem as easily solved suggests that he views the *De Grav* hypothesis (unlike the established results of the *Principia*) merely as an attractive speculation.[50]

References

Ayers, M. (1975). "The Ideas of Power and Substance in Locke's Philosophy." *Philosophical Quarterly* 25:1–27.

Bennett, J., and P. Remnant. (1978). "How Matter Might First Be Made." In *Special Issue: Supplementary Volume: New Essays on Rationalism and Empiricism*. Edited by C. E. Jarrett, J. King-Farlow, and F. J. Pelletier. *Canadian Journal of Philosophy* 4: 1–11.

Brading, K. (2012). "Newton's Law-Constitutive Approach to Bodies: A Response to Descartes." In A. Janiak and E. Schliesser, eds. *Interpreting Newton: Critical Essays*. Cambridge, UK: Cambridge University Press, 13–32.

Desaguliers, J. T. (1734). *A Course of Experimental Philosophy*. Vol. 1. London: John Senex.

Downing, L. (1997). "Locke's Newtonianism and Lockean Newtonianism." *Perspectives on Science* 5 (3): 285–310.

——. (1998). "The Status of Mechanism in Locke's *Essay*." *The Philosophical Review* 107 (3): 381–414.

——. (2007). "Locke's Ontology." In L. Newman, ed. *The Cambridge Companion to Locke's "Essay Concerning Human Understanding."* Cambridge, UK: Cambridge University Press, 352–380.

——. (2008). "The 'Sensible Object' and the 'Uncertain Philosophical Cause.'" In D. Garber and Longuenesse, B., eds. *Kant and the Early Moderns*. Princeton, NJ: Princeton University Press, 100–116.

——. (2013). "Mechanism and Essentialism in Locke's Thought." In S. Duncan and A. LoLordo, eds. Debates in Modern Philosophy. New York: Routledge, 159–170.

the Newtonian hypothesis would not leave the creation ex nihilo of matter easier to conceive than the creation ex nihilo of spirit, which would undermine Locke's stated point in introducing it in the first place. (I owe this point to Don Baxter.) Several interpretive possibilities seem open here. One is that Locke simply saw the *De Grav* hypothesis as bound up with dualism. A second is that he thought that the model of God's continuously producing the powers, if applied to minds, would take away "Freedom, Power, Choice" (4.10.17) and so could not be right for rational minds. A third is that he had in mind Coste's version of the hypothesis, which leaves out the ability to interact with minds, and that he believed (perhaps mistakenly) the story about mobile impenetrability to be easier to understand than the production of the power of thought in empty space. A fourth is to stress the phrase "would be found" in 4.10.18, and to suggest that Locke was not committing himself as to whether the creation of spirit would actually be less intelligible on this hypothesis. (I do not wish to take a position here on the difficult question what Newton wants to say in *De Grav* about dualism vs. monism. Gorham (2011, pp. 25–27) contains some pointed criticisms of monist interpretations of *De Grav*).

[50] This paper has benefitted greatly from comments from the editors, Zvi Biener and Eric Schliesser, as well as from audiences at the University of South Carolina, University of Pittsburgh, University of Colorado, University of Guelph, McGill University, and University of Connecticut. Thanks to Don Baxter, Ben Caplan, Geoffrey Gorham, Abe Roth, Lionel Shapiro, and William Taschek for helpful conversation/comments (and apologies for any I've forgotten).

Gorham, G. (2011). "How Newton Solved the Mind-Body Problem." *History of Philosophy Quarterly* 28 (1): 21–44.

Hill, B. (2003). "Newton's *De gravitatione et aequipondio fluidorum* and Lockean Four-Dimensionalism." *British Journal for the History of Philosophy* 11 (2): 309–321.

Janiak, A. (2008). *Newton as Philosopher*. Cambridge, UK: Cambridge University Press.

——. (2009). "Newton's Philosophy." In E. N. Zalta, ed. The Stanford Encyclopedia of Philosophy. http://plato.stanford.edu/archives/win2009/entries/newton-philosophy/

Koyré, A. (1965). *Newtonian Studies*. Cambridge, MA: Harvard University Press.

Lee, S. (2004). "Leibniz on Divine Concurrence." *Philosophical Review* 113 (2): 203–248.

Leibniz, G. W. (1985). *Theodicy: Essays on the Goodness of God, the Freedom of Man, and the Origin of Evil*. Edited by A. Farrar. Translated by E. M. Huggard. La Salle, IL: Open Court.

——. (1996). *New Essays on the Human Understanding*. Edited by J. Remnant and J. Bennett. Cambridge, UK: Cambridge University Press.

Locke, J. (1688). "Review of *Philosophiae Naturalis Principia Mathematica*." In J. le Clerq, ed. Bibliotheque Universelle & Historique. Vol. 8, pp. 436–451. Reprinted by Slatkine Reprints, 1968.

——. (1729). *Essai philosophique concernant l'entendement humain*. Translated by P. Coste. 2nd ed. Amsterdam: Pierre Mortier.

——. (1823). *The Works of John Locke*. 10 vols. London: Thomas Davison, Whitefriars.

——. (1975). *An Essay Concerning Human Understanding*. Edited by P. H. Nidditch. Oxford: Oxford University Press.

——. (1989). *Some Thoughts Concerning Education*. Edited by J. W. Yolton and J. S. Yolton. Oxford: Oxford University Press.

——. (1990). *Drafts for the Essay Concerning Human Understanding and Other Philosophical Writings*. Edited by P. H. Nidditch and G. A. J. Rogers. Oxford: Oxford University Press.

McCann, E. (1994). "Locke's Philosophy of Body." In V. Chappell, ed. The Cambridge Companion to Locke. Cambridge, UK: Cambridge University Press, 56–88.

——. (2001). "Locke's Theory of Substance Under Attack!" *Philosophical Studies* 106 (1–2): 87–105.

Newton, I. (1962). *Unpublished Scientific Papers of Isaac Newton*. Edited by A. R. Hall and M. B. Hall. Cambridge, UK: Cambridge University Press.

——. (2004). *Philosophical Writings*. Edited by A. Janiak. Cambridge, UK: Cambridge University Press.

Schliesser, E. (2012). "Newtonian Emanation, Spinozism, Measurement and the Baconian Origins of the Laws of Nature." *Foundations of Science* 18.3 (April): 449–466. Published online. doi: 10.1007/s10699–011–9279–y

Stein, H. (1970). "On the Notion of a Field in Newton, Maxwell and Beyond." In R. H. Stuewer, ed. *Historical and Philosophical Perspectives of Science*. Minneapolis: University of Minnesota Press, 264–287.

——. (1990). "On Locke, 'the Great Huygenius, and the Incomparable Mr. Newton.'" In P. Bricker and R. I. G. Hughes, eds. *Philosophical Perspectives on Newtonian Science*. Cambridge, MA: MIT Press, 17–47.

——. (2002). "Newton's Metaphysics." In I. B. Cohen and G. E. Smith, eds. *Cambridge Companion to Newton*. Cambridge, UK: Cambridge University Press, 256–307.

Stuart, M. (1998). "Locke on Superaddition and Mechanism." *British Journal for the History of Philosophy* 6 (3): 351–379.

Tamny, M. (1979). "Newton, Creation, and Perception." *Isis* 70: 48–58.

Winkler, K. P. (2008). "Locke's Defense of Mathematical Physics." In P. Hoffman, D. Owen, and G. Yaffe, eds. Contemporary Perspectives on Early Modern Philosophy: Essays in Honor of Vere Chappell. Peterborough, Ontario: Broadview Press, 231–252.

Wilson, M. (1979). "Superadded Properties: The Limits of Mechanism in Locke." *American Philosophical Quarterly* 16: 143–150.

Woolhouse, R. S. (1982). "Reid and Stewart on Lockean Creation." *Journal of the History of Philosophy* 20:84–90.