Qualities, Properties, and Laws in Newton's Induction

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Newton's argument for universal gravitation in the *Principia* eventually rested on the third "Rule of Philosophizing," which warrants the generalization of "qualities of bodies." An analysis of the rule and the history of its development indicate that the term 'quality' should be taken to include both inherent properties of bodies and relations among systems of bodies, generalized into 'laws'. By incorporating law-induction into the rule, Newton could legitimately rebuff objections to his theory by claiming that universal *gravitation* was justified by his method even if he could not specify the cause of *gravity*.

1. Introduction. Essentially, Newton's *Principia* is a set of inductive arguments ultimately meant to establish that "impenetrability, mobility, and impetus of bodies, and the laws of motion and the law of gravity" are features of every system of bodies in the universe (Newton 1999, 943). Each of these features is generalized according to the rules of "experimental philosophy," in which "propositions are deduced from the phenomena and are made general by induction" (943). That is, if the same particular proposition obtains for all observed phenomena, one can conclude that it is true of all phenomena whatsoever. This inductive method is of the utmost importance to Newton's overall project, of course, since it yields the law of universal gravitation—his most significant result. However, Newton leaves open the question of what kinds of propositions are subject to generalization. If a particular proposition is "deduced" from

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phenomena, to which features of the phenomena can the "deduction" refer?[1]

Newton's third "Rule of Philosophizing," first published in the second edition of the *Principia* (1713), warrants the generalization of "qualities" of bodies. Most authors have assumed that "qualities" are identical to "properties" and have therefore puzzled over Newton's justification for the law of gravitation, which does not seem to follow the rule (e.g., McGuire [1968] 1995; McMullin 1978; Shapiro 2004). Based on a philosophical and historical examination of the rule, this paper argues that Newton's *Principia*, in its mature form, warranted inductive generalizations of two kinds of "quality." Originally, Newton appealed only to the induction of inherent properties of bodies. Facing unsympathetic interpretations and criticism of this position, he expanded his inductive method to include a second kind of "quality": relations between bodies generalized into "laws." This form of induction warrants conclusions about relations found in systems of bodies, not about the properties of bodies themselves. Therefore, since universal gravitation follows from law-induction, only the *gravitation* found in systems of bodies is generalized, not the *gravity* proper to each body. While this move allowed Newton to respond to his critics, it introduced a measure of metaphysical ambiguity regarding the nature of gravity. Newton insisted that gravity was "real," but law-induction does not require relations to be reduced to the features of particular substances. Hence, it was unclear where gravity was to be located in reality.

2. Property-Induction and Law-Induction. The key passage in any discussion of Newton's inductive method is the third "Rule of Philosophizing,"[2] which justifies inductive generalizations by simply stipulating:

> Those qualities of bodies that cannot be intended and remitted and that belong to all bodies on which experiments can be made should be taken as qualities of all bodies universally. (Newton 1999, 795)

This rule constrains the class of phenomenal features that can be generalized. Newton warrants only inductive arguments concerning "qualities of bodies." The particular propositions to be generalized must refer to

1. Newton's "deductions" from phenomena are not straightforward. They involve problematic inferences from whole to parts and the "measure" of forces by their effects on motion (as described in the definitions preceding Book I). It is even a matter of debate how "deductions" are to be separated from "inductions." These issues are not to be resolved here. See, e.g., McMullin 1978; Stein 1990; Belkind, forthcoming.

2. Rule IV notwithstanding. Rule IV was added only in the third edition (1726) and plays a limited role in Newton's explicit argument for universal gravitation.

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the qualities found in bodies "on which experiments can be made," for it is only such qualities that can be extended on the basis of Rule III. Nevertheless, this constraint only pushes the original question back. Now it needs to be asked what counts as a "quality." Which qualities can be universalized if they are found, without intension or remission, in all bodies subject to experiment?

The elaboration of Rule III provides examples of the "qualities" subject to induction. In the first place, Newton obviously allows the induction of sensible properties of material bodies. Extension and impenetrability, for instance, are "known to us only through the senses," but since they are found in "all sensible bodies," they can be "ascribed to all bodies universally" (Newton 1999, 795).

Newton also allows inductive arguments regarding insensible properties. In these cases, both sensation and reason are involved in the "deduction" of particular propositions from phenomena. The force of inertia, for example, is known in part by experience and in part by rational inference:

> That all bodies are movable and persevere in motion or in rest by means of certain forces (which we call forces of inertia) we infer from finding these properties in the bodies that we have seen. (Newton 1999, 795)

A body's "force of inertia" is not a sensible property. One cannot directly sense its presence or action. The force manifests itself, though, by causing a body to move and resist changes to its motion or rest. This motion and resistance are sensible, so it is possible to infer the cause—the force of inertia—from its observed effects. Because this "deduction" can be drawn in all observable situations, the force of inertia can be inductively generalized.

The "qualities" discussed so far are all inherent qualities—that is, properties pertaining to individual material objects. Extension and so forth are all *proper* to a body. Their existence requires no (physical) substance other than the body that possesses them. A body alone in a void, for instance, could be extended, impenetrable, and so on (see McMullin 1978, 60). Consequently, the particular propositions describing these properties assert facts about individual bodies, and the generalized conclusions make claims about all bodies individually.

However, inherent properties do not exhaust the features of phenomena that can be generalized according to Rule III. Newton also seems to admit that *relations* can count as "qualities" subject to generalization. As written, the rule does not preclude qualities that (unlike properties) qualify more than one body at a time. All that is required is that such a distributed quality be found to hold of any experimental *system* of bodies. The qualities that "belong to all bodies on which experiments can be made" include

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qualities that belong to a system as a whole, in addition to the inherent properties of the bodies within the system. Thus, a particular proposition might refer to a feature of an entire experimental system, expressing some relation between the bodies and/or properties that constitute the system. If this relation is then found to hold without alteration in all observed systems, it can be generalized. It becomes a "law": the relation holds in all systems whatsoever, and it obtains "of all bodies universally" in the derivative sense that all bodies are subject to the law in whatever system they are found. Taken literally, Newton's rule for induction can be deployed in two ways: the "property-induction" of the inherent properties of bodies and the "law-induction" of the relations between them.

There is a marked difference between the inductive generalization of laws and that of properties. Property-induction, as we have seen, generalizes over individual bodies: if all observed bodies are found to possess some property, the property can be attributed to all bodies. Law-induction generalizes over systems of bodies: if all observed systems are found to possess some relation, the relation can be attributed to all systems.[3] Law-induction does not make any claims about anything other than whole systems of bodies. Neither the relation expressed by a particular proposition nor the general law refers to the inherent features of bodies. So, for instance, law-induction cannot say anything about a body alone in a void, though the case is unproblematic since it is not one "on which experiments can be made." One cannot infer from a universal law anything about particular bodies.

By the same token, law-induction does not require that a relation between bodies can or must be reduced to the inherent properties of individual bodies. The inductive inference applies directly to the relation itself, not to its relata. The assertion of a law does not require any discussion of the properties that bring the relation about. It is enough to derive particular propositions describing the relation by some combination of observation and reasoning (as in the case of properties) and then generalize this description. Thus, one need not speculate about causes. A law can be asserted without explaining it.

Our reading of law-induction in Rule III garners some weak support

3. Interestingly, contemporary treatments of induction deal only with the projection of monadic or invariantly polyadic predicates. However, Newton's use of law-induction involves *variably* polyadic predicates: the law of universal gravitation is the generalization of a relation that obtains between varying numbers of relata and yet somehow remains one and the same relation in all cases. At present, there is (as far as I am aware) no straightforward philosophical characterization of variably polyadic predicates, but Newton's case seems to demonstrate that the induction of such predicates is an important kind of scientific inference.

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from the General Scholium of the *Principia*, also added to the second edition, which enumerates what the book has established by induction:

> In this [experimental] philosophy, propositions are deduced from phenomena and are rendered general by induction. Thus [by this method] the impenetrability, the mobility, and the impetus of bodies, and the laws of motion and the law of gravity have been found. [*In hac Philosophia Propositiones deducuntur ex Phaenomenis, & redduntur generales per Inductionem. Sic impenetrabilitas, mobilitas, & impetus corporum & leges motuum & gravitatis innotuerunt*.] (Newton 1713, 484; 1999, 943)

Notice the third "and" (&) in the second sentence, suggesting that there are two separate lists of conclusions, one corresponding to properties ("the impenetrability, the mobility, and the impetus of bodies") and the other comprising the "laws" of motion and gravity.[4] In other words, Newton takes his arguments to have shown that all bodies have certain properties, on the one hand, and are subject to certain laws, on the other. Nevertheless, laws are "rendered general by induction." They count as "qualities of bodies" as described in Rule III.

Niceties of syntax aside, the notion that inducible qualities include both properties and laws is further supported by the history of the third rule itself. In the first edition of the *Principia* (1687), the warrant for inductive inference, given in "Hypothesis III," is the fact that any one kind of material thing can be converted into any other kind of material thing:

> Every body can be transformed into body of any other kind, and can assume successively all intermediate degrees of quality. (Newton 1687, 402; Koyré 1965, 263)

This implies that all bodies are ultimately composed of a single basic "stuff"—a primary matter. Bodies can be transformed by reduction to and regeneration from the underlying "stuff" (or other intermediate states). From this, one can infer that a quality found in all observed bodies must be a quality of the primary matter and, thus, a quality of all bodies whatsoever. This argument, however, is applicable only to the *inherent* qualities of bodies. So, while Hypothesis III supports the induction of properties, it does not warrant the induction of relations, unless relations can somehow be reduced to properties. The fact that Newton felt compelled to abandon Hypothesis III in favor of Rule III shows that Rule III is meant to apply to more than properties, since properties could

4. Koyré (1965, 157–158) and Shapiro (2004) also note the heterogeneity of this list.

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already be induced by Hypothesis III (see McGuire [1967] 1995, especially 279–280; McMullin 1978, 5–9). I shall return to this below.

Newton's drafts of the new rule, prepared during the early 1690s, make this intended distinction between property-induction and law-induction patent. In the first version of Rule III, Newton explicitly mentions "laws" and "properties":

> The laws ⟨and properties⟩ of all bodies on which it is possible to institute experiments, are laws ⟨and properties⟩ of all bodies whatsoever. (Cohen 1971, 25; see also McGuire [1970] 1995, 89; [1968] 1995, 241)

In fact, the angle brackets here indicate additions to the text, so Newton first wrote "the laws of all bodies" and only thereafter interpolated "and properties." In later drafts, Newton often crossed out "properties" in favor of "qualities." Thus, the "qualities" in the final Rule III were originally "laws and properties," and the fact that Newton avoided the term "properties" thereafter suggests he continued to suppose that "qualities" were distinct from properties and included relations (generalized into "laws") as well. In sum, Rule III's application of induction to relations is a deliberate extension of the inductive method between the first two editions of the *Principia* specifically intended to defend the inductions of relations into laws.[5]

3. Gravity and Gravitation. Of course, the most important result of Newton's inductive method was the law of universal gravitation, and his arguments for this principle fit the model of law-induction I have proposed. For instance, the elaboration of the third rule provides a synopsis of the argument that follows in Book III. Newton provides five particular cases in which gravity is found in order to support the claim that gravity is found in all cases. Each case, however, is a system of observed bodies. Gravitation can be "deduced" from observations of "bodies on or near the earth" in relation to the earth itself, the moon in relation to the earth, the sea in relation to the moon, the planets in relation to each other, and comets in relation to the sun (Newton 1999, 796). These "deductions" are carried out in Book III, where Newton shows that the geometrical and mathematical proportions distinctive of an inverse-square centripetal force, demonstrated in Book I, are exhibited by each of the phenomena (see Stein 1990; Harper 2004; Smith 2004). By inductive generalization

5. McGuire ([1970] 1995, [1968] 1995) assumes that "qualities" do not include "laws" and wonders why laws were left out of the rule used to justify them. My view is that the rule does not establish the "essential qualities of matter," but merely what can be established by induction. See also Okruhlik 1989; Harper 1993, 167.

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according to Rule III, one reaches the conclusion that the proportions obtain in all cases. That is, all bodies "gravitate toward one another" in proportion to quantity of matter and the inverse-square of the distance.

Nowhere in the course of this argument does Newton assert that a property or power of "gravity" is found in individual bodies. Neither the particular propositions nor the general conclusion describes bodies in isolation. Indeed, Newton explicitly denies that the *Principia* makes any claim about "gravity" as a universal property in an emendation of Rule III's elaboration that appeared in the third edition (1726):

> Yet I am by no means affirming that gravity is essential to bodies. By inherent force I mean only the force of inertia. This is immutable. Gravity is diminished as bodies recede from the earth. (Newton 1999, 796)

The only force found in individual bodies without intension and remission is the force of inertia. A body's proper gravity or "heaviness" remits in proportion to the square of the distance. Hence, it fails as a candidate for inductive generalization, and nothing can be concluded about its presence in unobserved bodies. The only "gravity" that can be generalized is the "law" of universal gravitation itself: the invariant proportion between attractive force, mass, and distance. The law is general, not the property.[6]

This emphasis on the proportionate relation is also seen in Newton's comments outside the *Principia*. When discussing universal gravitation, Newton nearly always refers to the "proportion," "ratio," or "law" that describes the relation in a system of bodies. This is visible, for example, in his correspondence with Leibniz (1693):

> [A]ll phenomena of the heavens and of the sea follow precisely, so far as I am aware, from nothing but gravity acting in accordance with the laws described by me. (Newton 2004, 108–109)

A similar locution appears in Newton's letter to the editor of the *Memoirs of Literature* (1712 or 1713[7]):

> It has been proved by some that all bodies upon the surface of the earth gravitate toward the earth in proportion to the quantity of matter in each of them; that the moon tends toward the earth and all the planets toward one another by the same law; and that by this tendency all their motions are performed. (Newton 2004, 115)

Newton asserts that all phenomena exhibit gravitation as described by

6. Note that, contra McMullin 1978, 12–13, the intension/remission criterion is crucial in Newton's argument since it rules out gravity as an inherent property.

7. For the dating of this letter, see Shapiro 2004, 201.

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his law. Only this "proportion" or "law," which describes the relation between bodies by which "all their motions are performed," is universal. Again, the inductive conclusion applies only to the relation itself—a quality of systems—not to any properties of bodies.[8]

4. Ontological Ambiguity. It was noted above that law-induction does not require speculation regarding the causes of a universal relation. In particular, one need not locate the explanation of a relation among its relata. This is also true of gravity, and Newton famously refused to "feign hypotheses" about its cause, preferring to leave the law of universal gravitation unreduced and unexplained. Nevertheless, Newton also insisted that gravity was "real." This is clearest in the General Scholium:

> And it is enough that gravity really exists and acts according to the laws we have set forth and is sufficient to explain all the motions of the heavenly bodies and of our sea. (Newton 1999, 943)

Once again, Newton links gravity to its description by laws, but he also asserts the real existence of the object of the description. Thus, if we take "laws" to describe relations, he is asserting that there is a real relational entity present in every system of bodies. This insistence on the reality of gravitation is problematic, however, since it calls into question the ontological significance of the relation described by the law, a difficulty Newton and his readers were quick to notice.

On the standard metaphysics of Newton's day, reality was taken to consist of substances and their attributes.[9] Attributes depended on substances and could not exist without them. Inherent properties, like those found in the *Principia*, were easily accommodated by this view, since they correspond to the attributes of the bodily substances in which they inhere. Relations between substances, on the other hand, have a "weak" existence, since they must be further grounded on attributes inhering in substances. On this account, the "real" existence of the gravitational relationship described by Newton's law must be explained in terms of inherent properties of bodies. Moreover, Hypothesis III of the first edition was consistent with this standard picture since it refers only to the inherent properties of a primordial matter. Altogether, the readers of the first edition naturally expected some kind of reduction of gravitation to the inherent properties or powers of corporeal substances (see Stein 2002).

Newton realized that this expectation led to unsavory consequences.

8. See also a draft revision of Query 31 of the *Opticks* (c. 1716) in McMullin 1978, 61.

9. With or without a surrounding void—atomism and Aristotelianism, respectively. See Stein 2002.

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On the one hand, readers might assume that gravitational attraction is caused by a property of the attracting and/or attracted bodies themselves. Yet this would require one body to affect the behavior of a spatially separated body without the action of an intervening medium, and Newton found such action at a distance unintelligible. Reducing gravitational attraction to an inherent property of gravitating bodies leads to an "absurdity" Newton was unwilling to countenance (2004, 102). The alternative was to reduce gravitation to the inherent properties of bodies other than those attracted. For instance, gravitational attraction might be reduced to the mechanical properties (motion, inertia, impenetrability, etc.) of a fluid, ethereal medium. However, Newton offers no such explanation in the *Principia*. In fact, Book II demonstrates the striking lack of experimental evidence for any such gravitational ether.[10] As a result, those readers who ruled out action at a distance saw his project as incomplete, since Newton failed to elucidate the causes of gravity. A review in the *Journal des Sçavans* (1688), for instance, regarded the *Principia* as a work of "mechanics," but not physics, since universal gravitation is left as an "arbitrary supposition," "not having been proven."[11] Leibniz and Huygens also objected that Newton's project failed to explain gravitation in terms of properties, and they continued to seek explanations based on mechanical properties (see, e.g., Huygens 1888–1950, 21:466–488; Leibniz 1989, 310; see also Koyré 1965, 115–138; Hall 1980, Chapter 8; Snelders 1989).

Newton did not wish to admit that his explanatory project was incomplete. In particular, he thought that his laws were not arbitrary hypotheses, but proven principles properly established according to his philosophical method. Furthermore, he steadfastly maintained that gravity could be admitted as real even if it was not reduced to mechanical properties. Thus, the second edition insisted that gravity as described in the *Principia* is "sufficient to explain all the motions of the heavenly bodies and of our sea" (1999, 943). Elsewhere, Newton wrote that "Mr. Leibniz himself cannot deny" that the gravitation of all terrestrial and celestial bodies had been "proved," and he vehemently argued that one need not provide a mechanical cause in order to include gravity among the "real" qualities of bodies (2004, 115).

The inductive method warranted by Hypothesis III, as well as the pre-

10. Newton was sympathetic to the idea of a gravitational ether. For example, in Query 21 of the *Opticks* (1721, 325–327; 1979, 350–352), he describes the properties an ether must have in order to bring about gravitation. The ether is posed as a supposition, however, and Newton was never prepared to assert its existence as a reality.

11. "Mais come cette supposition est arbitraire, n'ayant pas esté prouvée, la demonstration qui en dépend ne peut estre que mecanique" (*Journal des Sçavans* 1688, 154).

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vailing metaphysics, required the reduction of the relation expressed by the law of gravity to inherent properties of bodies. Yet, while he wanted to assert the reality of gravity, he did not wish to definitively locate it either in the attracted bodies themselves, entailing an action at a distance, or in other bodies, for which he had no evidence (see Janiak 2007). The introduction of law-induction in Rule III offered a way out of this quandary by allowing the induction of relations that may or may not be reduced to inherent properties. By Rule III, Newton could generalize relations without asserting anything about the relata. Hence, he could legitimately argue that his explanatory project was complete and well grounded, since the law of universal gravity, as an unanalyzed relation, could be "proved by mathematical demonstrations grounded upon experiments and the phenomena of nature" (2004, 115). *Pace* his critics, he did not have to "feign hypotheses" about the cause of gravity. The law of universal gravitation had been made general by law-induction, and this was enough. By warranting law-induction directly, Newton could successfully resist demands to reduce his law of universal gravitation to the properties of bodies, mechanical or otherwise.[12]

This escape came at a cost. To avoid the implication that gravity must be reduced to inherent properties, Newton opened the possibility that gravity cannot be reduced at all. In other words, Rule III, unlike Hypothesis III, admits the possibility that gravity is a real, unreducible relation that does not depend on corporeal substance. Otherwise, Newton must admit that gravity is reducible, and he is forced into his former position: gravity is an action at a distance or is incompletely explained. An unreduced relation, though, would be metaphysically heterodox. It is a quality independent of substance, akin to a Platonic harmony or Stoic *pneuma*. Of course, Newton need not assert that gravity actually *is* an irreducible relation, but to avoid the misapprehensions and objections of Bentley, Leibniz, and others, he must leave this as an open possibility (see also Newton 1721, 376–378; 1979, 401–402).

As his treatments of space and force show, Newton was not always averse to ontological novelties, but he was likely wary of advertising this move and would have avoided explicit appeals to unreduced relations. This could be the reason the term 'law' was dropped from Rule III in favor of 'quality'. The latter sounds more like an attribute and would not

12. This speaks against the "field" interpretation, associated mainly with Howard Stein, which takes Newton to assert that gravity is (or is caused by) a qualification of space itself (which Newton [2004, 21] holds has its "own manner of existing" as neither substance nor accident). It seems Newton would not have introduced law-induction had he intended gravity to be what amounts to an inherent property of space. See Dingle 1967; Stein 1990, 2002; McMullin 2002; Harper 2004, 188.

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have immediately raised ontological questions. Also, in the elaboration of Rule III, the paragraph describing the law-induction of universal gravitation follows a much lengthier description of the inherent properties of all bodies, as if the juxtaposition is meant to allow the metaphysically suspicious induction of "laws" to pass beneath the cloak of the more conventional induction of properties.[13]

5. Conclusion. The third Rule of Philosophizing warrants two types of inductive generalizations: property-induction and law-induction. The former applies to the inherent properties of bodies, such as impenetrability, the mobility, and the impetus of bodies. The latter allows Newton to generalize the "laws of motion and the law of gravity," but does not support or require any further explanation of gravity. The law applies only to the behavior of systems of bodies in their entirety. Newton's assertions about universal gravity cannot be taken to imply anything about the nature of corporeal substance. This position enables Newton to rebuff objections that his physics requires action at a distance or fails to provide adequate proofs. Nevertheless, this argumentative coherence comes at the expense of a metaphysical ambiguity. Newton insists that gravity is "real," but law-induction does not allow him to locate gravity in any particular aspect of reality. Specifically, law-induction raises the possibility that gravity is a substance-independent relation. In the end, Newton faced three unattractive possibilities. Gravity either was reducible to properties of attracted bodies, was reducible to properties of a medium, or was an unreducible relation. To Newton, the first solution was unintelligible, the second empirically unsupported, and the third metaphysically suspect. As a result, he simply refused to clarify the status of gravity. The onus was now on his opponents to force him onto a horn of his position, but to do so they, not Newton, had to "feign hypotheses."

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13. This line of argument corresponds closely with Janiak 2007.

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