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NATURE AND INERTIA

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NEWTON'S FIRST LAW OF MOTION, also known as the principle of inertia, says "Every body perseveres in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by forces impressed."[1] I will argue that inertia is an inherent principle and that inertia and Newton's First Law are in this way natural in the Aristotelian sense. Indeed, many difficulties concerning inertia and the First Law of Motion may be resolved by understanding them through an Aristotelian conception of nature.

However, philosophers from different traditions have argued that the principle of inertia treats a body as if it had no inherent principle of nature and were devoid of an inner source of activity. According to Kant,

> This mechanical law alone must be called the law of inertia (lex inertiae); the law that every action has an equal and opposite reaction cannot bear this name. For the latter says what matter does, but the former only what it does not do, and this is better adapted to the expression of inertia. The inertia of matter is and signifies nothing but its lifelessness, as matter in itself. . . . From the very concept of inertia as mere lifelessness there follows of itself the fact that inertia does not signify a positive effort of something to maintain its state.[2]

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[1] Isaac Newton, *The Principia. Mathematical Principles of Natural Philosophy. A New Translation*, trans. I. Bernard Cohen and Anne Whitman, assisted by Julia Budenz (Univ. of California Press: Berkeley, 1999), 416. All English quotations from Newton's *Principia* are from this work, unless otherwise indicated. This edition is prefaced by Cohen's *A Guide to Newton's Principia*.

[2] Immanuel Kant, *Metaphysical Foundations of Natural Science*, trans. with intro. by James Ellington (Indianapolis: Bobbs-Merrill Co., 1970), 105–6. According to Heidegger, "How does Aristotle's descriptive observation of nature and concept of motion relate to the modern one, which got an essential foundation in the first axiom of Newton? . . . Motions themselves are not determined according to different natures, capacities, and forces, the elements of the body, but, in reverse, the essence of force is determined by the fundamental law of motion: Every body, left to itself, moves uniformly in a straight

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According to Sir Alfred North Whitehead, the creed of science is mechanism:

> The great forces of nature, such as gravitation, were entirely determined by the configurations of masses. Thus the configurations determined their own changes, so that the circle of scientific thought was completely closed. This is the famous mechanistic theory of nature, which has reigned supreme ever since the seventeenth century. It is just the orthodox creed of physical science.[3]

Whitehead holds that Newton's First Law of Motion "is the first article of the creed of science."[4] This orthodox creed denies inherent natures and final causes:

> There persists, however, throughout the whole period the fixed scientific cosmology which presupposes the ultimate fact of an irreducible brute matter . . . senseless, valueless, purposeless. It just does what it does do, following a fixed routine imposed by external relations which do not spring from the nature of its being.[5]

The Thomistic natural philosopher James Weisheipl claims that the principle of inertia treats a body as having no nature:

> In this formulation [Newton's First Law of Motion], it would seem, two original ideas are assumed and one ancient idea is affirmed. First, a three-dimensional body (*corpus*) is conceived as a *corpus mathematicum* completely devoid of "nature" in the Aristotelian sense, or of anything that would affect the presence or absence of motion.[6]

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line. . . . Therefore, the difference between natural and against nature, i.e., forced, is also eliminated; the βία, violence, is as force only a measure of the change of motion and is no longer special in kind. . . . Therefore, the concept of nature in general changes. Nature is no longer the *inner* principle out of which the motion of the body follows; rather nature is the mode of the variety of the changing relative positions of bodies, the manner in which they are present in space and time, which themselves are domains of possible positional orders and determinations of order and have no special traits anywhere." Martin Heidegger, *What is a Thing?* trans. W.B. Barton and Vera Deutsch (Chicago: Henry Regnery Co., 1967), 85–8.

[3] Alfred North Whitehead, *Science and the Modern World* (New York: The Free Press, 1925), 50.

[4] Alfred North Whitehead, *Essays in Science and Philosophy* (New York: Philosophical Library, 1948), 171.

[5] Whitehead, *Science and the Modern World*, 17.

[6] James A. Weisheipl, O.P., "Galileo and the Principle of Inertia," in *Nature and Motion in the Middle Ages*, ed. William Carroll (Washington, D.C.: Catholic Univ. Press, 1985), 69. According to Vincent Smith, "The empiriological physicist, as such, must ignore being. His view of reality feeds on the notion of inertia, which thins a material thing into an indifferent state, depending for its reality wholly on the transeunt forces acting from outside of it. Such an inert and indifferent thing, when considered in itself, is really nothing." Vincent Edward Smith, *Philosophical Physics* (New York: Harper & Brothers, 1950), 142.

Other philosophers assert the complementary view that "the principle of inertia does not even try to explain uniform rectilinear motion, but only says it needs no explanation."[7]

Against the views of these philosophers, one begins to see that inertia is an inherent principle and is natural in the Aristotelian sense by considering why Newton's First Law of Motion is also called the principle of inertia. Newton explains what he means by inertia in Definition III of the *Principia*, a definition that implies and partly explains the First Law:

> *Inherent force of matter* [*Materiae vis insita*] *is the power of resisting by which every body, so far as it is able* [*quantum in se est*], *perseveres in its state either of resting or of moving uniformly straight forward.* This force is always proportional to the body and does not differ in any way from the inertia of the mass [inertia massae] except in the manner in which it is conceived. Because of the inertia of matter [inertiam materiae], every body is only with difficulty put out of its state either of resting or of moving. Consequently, inherent force [vis insita] may also be called by the very significant name of force of inertia [vis Inertiae]. Moreover a body exerts this force only during a change of its state, caused by another force impressed upon it, and this exercise of force is, depending on the viewpoint, both resistance and impetus: resistance insofar as the body, in order to maintain its state, strives against the impressed force, and impetus insofar as the same body, yielding only with difficulty to the force of a resisting obstacle, endeavors to change the state of that obstacle. Resistance is commonly attributed to resting bodies and impetus to moving bodies; but motion and rest, in the popular sense of the terms, are distinguished from each other only by point of view, and bodies commonly regarded as being at rest are not always truly at rest.[8]

About this definition, the Nobel Prize winning physicist S. Chandrasekhar comments: "There is hardly anything that one can usefully add to Newton's careful explanation of the concept of inertia."[9] Nevertheless, the passage is full of paradoxes and difficulties,[10] for Newton is struggling with the fact that inertia is not inert.

Before taking up what Newton means by calling inertia an inherent force, I shall first consider inertia's characteristic activities. In Definition 3 of the *Principia*, Newton maintains that the inertia of a body is an inherent source of two characteristic activities, perseverance in uniform rectilinear motion or rest and resistance to external

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[7] Glen Coughlin, *Aristotle's Physics, or Natural Hearing* (St. Augustine's Press: South Bend, IN, 2005), 276.

[8] Newton, *Principia*, Def. 3, 404–5.

[9] S. Chandrasekhar, *Newton's Principia for the Common Reader* (Oxford: Clarendon, 1995), 19.

[10] "Def. 3 is, in many ways, the most puzzling of all the definitions in the *Principia*." Cohen, *Guide to Newton's Principia*, 96.

impressed forces. Contemporary physicists also view inertia as the source of these same two activities. With respect to perseverance in uniform rectilinear motion or rest, the Nobel Prize winning physicist Richard Feynman writes, "[the] property of inertia: if a particle is moving it keeps on going in the same direction unless *forces* act upon it."[11] In their textbook, *Elements of Newtonian Mechanics*, physicists Knudsen and Hjorth say, "No external force is necessary to maintain uniform motion. The motion continues unchanged due to a property of matter we call inertia."[12] A baseball, after being thrown, continues moving not only because it is in a state of motion but also in some way because of its inertia. Of course, the baseball does not continue moving in a straight line at a constant speed but that is because various forces, such as gravity or air resistance, are acting upon it. The baseball's motion is complex and determined by multiple principles. The continuing motions of other projectiles and of orbiting bodies, such as planets, or rotating bodies, such as a child's top, are similarly explained. The inertial component of such motions, unlike the external force component, persists without any ongoing mover and without any manifest effort or labor. Although physicists do not regard inertia as a moving cause, nevertheless, three hundred years after Newton, it would be odd for them to talk about inertia as a property of matter if, as Kant maintains, it only signified what a body does not do. Rather, the point made by physicists is just the opposite. A body, once put in its state, perseveres in inertial motion of itself and not through the constant action of another.[13] In what sense a body's inertia is present in persevering in inertial motion or rest will be considered later.

A body's inertia is also an inherent source of its resistance to impressed forces. The quantitative measure of this resistance is called mass or, more properly, inertial mass. A.P. French, in his textbook *Newtonian Physics*, writes "'*Inertial mass*' is the technical phrase for that property which determines how difficult it is for a given applied force to change the state of motion of an object."[14] Hans Ohanian, a former associate editor of the *American Journal of Physics*, says

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[11] Richard P. Feynman, Robert B. Leighton, and Matthew Sands, *The Feynman Lectures on Physics*, vol. 1 (Reading: Addison-Wesley Pub. Co., 1963), chap. 2, p. 3.

[12] Jens M. Knudsen and Poul G. Hjorth, *Elements of Newtonian Mechanics*, 2nd ed. (New York: Springer-Verlag, 1996), 27.

[13] "[T]he natural tendency of a body is to continue moving in a straight line." Raymond A. Serway and Jerry S. Faughn, *College Physics*, 3rd ed. (New York: Harcourt Brace Jovanovich, 1992), 183.

[14] A.P. French, *Newtonian Mechanics* (New York: W.W. Norton & Co., 1971), 164.

"mass is an *intrinsic* property of a body, measuring the resistance (inertia) with which the body opposes changes in its motion."[15] A bowling ball has a greater inertial mass than a baseball and, other things being equal, thereby exerts a greater resistance to efforts at throwing it, changing its speed or direction, or stopping it. The same amount of force applied to the bowling ball and the baseball produces different responses—the baseball offers less resistance and accelerates more. Consequently, inertia can not signify merely what bodies do not do, and the principle of inertia does not treat bodies as lacking an inherent principle or as entirely under the control of external forces.[16]

Resistance is often associated with weight or perhaps with some other force such as friction, or with a property such as solidity. However, these are not the resistance of inertia. Bodies resist impressed forces even in the weightless environment of an orbiting space station.[17] An astronaut pushing or pulling a container would find that the container resisted such efforts, though once the container was in motion no effort would be required to keep it going. A mundane experience of inertia also helps distinguish it from weight. When we want to find out how difficult a box is to move or how much more difficult one box is to move than another, we sometimes heft the box up and down rather than just holding or lifting the box to determine its weight. In hefting the box, we are not seeking to find its weight but its resistance to our efforts to change its motion or rest and its tendency to continue moving. Our concern is not so much with the box's weight but with a different though related property, its inertia.[18] In addition, a body's inertia is the same whether it is on the Earth, the Moon, or in interstellar space whereas its weight varies with location. Indeed, the fact that a body's inertia is the same everywhere indicates that it is inherent and that the body is not entirely determined by its external relations with other bodies.

The resistance of inertia is evident in ordinary cases of accelerating, braking, or turning in cars or other vehicles. In accelerating, we

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[15] Hans C. Ohanian, *Physics*, vol. 1 (New York: W.W. Norton & Co., 1985), 122. Italics in original.

[16] Historians of science have also made this point: "Meanwhile it was apparent to everyone that matter cannot be wholly indifferent to motion since unequal amounts of effort are required to cause equal changes of velocity in unequal bodies." Richard S. Westfall, *Force in Newton's Physics* (New York: American Elsevier Pub. Co., 1971), 450.

[17] Weightless bodies on Earth also resist forces. For example, tying up a blimp requires handling by teams of workers.

[18] I. Bernard Cohen, *The Birth of a New Physics* (New York: W.W. Norton, 1985), 157.

feel pressed back into our seat. In braking, we feel pushed forward, and in turning, we feel shoved to the side. Nevertheless, no external force is pressing, pushing, or shoving us. Instead, we are experiencing our inertia. As a car accelerates forward, the backs of the passengers' seats press against the passengers to accelerate them with the car, but the passengers inherently tend to remain either at rest or moving with uniform velocity. Because they tend to continue as they are, the passengers, in virtue of their inertia, resist the impressed forces exerted by their seats and thereby press into them. Inertial resistance is especially manifest in cases of very great acceleration or deceleration, such as that experienced by passengers in a car brought to a sudden and violent halt. As the car suddenly halts, the passengers' inertial tendency is to continue moving at, for example, sixty miles per hour. The passengers resist the restraining force of their seatbelts, which must exert considerable force in order to keep the passengers from continuing at the same velocity toward an impact with the dashboard or a flight through the windshield.[19]

In the above examples, no efficient cause makes a body resist external forces. The body, in virtue of its inertia, does so from within as a spontaneous and automatic response to an impressed force. Currently, no one knows how to turn off a body's inertial resistance, all of which indicates that inertia is, contra Kant, something positive within a thing by which it tends to maintain its state.

As Newton notes in Definition 3, the exercise of inertia in response to an impressed force is both resistance and impetus, depending upon the point of view. Resistance and impetus are different considerations of the same exercise of the *vis inertiae*. A body, when acted upon, resists actions that would change its state, and in resisting endeavors to change the state of the body that acts upon it. Thus, the *vis inertiae* can be the source of an impressed force exerted upon another body. A couple of dramatic examples illustrate the impetus or endeavor of inertia. Occasionally, construction workers are injured when they try to stop a massive moving beam. They think that because a crane supports the beam's weight and because the sideways motion of the beam is slow and not sustained by a continuously acting mover that merely by holding out a hand or foot they can easily stop the beam's sideways motion. The beam, as they think of it, does not have any significant inherent capacity to act upon them. However, the beam, in virtue of its rather considerable inertia, resists the

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[19] Louis A. Bloomfield, *How Things Work: The Physics of Everyday Life* (New York: John Wiley & Sons, 1997), 106–17.

efforts of the construction workers to stop it and, by persisting in its motion, acts upon the workers and injures them. Similarly, an astronaut building a space station could conceivably be injured or killed by a weightless girder. Because of its inertia, a moving girder will resist the efforts of an astronaut to stop it. The girder, though weightless, might then pin and crush the astronaut against the space station.[20] The 1997 impact of a supply ship with the Mir space station illustrates the danger of collisions between weightless bodies whose inertia is indeed something positive by which they tend to maintain their state.

Inertia also has various practical applications, such as inertial guidance systems[21], inertial stabilizers on ocean liners, and the inertial containment of nuclear fusion reactions.[22] These practical applications, such as the use of inertial navigation by submarines to sail under the north polar ice cap, help show that inertia is something definite within bodies by which they act in uniform and characteristic ways and is not, as described by the philosophers noted above, indifferent, purely negative, null, or nothing. The views of such philosophers do not accurately reflect the physics of inertia and the First Law of Motion.

In order to show that inertia and Newton's First Law are natural in the Aristotelian sense, I now want to consider Aristotle's conception of nature. According to Aristotle, "*nature is a source or cause of being moved and of being at rest in that to which it belongs primarily*, in virtue of itself and not in virtue of a concomitant attribute."[23] An important feature of the Aristotelian definition, and the one with which I shall be most concerned, is that nature is an intrinsic principle. According to Aristotle, a thing that exists by nature "has *within itself* a principle of motion and of stationariness."[24] Commenting on Aristotle, Aquinas writes, "We say that those things whose principle of

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[20] Isaac Asimov, *Understanding Physics: Motion, Sound, and Heat* (New York: New American Library, 1966), 60.

[21] "The inertial guidance systems used aboard ships, aircraft, and missiles take advantage of the absolute character of acceleration to keep track of the motion of the reference frame. . . . From a knowledge of the acceleration (both the magnitude and direction) as a function of time and a knowledge of the initial position and velocity, a computer can automatically calculate the position and velocity of the ship at any later time." Ohanian, *Physics*, vol. 1, 110.

[22] Ohanian, *Physics*, vol. 2, interlude J, p. 10–11.

[23] Aristotle, *Physics* 2.1.192b23, trans. R.P. Hardie and R.K. Gaye in *The Basic Works of Aristotle*, ed. Richard McKeon (New York: Random House, 1941). All references herein to Aristotle are from McKeon, except where otherwise noted.

[24] Aristotle, *Physics* 2.1.192b14–5.

motion is in themselves are moved by nature."[25] In addition, Aristotle's definition regards a body as acting from itself in a uniform way.[26] Further, what acts naturally does so without effort.[27] Finally, and very famously, according to Aristotle, nature acts for an end.[28] This paper will not directly address issues related to final causality, a topic which would require more lengthy treatment.

In Aristotle's definition, nature is proper to a specific kind of thing. For example, an element, such as carbon, has characteristics that are necessary and peculiar to carbon and do not belong to the other elements. Inertia, however, is not proper to bodies of only one specific nature, for bodies of many different natures have inertia. Nevertheless, as Vincent Smith notes,

> We often use the terms **nature** and **natural** for any essential intrinsic characteristic even though that characteristic is not primary. Thus we say that man walks by nature or naturally even though he does so because of the genus to which he belongs and not because of what he has primarily. To know what is essential to a thing but not proper to it is to know its nature in only an imperfect way.[29]

Similarly, I will argue that inertia is a generic natural principle, not a nature; and, I will grant that considering a body only with respect to its inertia is a very incomplete consideration, especially since inertia is nature considered at a very minimal—perhaps its most minimal—formed level.

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[25] St. Thomas Aquinas, *Commentary on Aristotle's Physics*, trans. Richard J. Blackwell, Richard J. Spath, and W. Edmund Thirlkel (New Haven: Yale University Press, 1963), bk. 8, §1023. All English quotations from Aquinas' *In Octo Libros Physicorum Aristotelis Expositio* are from this translation.

[26] "For since nature always operates in the same way, it is natural for the other cases to be the same." Aquinas, *On Aristotle's Physics*, bk. 8, §1103.

[27] "For whatever is moved with labor is being moved against the natural motion of its body—for which reason it is laborious for an animal to move upwards. Now in the case of things moved against their nature, if such a motion is to continue, it must be maintained by some violent mover imposing on them a motion of coercion—for natural necessity leads only to what is according to nature. Everything such, i.e., which is subject to a motion contrary to its nature, must be in more and more labor . . . as it is more alien to its best disposition, i.e., that which is according to its nature." Aquinas, *Exposition of Aristotle's Treatise On the Heavens*, trans. R.F. Larcher and Pierre H. Conway (Columbus: College of St. Mary of the Springs, 1963) bk. 2, §294. All English quotations from Aquinas' *In Aristotelis Libros De Caelo et Mundo Expositio* are from this translation.

[28] "Nature belongs to the class of causes that act for the sake of something." Aristotle, *Physics* 2.8.198b10.

[29] Vincent Edward Smith, *The General Science of Nature* (Milwaukee: Bruce Pub. Co., 1958), 132.

Even though inertia is a principle of nature considered at a very minimal level, to show that inertia is natural is significant because the genus that inertia properly characterizes is very wide and because inertia and the First Law are fundamental to Newtonian and relativistic physics.[30] Aristotelian science, by contrast, did not know of such a broad commonality, a property possessed by celestial and terrestrial bodies, by all the elements, and by animate and inanimate things. Fire and earth, for example, possessed levity and gravity respectively. Because inertia is common to so many different kinds of bodies, the proper principles of many different natures can be neglected for various purposes and nature can be analyzed at a minimal level. That a given inertial body is a pumpkin is irrelevant for some purposes, and this is not only a consequence of the mathematization of nature. Inertia is undoubtedly a thin treatment of nature, but that is not the same as treating a body as if it had no nature nor need it exclude a fuller treatment of a body's nature. Failure to recognize this point may mislead a thinker into maintaining that the principle of inertia denies inherent principles of nature.

Another distinction is also necessary. Kant and other thinkers are in one sense quite correct. The principle of inertia is opposed to many of Aristotle's specific conceptions of the natures of things. Aristotle held that the sublunar elemental bodies, earth, water, air, and fire, have natural motions following from inherent tendencies to natural places which are absolutely situated in the universe.[31] Unless restrained, the elemental bodies do not remain at rest outside their

[30] The question of what kinds of bodies do or do not have inertia will not be addressed here. Some bodies, such as light, do not have rest mass, and, therefore, might be said not to have inertia. The nature and status of massless entities is, however, not exactly settled physics. Born, for example, argued that even though photons do not have rest mass, they do have inertia inasmuch as photons have energy and momentum. See Max Born, *Atomic Physics*, 8th rev. ed., trans. John Dougall, rev. R.J. Blin-Stoyle and J.M. Radcliffe (New York: Dover Pub., 1989), 57–9, 375.

[31] "So, too, with heavy and light: light is generated from heavy, e.g. air from water (for water is the first thing that is potentially light), and air is actually light, and will at once realize its proper activity as such unless something prevents it. The activity of lightness consists in the light thing being in a certain situation, namely high up. . . . How can we account for the motion of light things and heavy things to their proper situations? The reason for it is that they have a natural tendency respectively towards a certain position: and this constitutes the essence of lightness and heaviness, the former being determined by an upward, the later by a downward, tendency. . . . For it may be that through some hindrance it does not occupy an upper position, whereas, if what hinders it is removed, it realizes its activity and continues to rise higher." Aristotle, *Physics* 8.4.255b8–21. See also Aristotle, *On the Heavens* 1.8.276a18–277b25.

natural places but immediately move toward them. Once brought to rest in the places proper to their natures, the elemental bodies remain at rest in virtue of an inherent natural principle. For example, an earthy body is inherently heavy and falls toward the center of the universe where it is naturally at rest. Air is inherently light and naturally rises away from the center of the universe and toward a region above earth and water but below the region proper to fire. Contrarily, the principle of inertia implies that bodies do not have inherent tendencies by which they spontaneously move toward natural places. Inertia has no preferred direction or inherent orientation to a place. According to the principle of inertia, unless acted upon by external forces, a body at rest tends to remain at rest wherever it is, and a body in motion tends to continue moving at a constant speed in the same direction. In this sense, Newton's First Law of Motion is indifferent to place and is a universal law.

However, a general definition of nature should be distinguished from more specific conceptions of nature. The incompatibility of Newton's First Law with many of Aristotle's views about the nature of gravity, levity, and the elementary bodies need not imply that the First Law is also incompatible with Aristotle's general definition of nature. Heidegger and others go too far in thinking that a denial of natural motions following from inherent tendencies to natural places is a denial of an inner principle of nature simply and in general. One can reject Aristotle's specific views concerning the natural motions of the elemental bodies without rejecting his general conception of nature just as one can reject Aristotle's view that the purpose of leaves on a tree is to provide shade to the fruit and nevertheless insist that photosynthesis is natural and teleological.[32]

Similarly, the principle of inertia should be distinguished from the mechanistic philosophical lens through which it is commonly viewed and within which it was formulated. Whitehead and others go astray in failing to observe this distinction and in too readily reading mechanism into the principle of inertia. They have, in general, mistaken a certain philosophy of inertia, the lens through which inertia is typically conceived, for inertia itself. It is more appropriate to speak of inertia in the plural, of principles of inertia, in the way that John Paul II famously spoke of theories of evolution, the different theories

[32] "By gradual advance in this direction we come to see clearly that in plants too that is produced which is conducive to the end—leaves, e.g. grow to provide shade for the fruit." Aristotle, *Physics* 2.8.199a25.

being differentiated by the different natural philosophies upon which they draw.[33]

Newton's philosophy of inertia is partially expressed through his problematic conception of inertia as an inherent force. In Definition 3 of the *Principia*, Newton very strikingly and paradoxically describes inertia as *vis inertiae*, the force of inertia, and identifies this force with *materiae vis insita*, translated here as "inherent force of matter." The Latin *insita*, used here as a past participle modifying *vis*, is taken from *insero, inserere, insevi, insitus* and means implanted, innate, or inborn. About Newton's use of this word, the Newton scholar I. Bernard Cohen writes,

> Throughout this Introduction, and in other writings, I have translated Newton's 'vis insita' by 'inherent force' and 'vis insita materiae' by 'inherent force of matter' or 'force inherent in matter.' But the literature abounds with a different rendering, 'innate force.' We may learn what Newton's intention was by examining the intermediate usage in *De Motu corporum*, prior to *LL*, *M*, or the printed editions. 'Vis insita' or 'vis insita materiae' is a difficult concept to render into English. The root meaning of 'insita' is 'implanted' or 'inserted'; it would usually be rendered by 'ingrafted.' But Newton was not referring specifically to an act of putting this 'power' into matter; rather he was using the derived meaning of 'naturally inborn' and hence 'innate' or even 'natural,' as commonly used even in classical Latin. Thus Newton's 'vis insita' is necessarily present in a body from time past to time future, infinitely, and so is almost an 'immanent force.'[34]

In Book 3 of the *Principia*, when Newton contrasts gravity and inertia, he reiterates his view that by the term "*vis insita*" he means inertia: "Yet I am by no means affirming that gravity is essential to bodies. By inherent force [*vis insita*] I mean only the force of inertia [*vis inertiae*]. This is immutable."[35] Inertia, according to Newton, is some kind of inherent, unchanging, natural force that is essential to matter. It does not depend upon external forces or the changing relative positions of bodies.

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[33] John Paul II also distinguished different theories of evolution by the different mechanisms of evolution that they posit. EWTN Document Library, John Paul II, "Message to the Pontifical Academy of Sciences: On Evolution," available at http://www.ewtn.com/library/PAPALDOC/JP961022.HTM.

[34] I. Bernard Cohen, *Introduction to Newton's 'Principia'* (Cambridge: Harvard Univ. Press, 1971), 66–7.

[35] Newton, *Principia*, Bk. 3, Rule 3, 796.

Newton's Definition 3 also contains the unusual phrase *quantum in se est*, here translated as "so far as it is able."[36] According to Cohen, by "*quantum in se est*" Newton means "to the degree that it can of and by itself."[37] Cohen argues that Newton took the phrase from Descartes, who had taken it directly from Lucretius' *De Rerum Natura*.[38] Newton's plan to include 90 lines from *De Rerum Natura* in the second edition (1713) of the *Principia* also contained references to the phrase *quantum in se est*.[39] According to Cohen, in using the phrase, Newton is saying that the capacity of a body to persevere in its state is both quantitatively limited and due to its own nature or natural power.[40] Thus, for Newton, uniform rectilinear motion and rest are natural.

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[36] Motte, in his translation of the *Principia*, renders the phrase "as much as in it lies." Cajori's revision of Motte's translation retains this rendering. See Sir Isaac Newton, *Sir Isaac Newton's 'Mathematical Principles of Natural Philosophy' and his 'System of the World,'* trans. Andrew Motte, rev. Florian Cajori (Berkeley: Univ. of California Press, 1962), Def. 3, p. 2.

[37] Newton, *Principia*, 404, note a.

[38] I. Bernard Cohen, "'Quantum In Se Est': Newton's Concept of Inertia in Relation to Descartes and Lucretius," *Notes and Records of the Royal Society of London* 19 (1964): 131–54. Henceforth, Cohen, "'Quantum In Se Est'" *Roy. Soc.* I. Bernard Cohen, "'Quantum In Se Est': Newton, Kepler, Descartes, and Lucretius," *Proceedings of The American Catholic Philosophical Association* (1964): 36–46. Henceforth, Cohen, "'Quantum In Se Est'" *ACPQ*. Other scholars have followed Cohen in recognizing the phrase as linking Lucretius, Descartes, and Newton. See J.E. McGuire, "Natural Motion and Its Causes: Newton on the 'Vis Insita' of Bodies," in *Self-Motion from Aristotle to Newton*, eds. Mary Louise Gill and James G. Lennox (Princeton: Princeton Univ. Press, 1994), 308; Alan Gabbey, "Force and Inertia in the Seventeenth Century: Descartes and Newton," in *Descartes: Philosophy, Mathematics and Physics*, ed. Stephen Gaukroger (Totowa, N.J.: Barnes and Noble, 1980), 248 and 315, n. 175. At least one historian of science argues that Newton may have taken the phrase directly from Lucretius or his commentators. See William L. Hine, "Inertia and Scientific Law in Sixteenth Century Commentaries on Lucretius," *Renaissance Quarterly* 48 (1995): 728–41.

[39] Cohen, "'Quantum In Se Est'" *ACPQ*, 46; Cohen, "'Quantum In Se Est'" *Roy. Soc.*, 148–9. Newton read and studied *De Rerum Natura* in the early 1690's. Also, about the same time as the publication of the first edition (1687) of the *Principia*, Newton wrote an unpublished draft in which he traced the origins of the principle of inertia back to the ancient philosophers. According to Cohen, "A major portion of this document deals with Lucretius, presented as one of those who knew the Law of Inertia." Cohen, "'Quantum In Se Est'" *Roy. Soc.*, 139, 141, 148–9.

[40] "Translators and commentators, unable to give equal emphasis to both meanings at once, have chosen to stick close to Newton's words, in the literal rendering 'as much as in it lie'. Because they have thereby stressed primarily the concept of a quantitative limitation of the inertial 'power' in bodies, their modern readers are apt to have lost the idea of 'naturally' or 'by its own force' which Newton and Descartes and the seventeenth-century students of Lucretius knew to be another essential part of the sense of *quantum in se est*." Cohen, "'Quantum In Se Est'" *Roy. Soc.*, 148.

However, for Newton, "nature" and "natural" have the sense, derived from Lucretius, of what a body would do if left to itself, although for Newton what comes from a body of itself is not, as it was for Lucretius, downward motion in a straight line. Instead, a body left to itself remains either at rest or in uniform rectilinear motion in whatever direction. It does not spontaneously move downward.[41] As the phrase "*quantum in se est*" indicates, the notion of "nature" survived in Newton's physics, although in a form that draws from Lucretius rather than Aristotle. Newton's use of the phrase also shows that he regarded inertia as a quantitatively limited source within a body from which certain characteristic activities proceed. He did not view the First Law as eliminating an inherent principle.

In order to cast more light on what Newton meant in calling inertia a force, I want to consider a further argument that persevering in either uniform rectilinear motion or rest, resisting an impressed force, and endeavoring to change the state of a body impressing a force are all activities that originate from within a body.

Not long after the publication of Newton's *Principia*, Leibniz considered the view that a body itself contributes nothing positive to its state of motion or rest and is entirely indifferent with respect to external forces. He did so while criticizing Descartes' views of motion. According to Leibniz,

> I admit that every object perseveres in its state until some sufficient reason for change arises. That is a principle approaching metaphysical necessity; but it is not the same thing whether we assert that something simply preserves its state until something happens to change it—a case which also arises when the subject is quite indifferent in regard to both states—or whether, on the other hand, we assert that it is not indifferent but possesses a power accompanied by an inclination to preserve its own state and thus to resist actively causes that would change it. I myself previously, in a youthful work, started from the assumption that matter was inherently indifferent to motion and rest; and then have demonstrated as a consequence of the laws of motion holding for such a system the hypothesis that a very large body at rest must be set into motion by the push of another body no matter how small that other body is without the least diminution of the latter's motion. The case of such a

[41] "Throughout the seventeenth century, therefore, *quantum in se est* was taken to mean 'naturally,' or 'by nature,' or 'without external force.' Descartes—and Newton, following Descartes—were thus merely specifying what would happen to a body left completely to itself. Lucretius was interpreted as referring to a body moving naturally, without any external forces producing a 'violent' motion. But Descartes and Newton, from the point of view of the new inertial physics, meant a body either at rest in a location where there were no external forces acting on it or in uniform rectilinear motion in the absence of external forces: in a nutshell, a body in a purely inertial state." Cohen, "'Quantum In Se Est'" *ACPQ*, 46.

> world in which matter at rest offers no resistance to being moved, might be conceived as possible, but it would be a pure chaos.[42]

Leibniz distinguishes between two different senses in which an object may persevere in a state. In one sense, an object has a power and a positive inclination to persevere in its state and as a consequence actively resists causes that would change its state. In another sense, an object lacks any power and positive inclination to persevere in its state and remains in its state only because nothing happens to change it. The object is completely passive and indifferent to its motion or rest. Leibniz argues that if bodies had no power and inclination to persevere in their states, then one body could not resist another nor could one body react to another, so that actions could occur without corresponding reactions. As Leibniz remarks elsewhere, "everything could be affected by any thing" and a quantitative science of dynamics would be impossible.[43] In a world in which the ground did not resist our efforts to push upon it and boulders did not resist our most meager pulls, motion and rest would be quite problematic. A body cannot be completely indifferent to its own condition. It must then have some positive power and inclination of persevering in its state.

Leibniz conceives of perseverance in uniform rectilinear motion or rest as following from a positive inclination arising from a power within a body. In virtue of this inclination to persevere, a body resists efforts to change its state of motion or rest. Resistance, for Leibniz, presumes a prior positive inclination to persevere. Newton, however, reverses the order of perseverance and resistance. The force of inertia is a force of resisting by which a body perseveres in its state; it is not a force of persevering by which a body resists changes to its state. Even though the word "perseverance" (*perseverare*) ordinarily connotes activity and though in Definition 4 Newton writes that "a body perseveres in any new state solely by the force of inertia," nevertheless, the *vis inertiae* operates only (*solommundo*) during a body's change of state in response to an impressed force. On Newton's account, mere perseverance in uniform rectilinear motion or rest is an inactivity and not a positive inclination originating from within a body, for a body does not exert its *vis inertiae* merely in persevering

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[42] Gottfried Wilhelm Leibniz, "On Substance as Active Force Rather Than Mere Extension," in *Leibniz: Selections*, ed. Philip P. Wiener (New York: Charles Scribner's Sons, 1951), 159–60.

[43] Gottfried Wilhelm Leibniz, "Specimen Dynamicum," in *Leibniz: Selections*, ed. Philip P. Wiener (New York: Charles Scribner's Sons, 1951), 129.

in a state. If a body were not subject to an impressed force, it would persevere in its state, but its *vis inertiae* would do nothing.

The *vis inertiae* is a very strange force. Kant regarded the expression "inertial force" as contradictory.[44] It is at least paradoxical. "Inertia," which usually means inactivity, absence of motion, or passivity, seems to have a meaning opposed to that of "force," which usually means an action by an agency producing some kind of effect. One translator of Newton's *Principia*, Florian Cajori, renders Newton's "*vis inertiae*" as "force of inactivity."[45] The historian Richard Westfall makes a similar point: "In the *Principia*, Newton himself summarised the paradox in another anomalous phrase, *vis inertiae*, which we might translate freely as 'the activity of inactivity', or perhaps 'the ertness of inertness'."[46] Similarly, an inactive motion is an odd conception, for motion is typically regarded as the paradigm case of activity.[47]

Newton uses the same word "force" in two very different ways. In one way, "force" means what Newton calls "impressed force," an action exerted on a body that tends to change its state of uniform rectilinear motion or rest, that is, to accelerate a body. It originates in a cause external to the body acted upon.[48] Newton's First, Second, and Third Laws of Motion and Universal Law of Gravitation use "force" in this sense. Contemporary physicists, in speaking of the four

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[44] "The designation force of inertia (*vis inertiae*) must, then, in spite of the famous name of its originator, be entirely dismissed from natural science. This must be done not only because this designation carries with it a contradiction in the expression itself . . ." Kant, *Metaphysical Foundations of Natural Science*, 114.

[45] *Sir Isaac Newton's 'Mathematical Principles of Natural Philosophy,'* Def. 3, p. 2.

[46] Westfall, *Force in Newton's Physics*, 450.

[47] Aristotle, *Metaphysics* 9.3.1047a30–32; Aquinas, *Commentary on the Metaphysics of Aristotle*, trans. John R. Rowan (Chicago: Henry Regnery, 1961), bk. 9, §1805. Descartes, though disagreeing with the common conception of motion, acknowledges that motion is ordinarily understood as an action. See René Descartes, *Principles of Philosophy*, trans. John Cottingham, in *The Philosophical Writings of Descartes*, vol. I (Cambridge: Cambridge University Press, 1985) bk. 2, §24–5.

[48] "*Impressed force is the action exerted on a body to change its state either of resting or of moving uniformly straight forward.* This force consists solely in the action and does not remain in a body after the action has ceased. For a body perseveres in any new state solely by the force of inertia. Moreover, there are various sources of impressed force, such as percussion, pressure, or centripetal force." Newton, *Principia*, Def. 3, 405. Contemporary physicists often make the same claim: "In Newtonian mechanics, the force acting on a body is considered to be the *cause* of the acceleration of the body." Knudsen and Hjorth, *Elements of Newtonian Mechanics*, 73. "In this chapter we will see that the cause of acceleration is force." Ohanian, *Physics*, vol. 1, 91.

fundamental forces of nature, also use the term "force" in roughly this sense. Although contemporary physicists usually refer to inertia as a property and not as a force, they do sometimes use the term "inertial force" in reference to fictitious or pseudo forces. A.P. French's explanation is worth quoting at length:

> Imagine that you are sitting in a car on a very smooth road. You are holding a heavy package. The car is moving, but you cannot see the speedometer from where you sit. All at once you get the feeling that the package, instead of being just a dead weight on your knees, has begun to push backward horizontally on you as well. Even though the package is not in contact with anything except yourself, the effect is as if a force were being applied to it and transmitted to you as you hold it still with respect to yourself and the car. If you did not restrain the package in this way, it would in fact be pushed backward. You notice that this is what happens to a mascot that has been hanging at the end of a previously vertical string attached to the roof of the car.
>
> How do you interpret these observations? If you have any previous experience of such phenomena, you will have no hesitation in saying that they are associated with an increase of velocity of the car—i.e., with a positive acceleration. . . . Nonetheless, it does feel just as if the package itself is somehow subjected to an extra force—a "force of inertia"—that comes into play whenever the effort is made to change the state of motion of an object.
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> These extra forces form an important class. They can be held responsible for such phenomena as the motion of a Foucault pendulum, the effects in a high-speed centrifuge, the so-called *g* forces on an astronaut during launching, and the preferred direction of rotation of cyclones in the northern and southern hemispheres. These forces are unique, however, in the sense that one cannot trace their origins to some other physical system, as was possible for all the forces previously considered. Gravitational, electromagnetic, and contact forces, for example, have their origins in other masses, other charges, or the "contact" of another object. But the additional forces that make their appearance when an object is being accelerated have no such physical objects as sources. Are these inertial forces real or not?[49]

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[49] French, *Newtonian Mechanics*, 493–4. "One can do this by comparing the gravitational force of the earth with the centrifugal force due to the earth's rotation, which is a purely inertial effect. . . . A similar experiment may be carried out by comparing the gravitational force due to the sun, to the inertial forces associated with our orbital motion about the sun." Richard P. Feynman, *Feynman Lectures on Gravitation*, ed. Brian Hatfield (Reading, MA: Perseus Books, 1995), 3–4. "This new type of force clearly is *not* an interaction force. It is called an *inertial force* and arises because of the acceleration of the coordinate system S′. An accelerated coordinate system is not an inertial frame. Inertial forces occur only in accelerated and rotating coordinate systems, never in inertial frames." Uno Ingard and William L. Kraushaar, *Introduction to Mechanics, Matter, and Waves* (Reading, Mass.: Addison-Wesley Pub., 1960), 295.

In the above example, a car with a passenger in it begins to accelerate with respect to the road on which it is moving. The behavior of the package on the passenger's lap is due to its inertial tendency to persevere in its state of uniform rectilinear motion, to resist accelerating with the passenger and the car, and to endeavor to change their state of motion. The action of the package even retards (slightly) the car's acceleration.

For some purposes, however, it is very useful to adopt the car as a reference frame and regard it as if it were not accelerating but were at rest or moving uniformly in a straight line (that is, an inertial frame). Viewed in such a way, the behavior of the package in pressing against the passenger may usefully be regarded as produced by an external force, as if something external to the package were pressing it into the passenger. However, no such external force exists. No cause external to the package is pushing it into the passenger. The passenger has simply regarded the reference frame of the car as if it were at rest (or in uniform rectilinear motion) instead of regarding it as accelerating with respect to the reference frame of, for example, the road.[50] The "force" experienced by the passenger is then fictitious. The package, considered as being pressed into the passenger's stomach by a fictitious force, does not react (via Newton's Third Law of Motion,

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[50] "That is, since Moe's coordinate system is accelerating with respect to Joe's, the extra term *ma* comes in, and Moe will have to correct his forces by that amount in order to get Newton's laws to work. In other words, here is an apparent, mysterious new force of unknown origin which arises, of course, because Moe has the wrong coordinate system. This is an example of a pseudo force; other examples occur in coordinate systems that are *rotating*." Feynman, *Feynman Lectures on Physics*, vol. 1, 12.11. "Fictitious forces are distinguished from 'actual' forces by the fact that the *fictitious forces depend only on the motion . . . of the frame S*, the position . . . , and the velocity . . . of the particle, and on the inertial mass of the particle. The presence of an actual force F can always be related to an interaction between the particle and another material body. For example, if an electrical force acts on the particle . . . there is an interaction with other electrically charged particles. If a gravitational force acts, there is an interaction with some body. . . . The fictitious forces cannot in any obvious way be related to an interaction with other bodies. . . . The third law, the law of action and reaction, is *not valid for fictitious forces*; for there is no other body upon which a reaction force can act." Knudsen and Hjorth, *Elements of Newtonian Mechanics*, 108.

action and reaction) upon the source of the fictitious force, for no such source exists.[51]

As spoken of by contemporary physicists, inertial or fictitious forces, though related to Newton's *vis inertiae*, do not have exactly the same meaning, though for both, a body's inertia is acknowledged as a true source of the phenomena under consideration. In any case, in speaking of fictitious forces, physicists acknowledge a whole class of phenomena that arise from a body's inertia. In the above example, the behavior of the package and the experience of the passenger are certainly real, and even deliberately imaginary explanations of them

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[51] "We now want to compare . . . what we observe when we are moving with a uniformly rotating reference frame. . . . The observer intuits that a force is acting even when there is no force. The impression is so strong that it is actually useful, and leads to the invention of the class of nonexistent, apparent, virtual, fake or adventitious forces called 'centrifugal' force and 'Coriolis force.'" Henry M. Stommel and Dennis W. Moore, *An Introduction to the Coriolis Force* (New York: Columbia Univ. Press, 1989), 12. "Since we have used . . . the term 'centrifugal force' and have now introduced the 'Coriolis force,' it is necessary to inquire as to the physical meaning of these quantities. It is important to realize that the centrifugal and Coriolis forces are not 'forces' in the usual sense of the word; they have been introduced in an artificial manner as a result of our arbitrary requirement that we be able to write an equation which resembles Newton's equation and at the same time is valid in a noninertial reference frame. . . . In spite of their artificiality, the usefulness of the concepts of centrifugal and Coriolis forces is obvious. To describe the motion of a particle relative to a body that is rotating with respect to an inertial reference frame is clearly a complicated matter. On the other hand, the problem can be made relatively easy by the simple expedient of introducing the 'noninertial forces' which then allows the use of an equation of motion that resembles Newton's equation." Jerry B. Marion, *Classical Dynamics of Particles and Systems* (New York: Academic Press, 1965), 347–8. "From the standpoint of an observer in the accelerating frame, the inertial force is actually present. If one took steps to keep an object 'at rest' in S′, by tying it down with springs, these springs would be observed to elongate or contract in such a way as to provide a counteracting force to balance the inertial force. To describe such a force as 'fictitious' is therefore somewhat misleading. One would like to have some convenient label that distinguishes inertial forces from forces that arise from true physical interactions, and the term 'pseudo-force' is often used. Even this, however, does not do justice to such forces as experienced by someone who is actually in the accelerating frame. Probably, the original, strictly technical name, 'inertial force,' which is free of any questionable overtones, remains the best description." French, *Newtonian Mechanics*, 499.

can be given, but they come forth from the inherent inertia of the package and not from an external force. It is precisely the point that a body, by virtue of its inertia, does some things of itself, for concerning these phenomena physicists employ external forces merely as useful fictions. Consequently, fictitious or inertial forces further show that the principle of inertia is a principle of nature, that the activities characteristic of inertia originate from within a body as spontaneous and automatic responses of a natural principle.

Since Newton's time, various physicists have sought to show that inertia and its characteristic activities have some external origin. Christiaan Huygens, Newton's great contemporary, developed an unsuccessful relativistic physics that sought to eliminate fictitious forces, especially centrifugal "force."[52] In the 19th Century and the early 20th Century, some physicists unsuccessfully sought to account for the inertia of bodies in terms of electromagnetism.[53] Some recent hypotheses also seek to explain the origin of inertia in terms of electromagnetic processes.[54]

Other thinkers have maintained that Einstein's Special Theory Relativity shows that inertia is not an inherent property of a body. In Special Relativity, the mass of a body increases with its velocity according to the formula:

$$m = m_0 / \sqrt{1 - v^2 / c^2}$$

where m is the relativistic mass of a body, v is its velocity relative to some frame of reference, m_0 is the rest mass of the body, and c is the speed of light.[55] The increase in mass with velocity is quite small, except when the velocity approaches that of light in a vacuum. Since the velocity of a body varies depending upon the frame of reference with respect to which it is measured, the mass of a body likewise depends upon the frame of reference with respect to which it is measured. Thus, since the mass of a body is not a constant but varies with and partly depends upon its relations to things external to it, Special

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[52] Max Jammer, *Concepts of Space*, 3rd ed. (New York: Dover Pub., 1993), 122–6.

[53] See Max Jammer, *Concepts of Mass in Classical and Modern Physics* (Mineola, NY: Dover Pub., 1997), 136–53.

[54] Bernard Haisch, Alfonso Rueda, and H.E. Puthoff, "Inertia as a zero-point-field Lorentz force," *Physical Review A* 49, no. 2 (1994): 678–94. For further references, see the articles listed at the Calphysics Institute, available at http://www.calphysics.org/index.html.

[55] "The mass that a particle has when at rest is sometimes called its rest mass." Ohanian, *Physics*, vol. 1, 186.

Relativity was viewed by some as showing that inertia is not an inherent property of a body.[56] However, the rest mass (m_0) in the equation is reasonably interpreted as referring to a constant, inherent property of the body, for it must be taken into account and has the same value from any reference frame that one might use to determine the body's relativistic mass. According to John Wheeler, "Does **rest mass** have the same value in every inertial frame? Yes. . . . Rest mass is thus an *invariant*."[57] Newton's fundamental insight that inertia is an inherent property of bodies is not overturned by Special Relativity but, considered as rest mass, is preserved and reinforced by it.

Another attempt to account for inertia and its activities is known as Mach's Principle and originated with the physicist and philosopher Ernst Mach and, to a lesser extent, the philosopher Berkeley.[58] Mach argued that inertial or fictitious forces are caused by the distant matter of the universe and that if the background of fixed stars did not exist, there would be no inertial forces. The physicist Dennis Sciama, a proponent of Mach's Principle, compares Newton's and Mach's different accounts of the origin of inertia:

> Ever since the time of Isaac Newton the classical view has been—and experiments have seemed to prove—that inertia is an intrinsic property of matter, *i.e.*, that the inertia of a body is in no way affected by its

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[56] "In the same way, the mass of a moving body was found to depend on its measured speed of motion, and this in turn depended on the measurer, or rather on the coordinate system he adopted. Thus absolute mass fell out of science." Sir James Jeans, *Growth of Physical Science* (Cambridge: Cambridge Univ. Press, 1951), 267.

[57] Edwin F. Taylor and John Archibald Wheeler, *Spacetime Physics* (San Francisco: W.H. Freeman and Co., 1966), 134. "It is very often said in textbooks that the theory of relativity has shown that mass increases with velocity according to the relation $m = m_0\gamma$, where m_0 is the rest mass. Expressed in this way it appears as a new and profound property of matter, whereas it is really a result of a particular definition of relativistic velocity. If we insist on retaining Newtonian dynamics, and the Newtonian definitions of velocity and acceleration, then we can still obtain relativistically correct results if we pay the price of allowing the mass to depend on the velocity. If however we adopt Einsteinian dynamics, the mass remains invariant." J.R. Lucas and P.E. Hodgson, *Spacetime and Electromagnetism* (Oxford: Clarendon Press, 1990), 192.

[58] C. Brans and R.H. Dicke, "Mach's Principle and a Relativistic Theory of Gravitation," *Physical Review* 124 (1961): 925. See Ernst Mach, *History and Root of the Principle of the Conservation of Energy*, trans. Philip E. B. Jourdain (Chicago: Open Court, 1911), 75–80; idem, *The Science of Mechanics*, 6th ed. with revisions through the 9th German edition, trans. Thomas J. McCormack (La Salle, Ill.: Open Court, 1989), 271–97; George Berkeley, *The Principles of Human Knowledge*, in *Berkeley's Philosophical Writings*, ed. David M. Armstong (New York: Macmillan, 1965), §111–17; and *De Motu*, trans. A.A. Luce, in *Berkeley's Philosophical Writings*, §52–71.

> environment. But a few physicists and philosophers have insisted on the opposite view: that a body has inertia only because it interacts in some way with other matter. I propose to uphold the second view here and to review the evidence, which seems to me strongly to favor the conclusion that the inertia of any body depends on the rest of the matter in the universe.[59]

Mach's Principle originated as a philosophical view that was only later developed into a theory of physics.[60] Einstein hoped that General Relativity would instantiate Mach's principle and "suggested that the inertial forces are not fictitious but are gravitational in origin."[61] General Relativity, however, fails to instantiate Mach's Principle, except in that instantiate Mach's Principle.[64] To date, these efforts have not succeeded.[65]

Physicists have also sought to account for inertia by means of quantum mechanics.[66] Recent theoretical work attempts to account for the origin of inertia in terms of the as yet undetected Higgs particle and field.[67] These speculative attempts have been unsuccessful so far, which is, of course, no reason why research into the origin of inertia should not continue.

Several conclusions may be drawn from these efforts to account for the origin of inertia. First, as the quotation from Sciama indicates, most physicists have regarded inertia as an inherent property that is a source of certain characteristic activities. Second, since Newton's

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[64] See, for example, Dennis Sciama, *The Unity of the Universe* (Garden City, NY: Doubleday Anchor, 1961), 69–160; idem, "On the Origin of Inertia," *Monthly Notices Roy Astron. Soc.* 113 (1953): 34; and Ignazio Ciufolini and John Archibald Wheeler, *Gravitation and Inertia* (Princeton: Princeton Univ. Press, 1995). Further attempts are described and cited in Peter Graneau and Neal Graneau, *Newton Versus Einstein: How Matter Interacts with Matter* (New York: Carlton Press, 1993), 59–101.

[65] "Einstein was strongly influenced by Mach's argument. However, Einstein's theory of general relativity does not satisfy Mach's principle, and many cosmologists, including Einstein himself, have tried in vain to incorporate the principle into the theory." Joseph Silk, *The Big Bang*, 3rd ed. (New York: W.H. Freeman and Co., 2001), 59. "If the philosopher is good enough, after some time he may come back and say, 'I understand. We really do not have such a thing as absolute rotation; we are really rotating *relative to the stars*, you see. And so some influence exerted by the stars on the object must cause the centrifugal force.' Now for all we know, that is true; we have no way, at the present time, of telling whether there would have been centrifugal force if there were no stars and nebulae around. We have not been able to do the experiment of removing all the nebulae and then measuring our rotation, so we simply do not know. We must admit that the philosopher may be right." Feynman, *Feynman Lectures on Physics*, vol. 1, 16.2. See also, Jammer, *Concepts of Space*, 215–37.

[66] See, for example, Corey S. Powell, "Unbearable Lightness," *Scientific American* 270 (May 1994): 30–31; and Jean-Pierre Vigier, "Derivation of Inertial Forces from the Einstein-de Broglie-Bohm (E.d.B.B.) Causal Stochastic Interpretation of Quantum Mechanics," *Foundations of Physics* 25 (1995): 1461–1494. Some physicists have sought to combine both approaches and establish Mach's principle as a theorem of a quantum mechanical theory of gravity. See, for example, K.P. Tod, "Mach's Principle Revisited," *General Relativity and Gravitation* 26 (1994): 103–111.

[67] Gordon Kane, "The Mysteries of Mass," *Scientific American* 293 (July 2005): 41–8; Frank Wilczek, "Mass without Mass I: Most of Matter," and "Mass without Mass II: The Medium is the Mass-Age," *Physics Today* 52 no. 11 (1999): 11–13 and 53 no. 1 (Jan. 2000): 13–14 respectively. Many particle physicists are optimistic that the Large Hadron Collider (LHC) will detect the Higgs particle. The LHC is located at CERN near Geneva, Switzerland and will resume operations in the spring of 2009.

time, some physicists have objected to this standard or classical view and have sought, so far unsuccessfully, to explain inertia by something external. These failed efforts show that those philosophers are mistaken who hold that the principle of inertia repudiates an inherent principle of nature or signifies merely what a body does not do. The opposite is indeed the case: the principle of inertia is itself an inherent principle. If the principle of inertia treated bodies as devoid of an inherent principle, then there would be no reason for physicists to look for an external cause of inertia. Three centuries of failed efforts to explain the origin of inertia by external forces and relations highlight the fact that the principle of inertia has so far always affirmed an inherent principle to bodies. No currently accepted physics has shown otherwise, and Special Relativity has even supported the classical view. With regard to modern physics, inertia is the obvious counterexample to an entirely mechanistic philosophy.

Attempts to explain the origin of inertia in terms of other principles may one day be successful. Then, it will be necessary to determine if such an explanation shows that inertia is or is not an inherent principle. Given what is now known about inertia, if inertia is explained in terms of other principles, it seems unlikely that any such explanation will show that inertia is not an inherent principle, though inertia may turn out to be a different kind of inherent principle than is currently thought. Perhaps, what may be shown is that inertia is like what is now called an emergent property. Another possibility is that if inertia does turn out to have some kind of extrinsic origin, then it may be natural somewhat in the way that gravity is natural in general relativity. Depending upon one's conception of nature, an extrinsic cause need not mean that something is not natural.

Newton's use of the same word, "*vis*," in impressed force and inertial force and his use of the term *vis insita* may suggest that inertia is an internal efficient cause or agency that moves a body from within, and some writers have interpreted Newton in just such a way.[68] However, as we have seen, Newton is at pains to maintain that a body

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[68] See, for example, E.J. Dijksterhuis, *The Mechanization of the World Picture*, trans. C. Dikshoorn (Oxford: Oxford Univ.Press, 1961), 466; McGuire, "Natural Motion and Its Causes," 310; Zev Bechler, "Newton's Ontology of the Force of Inertia," in *The Investigation of Difficult Things: Essays on Newton and the History of the Exact Sciences in Honour of D.T. Whiteside*, eds. Peter M. Harman and Alan E. Shapiro (Cambridge: Cambridge Univ. Press, 1992), 287–304; and Cohen, *Guide to Newton's Principia*, 98.

persevering in uniform rectilinear motion is not moving itself.[69] In the *Opticks*, first published in 1704, Newton also makes it clear that the *vis inertiae* is not an agency within a body that causes it to move or rest:

> The *vis inertiae* is a passive principle by which bodies persist in their motion or rest, receive motion in proportion to the force impressing it, and resist as much as they are resisted. By this principle alone there could never have been any motion in the world. Some other Principle was necessary for putting Bodies into Motion; and now they are in motion, some other principle is necessary for conserving the motion.[70]

In contrast to inertia as a source of characteristic activities, this passage emphasizes passivity. The passivity of the *vis inertiae* precludes it from being an agency of a body's own uniform rectilinear motion or rest, for that would make it an active principle, which for Newton is a kind of efficient cause.[71] If inertia were an internal agency that moves a body from within, then Newton could not reasonably claim that on the basis of the *vis inertiae* alone there could never have been any motion in the world. Thus, by its inertia, a body cannot drive or push itself to continue moving in a straight line at constant speed nor can it force itself to rest.

A comparison with Kepler further illuminates this point.[72] Kepler conceived of inertia as an inherent inclination of matter to resist motion and to be at rest.[73] By contrast, Newton conceived of inertia as

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[69] For further argumentation in support of this claim, see Dudley Shapere, "The Philosophical Significance of Newton's Science," in *The Annus Mirabilis of Sir Isaac Newton 1666-1966* (Cambridge, Mass.: M.I.T. Press, 1970), 287–9.

[70] Sir Isaac Newton, *Opticks*, bk. 3, query 31, p. 397 (New York: Dover, 1979), 397.

[71] "Seeing therefore the variety of Motion which we find in the World is always decreasing, there is a necessity of conserving and recruiting it by active principles, such as are the cause of gravity . . . and the cause of fermentation." Ibid., 399.

[72] Newton planned but did not carry out an emendation to the third edition of the *Principia* that would add the following to Def. 3: "I do not mean Kepler's force of inertia, by which bodies tend toward rest, but a force of remaining in the same state either of resting or of moving." Newton, *Principia*, 404, note c; and, Cohen, *A Guide to Newton's Principia*, 101. Newton's position is a kind of middle way between that of Lucretius in which atoms are never at rest and Kepler's in which bodies tend toward rest.

[73] According to Kepler, inertia "a primary quality of matter, is a kind of laziness, an abhorrence of being moved." Cohen, "'Quantum In Se Est'" *ACPQ*, 41. See also Jammer, *Concepts of Mass*, 52–9.

persevering either at rest or in uniform rectilinear motion and as resisting changes to either state. However, uniform rectilinear motion and rest are opposed states, for a body cannot be in motion and at rest at the same time and in the same respect. Therefore, since a body by its inertia persists in either of the opposed states of uniform rectilinear motion or rest, inertia cannot be an agent cause of a body's uniform rectilinear motion or of its rest. If inertia were an agent cause of uniform rectilinear motion, then a body, by its inertia, could not also persist in a state of rest. Similarly, if inertia were an agent cause of a body's rest, then it could not also be that by which a body perseveres in uniform rectilinear motion. Consequently, a body, in virtue of its own inertia, is determined to neither state. Thus, inertia is neither a force of rest nor a force of uniform rectilinear motion.

However, the openness of inertia to either rest or uniform rectilinear motion is incompatible with Newton's conception of nature and natural as what a body does when left to itself. Given Newton's conception of inertia, a body left to itself would be neither moving nor resting. If a body is moving inertially or is at rest, then the action of some other body determined it to one or the other state and only then does the body, if left to itself, persevere at rest or in uniform rectilinear motion. Thus, Newton's conception of nature is inadequate because as the quote from the *Optics* makes clear, inertial motion implies a causal relationship to another body even if the action of that other body occurred only in the past. A notion of nature that excludes any kind of explanation in terms of external causes is too extreme for the First Law of Motion.

Newton has several dilemmas. On the one hand, he cannot ascribe a body's inertial motion to a continuously acting external force, nor can he ascribe its continuing motion to an inherent force, which would make a body self-propelled. On the other hand, he cannot maintain that a body of itself contributes nothing to its uniform rectilinear motion or rest and is entirely determined by external forces, for a body, in virtue of its inertia, acts uniformly in characteristic ways. Yet, inertia is passive, open to both uniform rectilinear motion and rest, and not ordered toward any particular place or direction. It is not an efficient cause of its own activity. Thus, inertial motion and rest point toward an external cause, which is problematic for Newton's conception of nature. However, inertia is inherent and necessary and thereby implies some conception of nature. Though Newton regards inertial motion and rest as inactive, nevertheless, inertia is somehow present in them. Also, for Newton, resistance is passive, although resistance to an impressed force is something a body does, and so seems active. Even more curiously, for Newton, inertia is a passive principle, although by it a body endeavors to change the state of bodies that act upon it. Newton's solution to these difficulties and his explanation of the First Law draw upon the very inadequate conceptions and language available to him in his own natural philosophy, the thinking characteristic of his age, and a mathematical approach to nature, which are the sources of many of the paradoxes and difficulties of Definition 3 in the *Principia*. Newton's general framework fails to solve the dilemmas and difficulties posed by inertia and the First Law. Another framework is needed.

An Aristotelian conception of nature helps resolve Newton's dilemmas. In the Aristotelian sense, nature may be considered as material and as formal. As material, nature is the source of various potentialities for extrinsic influence. As formal, nature is a source of activity. Newton famously rejected the notion of form, but ironically the notion of form along with the attendant Aristotelian principles of potency and act can help explain how the principle of inertia is a natural principle. Inertia, considered in terms of these principles, would be a generic accident of a body that results from a form.[74] An accident further specifies its subject.[75] Some accidents are necessary to a thing and others are not.[76] Inertia would be an accident that necessarily belongs to a thing by virtue of the principles of its nature. As such, inertia would be inherent and inseparable from a body, a description of inertia that fits that given by physicists.

As an accident of a body resulting from a form, inertia is a form in a subject. Since a form is an act or actuality of that which it forms, inertia, considered as form, would be an act of a body.[77] As such, inertia

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[74] "[A]ccidents that result from the form are properties belonging to the genus or species, and consequently they are found in everything sharing the nature of the genus or species." Thomas Aquinas, *Being and Essence*, 2nd rev. ed., trans. and notes by Armand Maurer (Toronto: The Pontifical Institute of Medieval Studies, 1968), chap. 6, p. 69.

[75] "Because essence is what the definition signifies . . . accidents must have an essence in the same way that they have a definition. . . . Accidental being results from an accident and a subject when the former comes to the later." Aquinas, *Being and Essence*, 6.66

[76] Ibid., 4.56.

[77] "Because form causes actual existence, form is said to be an act." Thomas Aquinas, *The Principles of Nature*, in Joseph Bobik, *Aquinas on Matter and Form and the Elements: A Translation and Interpretation of the 'De Principiis Naturae' and the 'De Mixtione Elementorum' of St. Thomas Aquinas* (Notre Dame: Univ. of Notre Dame Press, 1998), chap. 1, p. 6.

would be an inherent principle by which a body acts in the characteristic ways that Newton ascribes to the *vis inertiae*, for everything acts according to its form.[78] Since inertia is an act, a body simply acts so as to persevere in uniform rectilinear motion or rest because "everything acts in so far as it is in act."[79] Put in another way, an inclination follows from every form.[80] Thus, if inertia were regarded as determined by a formal principle, a body in virtue of its inertia would have an inclination to persevere in either uniform rectilinear motion or rest, to resist impressed forces, and to endeavor to change the state of another body impressing a force upon it.

In addition, and very importantly, form, in inanimate things, is not an efficient cause of a body's own activity.[81] For Aquinas, nature is a principle of motion and should not be conceived as a moving cause.[82] Some of his harshest words are used for those who would modify Aristotle's definition of nature so that nature becomes a *vis insita*.[83] Thus, inertia considered as a form would not imply that a body is self-propelled or that it is moving itself through some kind of immanent force. Consequently, when physicists say that the motion of a body continues because of its inertia or that a body perseveres in uniform rectilinear motion or rest by the force of inertia, this should be understood to mean that inertia is a formal and not an efficient principle of a body's inertial motion or rest. Inertia "maintains" a body in uniform

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[78] "Everything acts in accord with its form." Thomas Aquinas, *Summa Theologica* I, q. 4, a. 3c in *The Basic Writings of St. Thomas Aquinas*, ed. Anton Pegis (New York: Random House, 1945). Henceforth *ST*. All references herein to *ST* are from Pegis, except where otherwise noted. "Nothing is actual except by its form." Aquinas, *ST* I, q. 7, a. 3c.

[79] Aquinas, *ST* I–II, q. 55, a. 2c.

[80] "[S]ome inclination follows every form." Aquinas, *ST* I, q. 80, a. 1c.

[81] Aristotle, *Physics* 8.4.255a5–19.

[82] On the distinction between a principle and a mover and the tendency of thinkers to reify principles, see James A. Weisheipl, O.P., "Specter of *Motor Coniunctus*," in *Nature and Motion in the Middle Ages*, ed. William Carroll (Washington, D.C.: Catholic Univ. Press, 1985), 100, 113–18; "Aristotle's Concept of Nature: Avicenna and Aquinas," in *Approaches to Nature*, ed. Lawrence D. Roberts (Binghamton, N.Y.: Center for Medieval & Early Renaissance Studies, 1982), 146–54; "The Principle *Omne quod movetur ab alio movetur* in Medieval Physics," *Isis* 56 (1965): 38–41; and *Nature and Gravitation* (River Forest, Ill.: Albertus Magnus Lyceum, 1955), 22–9.

[83] "Hence they are to be laughed at [*Unde deridendi sunt*] who, wishing to correct the definition of Aristotle, tried to define nature by something absolute, saying that nature is a power seated in things [*natura est vis insita rebus*] or something of this sort." Aquinas, *On Aristotle's Physics*, 2.145.

rectilinear motion or rest as a formal constituent from which such motion or rest follows.[84] As formal, inertia is not a propulsion source for a body's inertial motion. Put in another way, Kant's view of inertia as signifying nothing but the lifelessness of a body involves a false dichotomy: a body need not be alive to act from an inherent principle.

Furthermore, since the inertia of a body is not of itself determined to either of the opposed states of rest or of uniform rectilinear motion, inertia is open to one or the other of the opposed states. Thus, a principle of potency is implied, for a body that is open to opposed states must be in potency to them.[85] Consequently, some force external to a body must determine it to one or the other state, thereby further forming it. A body, after being acted upon by an external force, is then either in the act of rest or the act of uniform rectilinear motion. Motion or rest, which are generable and corruptible and caused by an external force, add to inertia, which is an inseparable but incomplete accident.[86]

Inertial motion, then, would follow from a form generated in a body by an external force that has further determined the body. So considered, inertial motion would be consistent with Newton's claim that the *vis inertiae* of a body does not operate as a continuous mover that keeps a body in uniform rectilinear motion. A body's inertial motion (as distinct from its inertia) would be received from another and would follow from an act enduring in the body as a further actualization of it. Thus, a body would persevere in inertial motion without requiring a continuous moving cause to sustain its ongoing uniform rectilinear motion, that is, it could persist in uniform rectilinear motion when it is no longer being acted upon. The body would just remain in act, which adequately captures the sense of passivity that Newton claims for the *vis inertiae* while at the same time doing

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[84] The conception of inertia as a formal constituent is represented mathematically in momentum mv and kinetic energy $\frac{1}{2}mv^2$ where m is the inertial mass and v is the velocity.

[85] "For the same thing can be potentially at the same time two contraries, but it cannot be actually." Aristotle, *Metaphysics*, trans. W.D. Ross, 4.5.1009a34–6,

[86] "But sometimes accidents are caused only as aptitudes, and they are completed by an external agent, like transparency in the air, which is complemented by an external luminous body. In cases like these the aptitude is an inseparable accident, whereas the completion that comes from a source external to the essence of the thing, or that does not enter into its constitution, will be separable from it, like movement and other accidents of this kind." Aquinas, *Being and Essence*, 6.69–70.

justice to the dynamic character of what inertia and inertial motion and rest do.

With respect to rest, Newton and other thinkers, such as Descartes, regarded rest as an absence of activity because a body at rest remains the same and is unchanging.[87] This would be true if "activity" were limited to change or the production of something new in or by a body. However, for Aristotle, rest is a motionless act or an unchanging activity.[88] If one embraces Aristotle's larger notion of activity in which a constant unchanging act is an activity, then rest is an activity. A body at rest is in act. Newton, following Descartes, not only conceived of rest as an unchanging state but also regarded uniform rectilinear motion as an unchanging state equivalent to rest.[89] For this reason, Descartes and Newton thought that uniform rectilinear motion, unlike accelerated motion, did not require a continuously acting mover.[90] Consequently, just as rest was not considered an activity, so too persevering in uniform rectilinear motion was not considered an activity, which is one reason that on Newton's account the *vis inertiae* is inactive in such motion. On this view, a body, whether at rest or in inertial motion, is not doing anything, and, thus, the *vis inertiae* need not operate. Newton, lacking Aristotle's analogical notion of act and activity, could not understand how inertial motion could be an activity and yet not be the result of a continuously acting agency. Newton, therefore, resorted to the paradoxical notion of *vis inertiae* in attempting to solve this and related problems.

Inertia, considered in terms of form, potency, and act not only better expresses the facts about inertia but also solves an additional problem to which Newton's *vis inertiae* gives rise. The problem concerns how Newton's inactive and passive *vis inertiae* is called into exercise when bodies collide.[91] Consider a collision between bodies A and B. According to Newton, each body, by means of its *vis inertiae*, resists the other and endeavors to change the state of the other. The

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[87] Descartes, *Principles of Philosophy* 2.24–8. For the influence of Descartes on Newton, see Alexandre Koyré, "Newton and Descartes," in *Newtonian Studies* (Cambridge, Mass.: Harvard Univ. Press, 1965), 53–114; and Gabbey, "Force and Inertia," 230–320.

[88] "[T]here is not only an activity of movement but an activity of immobility." Aristotle, *Nicomachean Ethics*, trans. W.D. Ross, 7.14.1154b26–7. See also Aristotle, *Metaphysics* 9.8.1050a15–1050b2.

[89] Shapere, "The Philosophical Significance of Newton's Science," 285–99.

[90] Descartes, *Principles of Philosophy* 2.37–8.

[91] Ernan McMullin, *Newton on Matter and Activity* (Notre Dame: Univ. of Notre Dame Press, 1978), 36–42.

two bodies supposedly impress forces upon each other as a result of resisting the impressed force of the other. The problem concerns the origin of the impressed forces. Neither body, in virtue of its *vis inertiae*, can exert an impressed force *upon* the other unless they resist an impressed force *from* the other. Body A cannot exert an impressed force on B unless B exerts an impressed force upon A. However, body B cannot exert an impressed force upon body A unless A exerts an impressed force upon body B. How does one get an original impressed force? Two passive and inactive forces cannot mutually set each other into operation. In order for the two colliding bodies to change from passive perseverance to active resistance, some other force must be involved, but Newton posits no such force. Thus, on Newton's account, two colliding bodies could not exercise their *vis inertiae* and could not resist and endeavor to change each other. However, inertia, considered as an act of a body, and inertial motion and rest, regarded as further actualizations of a body, explain how two bodies act upon each other in collisions. The bodies collide with each other and then act because they are already in act. Once brought into mutual contact, each of the colliding bodies, in virtue of its inertia and of its rest or uniform rectilinear motion, tends to persevere in its motion or rest and to resist and endeavor to change the other because a thing acts insofar as it is in act. Thus, the inertia of a body and its perseverance in inertial motion or rest are better understood as acts of that body and not as something inactive. Considering inertia and inertial motion and rest in this way avoids the problematic conception of inertia as a force and treats the resistance and endeavor of inertia as following upon its inclination to persevere in uniform rectilinear motion or rest rather than reversing the order of perseverance and resistance as Newton did.

Special Relativity further supports the notion that inertia is an act or activity, for according to Einstein's famous equation $E=mc^2$ the inertial mass of a body is itself a form of energy. Inertia is not accurately described as brute resistant matter. Even in prerelativistic physics, a body moving inertially has kinetic energy.[92] Thus, the inertial motion of a body is an energetic activity even if there is no

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[92] Kinetic energy is the energy of motion and is a measure of a body's capacity to do work in virtue of its velocity. A body's kinetic energy (in Newtonian physics) equals one half the mass of the body multiplied by its velocity squared ($\frac{1}{2}mv^2$). Ohanian, *Physics*, vol. 1, 162–3. The form by which a body moves inertially and its relation to kinetic energy, momentum, and heat are analyzed in Anthony Rizzi, *The Science Before Science* (Baton Rouge, LA: IAP Press, 2004), 193–203.

ongoing action of one thing upon another. A body at rest may also be thought to have energy in virtue of its position. For example, the work done in raising a heavy body some distance above the ground might be thought of as building work or energy into the body at its position.[93] In virtue of its position and in respect to an external force, the body then has potential energy.[94] Energy is commonly regarded as something active. Consequently, since inertia, uniform rectilinear motion, and rest all involve forms of energy, they are reasonably regarded as activities even though they need not involve the ongoing action of one thing upon another. Newton could not recognize this not only because he did not have the notion of energy but also because of his limited notion of activity.

The solution presented above offers several advantages from an Aristotelian or Thomistic perspective. First, the principle of inertia shows the dependence of motion on a mover better than the natural motions of the Aristotelian elemental bodies.[95] The natural motions of the sublunar bodies, though following upon their natures, are from another. For this reason, Aquinas says that *gravitas* is a passive principle.[96] The generator of a heavy or light body is the efficient cause of

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[93] "You will undoubtedly be familiar with another way of interpreting a potential energy such as $U(h)$ in the last equation. It represents exactly the amount of work that *we* would have to do in order to raise an object through a distance h, against the gravitational pull, without giving it any kinetic energy." French, *Newtonian Mechanics*, 378.

[94] Expressed mathematically, the gravitational potential energy of an apple with respect to the ground equals mgh (for small displacements near the Earth's surface) where m is the mass of the apple, g is the acceleration produced by gravity near the surface of the Earth, and h is the height of the apple above the ground. Since mg equals the constant force of gravity on the apple, the apple's potential energy with respect to the ground equals the force of gravity on the apple multiplied by its height above the ground. French, *Newtonian Mechanics*, 376–7.

[95] In previously published work, I have addressed issues concerning Newton's First Law of Motion, mover causality, and the Aristotelian definition of motion. See Thomas J. McLaughlin, "Aristotelian Mover-Causality and the Principle of Inertia," *International Philosophical Quarterly* 38 (1998): 137–51; and "Local Motion and the Principle of Inertia: Aquinas, Newtonian Physics, and Relativity," *International Philosophical Quarterly* 44 (2004): 239–64.

[96] "Now we do not find in any non-living body any originative source of motion. . . . There is in living things an active principle of motion, namely, the soul, while in non-living bodies there is no such active principle of motion which could move, but such things are moved by an external mover, which is the generator or that which removes what prevents motion. Yet they do have a passive principle of motion within, by which they are apt to be moved, for example, heaviness or lightness." Aquinas, *Exposition of Aristotle's On the Heavens*, 2.305.

its natural motion. Nevertheless, once formed, a sublunar body immediately moves toward a place that fulfills its nature. Its local motion is then consequent upon a formal principle of motion.[97] The movements of such bodies present the greatest difficulty because that from which their motion is derived is not clear. Therefore, it is not as evident that they are moved by another.[98] By contrast, the local motion of a body that has inertia is not inherently consequent upon its property of inertia.[99] Inertia, simply of itself, has no preferred direction or inherent orientation to a place. Motion does not follow from it alone because, of itself and wherever it may be, inertia is indeterminate with respect to motion or rest. Something further is required for a body to be in motion. In this respect, inertia is unlike the Aristotelian notions of *gravitas* and *levitas*, which are more easily misconstrued as movers than is inertia. A body, in virtue of its inertia, is more clearly moved by another than are the Aristotelian elemental bodies. Thus, the principle of inertia better shows the dependence of motion on a mover.

A second advantage from an Aristotelian or Thomistic perspective concerns the distinction between natural and compulsory motion. Heidegger, in a quotation footnoted at the beginning of this paper, asserts that Newton's First Law eliminates "the difference between natural and against nature, i.e., forced." However, the principle of inertia does provide a basis for a distinction between natural and compulsory motion if one considers the resistance of inertia to various impressed forces. For by its inertia, a body does not resist gravity in the way that it resists other forces. A body in freefall, that is a body

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[97] "However, in heavy [*gravibus*] and light [*levibus*] bodies there is a formal principle of motion. (But a formal principle of this sort cannot be called the active potency to which this motion pertains. Rather it is understood as passive potency. For heaviness [*gravitas*] in earth is not a principle for moving, but rather for being moved.) For just as the other accidents are consequent upon substantial form, so also is place, and thus also 'to be moved to place.' However, the natural form is not the mover. Rather the mover is that which generates and gives such and such a form upon which such a motion follows." Aquinas, *On Aristotle's Physics*, 2.144. "Hence, to ask why a heavy thing is moved downward is nothing other than to ask why it is heavy. The same thing which makes it heavy also makes it to be moved downward." *On Aristotle's Physics*, 8.1034.

[98] Aristotle, *Physics* 8.4.254b7–255a5. See also Aquinas, *On Aristotle's Physics*, 8.1021–8.

[99] The motion of bodies without rest mass, such as light, would seem to follow from their nature. Light, however, cannot rest, though it can be impeded.

which is not subject to any forces other than gravity, does not feel heavy nor do weighing scales and other such devices record any weight. In freefall, a body is weightless, though gravity is not, of course, absent. Weight requires an obstacle to gravity. When an obstacle prevents or hinders a body's gravitational motion, the body then feels heavy and measuring devices record a weight.[100] Consequently, in freefalling gravitational motion and in persevering in uniform rectilinear motion by its inertia, a body, in Aquinas' words, "is not moved with labor."[101] Such motions are natural. However, because of the way in which inertia resists many other forces, a body is moved by these other forces "with labor." They are resisted in manifest and measurable ways. Therefore, considered with respect to its inertia, the acceleration of a body by such forces would be compulsory.

An advantage of Aristotle's notion of nature compared to that of the ancient atomists is that on an Aristotelian conception of nature, something can have an extrinsic cause and still be natural. Some causes outside a body are natural and others are not.[102] Aristotle's principle of potency makes this broader conception of nature intelligible. As material, nature is the source of various potentialities for extrinsic influence, and so, a body's potency can be actualized by an extrinsic cause to which it is naturally disposed. The resulting motion or actualization would then be natural. Therefore, gravity and gravitational motion, even viewed as having an extrinsic cause, can be natural. Whether something is according to nature or against nature depends upon the potency of the body and its relation to an agent. Although a developed account of natural and compulsory motion will not be given here, the basis for distinguishing between natural and compulsory motion is present in inertial physics, even if physicists think of it in different, perhaps confusing, terms.[103]

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[100] French, *Newtonian Mechanics*, 285.

[101] See fn. 27.

[102] "And the motion of things that derive their motion from something else is in some cases natural, in others unnatural. . . . Some of them are capable of causing motion unnaturally (e.g. the lever is not naturally capable of moving the weight), others naturally (e.g. what is actually hot is naturally capable of moving what is potentially hot). . . . So when fire or earth is moved by something the motion is . . . natural when it brings to actuality the proper activities that they potentially possess." Aristotle, *Physics* 8.4.254b20–255a30.

[103] For an account of natural and compulsory motion and of final causality, see John W. Keck, "The Natural Motion of Matter in Newtonian and Post-Newtonian Physics," *The Thomist* 71 (2007): 529–54 .

Finally, according to Aristotle, nature acts for an end. As noted previously, the task of this paper is not to argue that inertia and motion according to Newton's First Law are goal directed. For now, I merely note that an argument for final causality *could* begin by considering the respects in which inertia and Newton's First Law are natural in the Aristotelian sense and then argue on the basis of the principle that nature acts for an end that Newton's First Law of Motion and the property of inertia must be teleological. The task would then be to discover that teleology.

Inertia is a generic principle of motion and rest within a body, though at a minimal formed level. Inertia informs the First Law of Motion, which is thereby called the principle of inertia. In virtue of its inertia, a body acts and is acted upon in very definite, characteristic and uniform ways. Newton and physicists from his time to ours have regarded inertia as an inherent principle by which a body perseveres in either uniform rectilinear motion or rest, resists impressed forces, and endeavors to change the state of those bodies upon which it acts. In short, inertia is not inert. The various physical examples given in this paper show that the principle of inertia does not treat a body as if it has no inherent principle. The unsuccessful attempts by physicists to find an extrinsic origin of inertia, though they may eventually lead to new discoveries, further support the view that inertia is an inherent principle of nature. Newton himself understood the principle of inertia through an eclectic but largely nonAristotelian conception of nature and matter and by the problematic notion of a *vis inertiae*. However, Newton's general philosophy of nature should be distinguished from the more specific content of the First Law and of inertia itself. A general Aristotelian conception of nature can resolve many of Newton's difficulties. Thus, inertia and the First Law of Motion are reasonably regarded as natural in the general Aristotelian sense, though a teleological account of these principles remains to be given.[104]

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[104] An early draft of this paper was read at the Summer Conference of the Institute for the Study of Nature on June 16th, 2007. I am grateful to those present for their many comments and suggestions.