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Aristotelian Mover-Causality and the Principle of Inertia

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THE PRINCIPLE OF INERTIA as formulated in Newton's first law states that "Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it."[1] Aristotle's mover-causality principle states that "whatever is moved is moved by another."[2] These two principles have frequently been thought of as incompatible, and their apparent incompatibility forms part of the great chasm along which ancient and modern physics have parted ways. The principle "whatever is moved is moved by another" is commonly thought to mean that a body's motion must be continuously sustained by a conjoined mover acting upon that body at every instant of its motion.[3] The principle of inertia repudiates such a requirement and states that without a continuous, conjoined mover a body in motion will continue in motion unless something acts upon it. Furthermore, the mover-causality principle depends upon a view of motion as a continuous change or process, whereas inertial motion is viewed as a state equivalent to rest.[4] A different conception of motion appears to underlie each principle. Thus understood, the principle of inertia and the mover-causality principle would seem to be incompatible.

If indeed these two principles were incompatible, the consequences would be serious for those systems of thought dependent on either one or both of them. For an Aristotelian or a Thomist the consequences could be costly because the mover-

[1]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) p. 13.

[2]*Phys.* VII.1.241b24.

[3]The Scholastic literature on this topic is briefly reviewed in Desmond J. FitzGerald, "The Problem of the Projectile Again," *Proceedings of the American Catholic Philosophical Association* 38 (1964) 186–201. For a recent treatment of the problem, see William A. Wallace, O.P., "Aquinas and Newton on the Causality of Nature and of God: the Medieval and Modern Problematic" in *Philosophy and the God of Abraham: Essays in Memory of James A. Weisheipl, O.P.*, ed. R. James Long (Toronto: Pontifical Institute of Medieval Studies, 1991) pp. 255–79. For the view that Aristotle and Aquinas did not maintain that the mover-causality principle requires that a body in motion have a continuous conjoined mover throughout its motion, see James A. Weisheipl, O.P., "The Principle *Omne quod movetur ab alio movetur* in Medieval Physics," *Isis* 56 (1965) 26–45. Weisheipl's interpretation is controversial. Opposing interpretations may be found in William A. Wallace, O.P., "Newtonian Antinomies Against the Prima Via" in *From A Realist Point of View* (Washington, D.C.: Univ. Press of America, 1979) pp. 359–64, and in Vincent E. Smith, *The General Science of Nature* (Milwaukee: Bruce, 1958) pp. 63–68.

[4]I. Bernard Cohen, *The Newtonian Revolution* (Cambridge: Cambridge Univ. Press, 1980) p. 182. 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. of America Press, 1985) pp. 58–62.

causality principle is a fundamental philosophical principle and serves as a premise in many of Aristotle's and Aquinas's arguments. Not only is the mover-causality principle used throughout Aristotle's physical treatises; it is also applied to many other problems, such as the existence of God,[5] the nature of the soul,[6] the movement of the will,[7] and the distinction between living and non-living beings.[8] Alternatively, with respect to present-day science, the principle of inertia is the foundation upon which much of modern physics is built.[9] It is used to explain, at least in part, everything from the flight of an arrow and the sloshing of water in a bucket to the persistence of orbital motions and the continued expansion of the universe. Thus an incompatibility between the two principles would have considerable consequences for our understanding of the world.

I will argue that the two principles are compatible. The argument will proceed along the following lines. In Aristotelian and Thomistic thought motion is a continuous actualization of a potency. This actualization can be brought about only by some object other than the object moved. In a purely inertial motion, however, no potency is actualized, and thus no continuous, conjoined mover is required. Since no actualization of a potency occurs, a body, once set in motion, will continue as it is in virtue of its inertia. The mover-causality principle is not violated. Inertial motion proceeds from a form or actuality somewhat as do qualities such as shape or texture. Next, I defend the position that motion is a continuous actualization of a potency even though an inertial motion does not involve a reduction from potency to act. Inertia is a principle of motion and not a particular type of real motion which occurs in the universe. No actual motions are or can be purely inertial. Instead, all motions are composites of inertial and other components, for a body in inertial motion is always also being acted upon by forces such as gravity. These forces originate in some physical source other than the body being acted upon and actualize some potency in that body. Thus all actual motions involve a continuous reduction of potency to act and have movers which cause any actualization of a potency.

Before I proceed to the argument, a few notes concerning terminology will be helpful. For the purposes of this paper, "force" is assumed to have the property of originating in something physical, and "impressed forces" will be taken to mean a causal action on a body from some physical source extrinsic to the body acted upon.[10] By "inertia" is meant a real, physical, inherent, and quantifiable property of a body in virtue of which it conserves its motion or rest, resists efforts to change its motion or rest, and, in resisting, acts or reacts upon another.[11] Finally, although the mover-causality principle has a wider application than merely to local motion, the principle of inertia does not, and so motion here refers only to local motion.

[5] *ST* I.2.3.

[6] *ST* I.75.1.

[7] *ST* I–II.9–10.

[8] *ST* I.75.1.

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

[10] Richard P. Feynman, Robert B. Leighton, and Matthew Sands, *The Feynman Lectures on Physics* (Reading: Addison-Wesley, 1963) I, pp. 12–1 to 12–3; hereafter *FL*. "Impressed" might be taken to imply a violent or compulsory motion. See, for example, William A. Wallace, O.P., "Is the Pull of Gravity Real?" in *From a Realist Point of View*, pp. 163–85. I do not intend to discuss this issue here.

[11] Sir Isaac Newton, *Opticks* (New York: Dover, 1952) L.III, Q.31, p. 397; *Principia*, Def. III, p. 2.

Aquinas gives three arguments for the mover-causality principle,[12] each of which is drawn from Aristotle's *Physics*. The first argument (*Phys.* VII.1) is a *reductio ad absurdum* of the assumption that something moves itself. The second argument (*Phys.* VIII.4) is an argument by induction. Aquinas identifies the movers for each of the different kinds of motion: essential and accidental, animate and inanimate, natural and violent. The third argument (*Phys.* VIII.5) argues for the mover-causality principle on the basis of what motion is. This paper will directly address only this last argument, although it has implications for the other two arguments as well.

This last argument is most familiar as it appears in the First Way of the *Summa theologiae*. According to Aquinas:

> Now whatever is moved is moved by another, for nothing is moved except as it is in potentiality to that to which it is moved; whereas it moves another inasmuch as it is in act. For to move is nothing else than to reduce something from potentiality to actuality. But from potentiality something cannot be reduced to act except by some being in act: just as that which is actually hot, like fire, makes wood, which is potentially hot, to be actually hot, and thereby moves and changes it. Now, it is not possible that the same thing should be at once in actuality and potentiality in the same respect, but only in different respects. For what is actually hot cannot simultaneously be potentially hot, but it is simultaneously potentially cold. Therefore it is impossible that in the same thing and in the same way a thing should be both mover and moved, or that it should move itself. Therefore whatever is moved must be moved by another.[13]

From Aquinas's argument one may ascertain a criterion for determining when a mover is required. According to Aquinas the mover-causality principle, "whatever is moved is moved by another," follows from the nature of motion. Motion is a reduction from potentiality to actuality, and as Aquinas argues, a reduction from potentiality to actuality requires a mover which is other than the thing moved. A thing cannot move itself or reduce itself from potency to act. A moveable object cannot give itself what it does not have, nor can it receive what it already possesses. Thus the mover-causality principle requires a mover for every reduction from potentiality to actuality, and a mover is an agency which reduces something from potentiality to actuality or which actualizes a potency.

The principle of inertia is not incompatible with the principles stated here by Aquinas because in purely inertial motion there is no ongoing reduction from potency to act. No potency is actualized, and thus no mover is required. To this claim one might object that a purely inertial motion would not be a motion at all since there is no reduction from potency to act. Indeed, one Thomist philosopher who noticed this feature of inertial motion refers to it as "motionless motion."[14] Inertial motion is paradoxical, as is indicated by the very term "inertial motion." "Inertia," which usually means inactivity, absence of motion, or resistance to change, seems to have a meaning opposed to that of "motion," which usually means some kind of change. This particular issue will be addressed later. First, the claim that

[12]St. Thomas Aquinas, *Summa Contra Gentiles*, trans. Anton C. Pegis (Notre Dame: Univ. of Notre Dame Press, 1975) I.13.

[13]*ST* I.2.3.

[14]Roman Kocourek, "Motionless Motion," *The Thomist* 24 (1961) 420.

inertial motion does not involve an actualization of a potency must be explained and defended.

In a purely inertial motion a body moves with constant velocity in a straight line in the complete absence of any impressed forces. Constant velocity means that the body moves with the same speed and in the same direction. The fundamental idea is that an object left to itself continues as it is—in its state, whether moving or resting. "State" means the condition of a thing with respect to its constitution, structure, or form. Water, for example, has liquid, solid, or gaseous states. Inertial motion is thought of as a state of a body, a state that is unchanging. By persisting in its state, a body once set in motion requires no additional conjoined mover to keep it moving throughout its motion. It moves in virtue of its state.

Since inertial motion is an unchanging state of a body, it is equivalent to rest, for in neither state is there any change. This equivalence between motion and rest applies only to inertial motion and not to motion in general.[15] This equivalence may be illustrated with a thought-experiment. One imagines a windowless spacecraft traveling in a straight line at constant velocity in the complete absence of impressed forces. In such a case there is no experiment or observation which anyone could perform within the spacecraft that would tell him whether he were moving or resting. Whether at rest or in purely inertial motion, his experiments and observations would be the same.[16] This thought-experiment is approximated by the flights of some spacecraft.

The equivalence between rest and purely inertial motion may also be illustrated with a somewhat different thought-experiment. One imagines a body A moving at a constant speed in a straight line with respect to some other bodies B.[17] Further, one abstracts from all dynamic or causal interactions on or between body A and the other bodies B so that A and B move in the complete absence of extrinsic forces. One might, for example, imagine A and B as spacecraft (with their engines off) moving far out in space, although in such a situation the spacecraft would not be entirely free of impressed forces. The conditions of the thought-experiment are idealized. Space is not, after all, a perfect vacuum, and bodies A and B are in a gravitational field, however weak, exerted both from each other and from distant bodies. Abstracted from all such forces, however, the motion of A and B would be merely an extrinsic change in spatial relations, that is, a relative change of distance and direction between the bodies. In such a case there would no way to determine whether A were moving and B at rest, B were moving and A at rest, or both A and B were moving. One might equally well regard A as moving and B as resting, A as resting and B as moving, or both A and B as moving. Even the constant velocity of light could not be used by observers on one body to determine whether they were at rest or in inertial motion—light has the same velocity irrespective of a body's state of motion or rest.

Since, in such a situation, no one on either A or B could in principle determine whether he were at rest or in motion, inertial motion and rest would be dynamically

[15]Cohen, *Newtonian Revolution*, p. 182.

[16]See *FL* II.42–48; Hans C. Ohanian, *Physics* (New York: W.W. Norton, 1985) p. 110; and I. Bernard Cohen, *The Birth of a New Physics*, rev. ed. (New York: W.W. Norton, 1985) pp. 82–85 (hereafter *BP*).

[17]See, for example, Albert Einstein, *Relativity: The Special and General Theory*, 16th ed. (New York: Crown, 1961) pp. 59–62.

indistinguishable and therefore equivalent. The point is not merely the epistemological one that human observers because of their limitations cannot discover which body is moving inertially and which is at rest. One might be tempted to think of a body in purely inertial motion as possessing something which a body at rest does not, namely, a form or an actuality or a momentum. Rather, the point is that there is no effect, attainment, or physical attribute which would make purely inertial motion and rest different from each other. To be at rest need not mean an absence of actuality; it may mean the possession of a full or unchanging actuality.[18] Likewise a body at rest also resists efforts to change its state.

A famous example (although it does not involve a purely inertial motion) will help illustrate this equivalence: namely, the apparent motion of the stars as seen from the Earth. If we watch the stars throughout the course of a cloudless night, we will see them move slowly across the sky from east to west; the same is true of the Sun's motion during the day. This apparent motion of the Sun and the stars is caused by the Earth's rotation in the opposite or eastward direction. The relative motion between bodies enables an observer to determine whether they are resting or moving only if that motion is not purely inertial. Indeed, the classical proofs of the Earth's motion—the Foucault pendulum, which proves the Earth's rotation about its axis, and the parallax, which proves its revolution about the Sun—both rely on the fact that the Earth's motion is not purely inertial.

A contrast may also prove helpful. In Aristotle's model of the universe, the celestial spheres define an absolute space. The universe has within it absolute, fixed positions which are correlated with various properties and attributes of bodies. For example, the weight of an earthy body varies with its distance from the center of the universe. Its natural place, towards which the body automatically and spontaneously moves, is also the center of the universe. In moving towards the center, "it is moving from potentiality to actuality, and that means attaining the place, quantity and quality proper to its actual state."[19] In James A. Weisheipl's words, for Aristotle "there exists an absolute matrix against which the immobility of positions has absolute physical significance."[20] Thus local motion involves a change in a body itself above and beyond its interactions with other bodies.

In contrast to Aristotle, many scientists have for some time accepted a principle of space-symmetry[21] or location-indifference.[22] According to this principle a change in a body's spatial orientation or position in space does not alter the body or produce any physical consequences. The body is the same irrespective of its orientation or position.[23] A book, for example, is the same whether it is held right side up or upside down or at an angle, or whether it is held in the air or set on a

[18]For rest as an unchanging act or activity, see Aristotle, *Metaphysics* IX.8.1050a15–b2.

[19]Aristotle, *On the Heavens* IV.3.311a5–7, trans. W. K. C. Guthrie (Cambridge: Harvard Univ. Press, 1939). For a clear and elegant presentation of this view, see Eric A. Reitan, O.P., "Nature, Place, and Space: Albert the Great and the Origins of Modern Science," *American Catholic Philosophical Quarterly* 70 (1996) 92–94.

[20]James A. Weisheipl, O.P., *Nature and Gravitation* (River Forest: Albertus Magnus Lyceum, 1955) p. 74; hereafter *NG*. In this regard one might consider the Michelson-Morley experiment as an argument against an ether and an absolute reference-frame. See Albert Einstein and Leopold Infeld, *The Evolution of Physics* (New York: Simon and Schuster, 1952) pp. 164–77.

[21]Richard P. Feynman, *The Character of Physical Law* (Cambridge: MIT Press, 1965) p. 85.

[22]Rom Harré, *The Principles of Scientific Thinking* (Chicago: Univ. of Chicago Press, 1970) p. 243.

[23]Feynman, *Physical Law*, pp. 84–85; Harré, pp. 243–45.

table or laid on the floor. But, one might object, it is frequently the case that, when we move something to a different place, it changes significantly: a book set in a puddle of water will be different from the same book set on a dry surface; and even when a book is held at different angles, it will reflect light differently. Similarly, a motion is a translation through something. Therefore, in a motion, some interaction between objects will occur. But a motion is very different depending on whether a body is moving through two feet of air, two feet of lead, two feet of interstellar space, or two feet of an aether reference-frame. A spatial re-location or re-orientation as such does not produce a change in the re-located body. A change in a body is produced by re-location with respect to other bodies and their causality. Other bodies produce the change in the moved body, and various forces and mechanisms are posited as causes.[24] Space itself is dynamically inefficacious.

This may be illustrated in a somewhat different way. If one moved a body and then, so to speak, moved all of the relevant things which accounted for its changing to where the body had been re-located, the body would behave in the same manner. For example, if the Earth and the Sun were located on the other side of the galaxy but the distance between them were kept the same, the gravitational force between them would remain the same.[25] Put in another way, the gravitational interaction of the Earth and the Sun is unaffected by the Sun's motion through space. Merely by studying the solar system, one cannot determine whether the Sun is at rest or moving inertially through space.[26] Thus spatial translation as such does not produce a change in a moving body, and thus mere spatial translation will not distinguish between moving and resting.

Aristotle understood something like the principle of space-symmetry, for he wrote that in a void "no one could say why a thing once set in motion should stop anywhere; for why should it stop *here* rather than *here*? So that a thing will either be at rest or must be moved *ad infinitum*, unless something more powerful get in its way."[27] Aristotle is of course arguing against the void. The principle of space-symmetry, however, does not necessarily imply the existence of a void or an absolute Newtonian space existing independently of physical bodies. Instead, space may be a system of relations among bodies "constituted by just those relations which are not dynamic, and are not associated with causes."[28] "Space" in this sense is what a closet never has enough of.

The equivalence of inertial motion and rest implies that a body in purely inertial motion does not change. To such a claim, however, one might object that, even in the complete absence of forces, a reduction from potency to act still occurs in an inertial motion. One might argue that the relative motion of bodies A and B described above does indeed involve an actualization of a potency. In that example A and B are moving at a constant speed in a straight line with respect to each

[24]Harré, pp. 236–37, 243–45.

[25]Feynman, *Physical Law*, pp. 85–86.

[26]*Ibid.*, pp. 90–91. See also Newton, *Principia*, Cor. V, p. 20: "The motions of bodies included in a given space are the same among themselves, whether that space is at rest, or moves uniformly forwards in a right line without any circular motion."

[27]Aristotle, *Phys.* IV.8.215a19–21, trans. R. P. Hardie and R. K. Gaye in *The Basic Works of Aristotle* (New York: Random House, 1941). In this regard see Edward Grant, "Motion in the Void and the Principle of Inertia in the Middle Ages," *Isis* 55 (1964) 265–92.

[28]Harré, p. 243.

other. Thus, from the point of view of either body, the distance and direction of the other body is continuously changing. Therefore one could say that at time t_0 the bodies are actually in a certain relative position X and potentially in a different relative position Y. At time t_1 the bodies are no longer in relative position X and are now actually in relative position Y. The potency of the bodies to be in relative position Y has been actualized, and therefore a potency is actualized in an inertial motion.

An examination of this objection will show that, for a body in purely inertial motion, there is no reduction from potency to act. In the example A and B change with respect to their relative distance and direction. Such motion is merely an extrinsic, accidental change in relation and does not require a simultaneous reduction of potency to act for bodies moving in such a way. In Book V of the *Physics*, Aristotle states that there is no motion in the category of relation: "Nor is there motion in respect of Relation: for it may happen that when one correlative changes, the other, although this does not itself change, is no longer applicable, so that in these cases the motion is accidental."[29] Changes in relation are not "motion" properly speaking. Motion properly speaking involves a change *in* the moveable and is *from* a cause or mover which is other than the moveable. For Aristotle and Aquinas motion is not a "betweenness" relation.[30] Motion properly speaking will be referred to as motion *per se* and motion in an accidental, relational sense will be referred to as motion *per accidens*.[31] Motion *per accidens* does not necessitate a reduction from potency to act for a body in relative motion.

According to Aristotle a relation is an ordering of two correlatives. If one correlative changes, then what is true about the other is no longer true even though it has not itself changed. A proposition about a body may be true at one time t_0 and false at another time t_1 even though no potency in the body is reduced to act. One may truly say that Socrates has become shorter than Theaetetus, but it is a mistake to think that Socrates has undergone a reduction from potency to act. His height is the same as before. We may say that Socrates's potency to be shorter than Theaetetus has been actualized, but we are mistaken if we think that any potency in Socrates has been reduced to actuality.[32] Similarly, someone may discover that what one thought was an oak tree is in fact an elm, but this does not mean that a potency in an oak tree has been actualized so that it is now an elm. No potency in the tree is actualized; a potency is actualized in the person who knows the tree. In neither Socrates nor the tree does any motion *per se* occur. Clearly, relative motion (motion *per accidens*) does not necessarily imply a reduction from potency to act (motion *per se*) in a subject of a relative motion.

In all of the examples given above, however, some motion *per se does* occur in one term of the relation, and this motion *per se* is the basis for the motion *per accidens*. Theaetetus grows *per se*; someone learns *per se* the truth about a tree.

[29]*Phys.* V.2.225b11–13.

[30]*Phys.* III.2–3.202a3–21. St. Thomas Aquinas, *Commentary on Aristotle's Physics*, trans. Richard J. Blackwell, Richard J. Spath, and W. Edmund Thirlkel (New Haven: Yale Univ. Press, 1963) III.4.297–307; hereafter *CP.*

[31]Aristotle introduces the distinction between motion *per se* and motion *per accidens* in *Phys.* V.1.224a21–b28. He applies this distinction to relative motion at 225b11–13. See also *CP* V.3.666–67.

[32]Peter Geach, "What Actually Exists" in *God and the Soul* (London: Routledge & Kegan Paul, 1969) pp. 71–72.

As Aristotle notes in the passage above, one of the correlatives does change in itself. In other words, the relative changes or motions *per accidens* of the examples are asymmetrical. Thus one might argue that, since an asymmetry is present in a motion *per accidens*, at least one correlate in the relative, extrinsic motion of bodies A and B in the example must be moved *per se*. Thus it would seem that in a purely inertial motion, some body must undergo a *per se* reduction from potency to act.

Of course, this difficulty does not occur for changes in relation that are symmetrical since there is no *per se* reduction from potency to act in either correlate of the relative change.[33] Purely inertial motion is precisely this kind of relative change in which neither correlate of the relation undergoes a reduction from potency to act. In purely inertial motion there is motion *per accidens* without a concurrent motion *per se*. In the example given earlier of bodies A and B moving at a constant speed in a straight line with respect to each other and in the complete absence of extrinsic forces, the motion of A and B was said to be a merely extrinsic change in the spatial relations of distance and direction. This change in spatial relations involves no *per se* actualization of a potency in either A or B.

What supports the claim that, in the idealized case of purely inertial motion, there can be such a change in relation in which neither one of the correlates of the relation undergoes any *per se* reduction from potency to act? First, the case for changes in relation which are asymmetrical is already well established, and thus the case for changes in relation which are symmetrical is, so to speak, halfway made. Something—Socrates or the elm tree, for example—can seem to change or be described as changing when it in fact does not.

Second, all of the evidence and arguments for the principle of inertia itself support the claim that there can be a change in relation which does not require motion *per se*. In other words, the same evidence that argues for the truth of the principle of inertia also argues for a change in relation which does not involve an actualization of a potency in either correlate of the relation. If the principle of inertia is a true physical principle of the motions of bodies, then purely inertial motion would be a case of a change in relation which does not involve a *per se* actualization of a potency in either correlate of the relation. It would be motion *per accidens* without a simultaneous motion *per se*. Although some of the evidence and arguments for the veracity of the principle of inertia have been presented here, a full presentation would be a lengthy undertaking considerably beyond the scope of this paper and will not be attempted.[34]

Third, one can provide examples of change which may be described by using the terminology of a reduction from potency to act but which are in fact symmetrical and involve no *per se* reduction of potency to act in the bodies so described. One may imagine two blocks resting on a desk at 4:00. These blocks are in potency to being in exactly the same location at 4:15. When it is 4:15, this potency of the blocks has been actualized. The blocks are in the same location at 4:15 as they were at 4:00. The time has changed, yet the blocks have undergone no *per se* reduction of potency to act. They remain the same as they were at 4:00. Thus one

[33]At *CP* V.3.677 Aquinas discusses the case of a change in relation when nothing new comes to either term of the relation. He considers these relations in respect to reason.

[34]For some of this evidence, see *BP*.

can describe a symmetrical change using the terminology of "reduction from potency to act" although *per se* actualization of a potency is not involved in either correlate of the relation.

Merely because one can use the terminology of "reduction from potency to act" does not mean that *per se* motion occurs, and one should not be misled by the terminology into thinking that it does. The example of the blocks shows that the terminology of motion can be formulated in an apparently sensible way which is in fact misleading. One can mistakenly judge an accidental change in relation to be a motion *per se*. For the idealized case of a purely inertial motion, the objection that a relative change in distance and direction *must* involve a simultaneous *per se* motion in at least one term of the relation thus fails. Therefore the claim stands: for a body in purely inertial motion, no actualization of a potency in the body occurs. The body remains the same.[35]

The point of this discussion about the equivalence of inertial motion and rest is to show that in a purely inertial motion there is no actualization of a potency and thus no necessity for a continuous, conjoined mover. Recognizing this point, some thinkers have seized upon it as evidence that the principle of inertia is merely or essentially a mathematical principle.[36] Undoubtedly the principle of inertia serves mathematical purposes. But the principle of inertia is not merely mathematical. Positing an equivalence between inertial motion and rest is also quite deliberately intended to serve as a physical explanation for facts about the nature and motions of bodies.

With respect to these facts, inertia is intended as an explanation for such problems as those which arise once one accepts that the Earth moves. One of these problems is that to us the Earth seems to be at rest, and we perform nearly all of our activities as if it were at rest, even though the Earth is in fact moving, and moving quite fast. An ancient experiment, one that Aristotle and Aquinas used as an argument to show that the Earth was at rest, will help in illustrating this problem.[37] An arrow is shot straight up into the air. We know from experience that the arrow will come down roughly in the same place from which it was shot. If we suppose that the arrow takes 10 seconds to go up and come back down, then we can figure out how far the point from which the arrow was launched moved during the arrow's flight. With respect to the Earth's rotation, a point at the equator moves about 1500 feet per second. Therefore, while the arrow was in flight, the place from which it was launched moved 10 times that far, or 15,000 feet, which is nearly 3 miles. Yet the arrow hits the ground not 3 miles away but at nearly the spot from which it was launched, just as if the Earth were at rest. Similarly, even

[35]For the discussion of this objection, I have benefited considerably from a colloquium I gave at the University of St. Thomas in Houston and from a follow-up colloquium given by Thomas Russman, OFM Cap. I have here borrowed Fr. Russman's example and argument, which uses blocks to illustrate a symmetrical change involving no reduction from potency to act in the objects so described.

[36]See references cited in note 3 above. Also see Kocourek, "Motionless Motion," pp. 419–30; *NG* 50–81; and Eric A. Reitan, O.P., "Thomistic Natural Philosophy and the Scientific Revolution," *The Modern Schoolman* 73 (1996) 265–81. For a response by some physicists to such a view, see William H. Kane, John D. Corcoran, Benedict M. Ashley, and Raymond J. Nogar, eds., *Science in Synthesis* (River Forest: Albertus Magnus Lyceum, 1953) pp. 30–66.

[37]Aristotle, *On the Heavens* II.14.296b22–26. St. Thomas 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) II.26.528.

though the Earth is moving around the Sun at about 19 miles per second, the clouds float calmly in the air and the birds, flying about undisturbed, do not hang onto the trees fearful of being left behind by a swiftly moving Earth.[38] The Earth's motion is in fact so nearly indistinguishable from rest that it was quite reasonable for most of the ancients and medievals to think that the Earth was in fact at rest.

How does inertia and inertial motion explain why the Earth seems to be at rest even though it is moving? A body in a purely inertial, force-free motion does not change, and thus its motion is equivalent to rest. Therefore, for a body in a purely inertial motion, there is no change to detect, no influence exerted. In the case of the arrow, the situation is complex. The arrow not only moves up and falls down but also moves horizontally (eastward) with the rotating Earth. The arrow moves eastward with the rotating Earth because, with respect to the Earth's eastward motion, the arrow remains in the same state that it was in while it was resting on the Earth's surface. The eastward component of the arrow's motion does not change or changes only a little as a result of the air's action. The arrow, in virtue of its inertia, keeps or preserves that part of its motion. Since, while the arrow is moving up and down, it is also moving eastward with the Earth, it lands roughly on the spot from which it was launched. Even though the Earth is moving, the arrow throughout its flight remains above its launch point.

Insofar as the Earth's motion is inertial, its motion is indistinguishable from rest and so does not affect the motion of the arrow or indeed most of our other actions. Of course, the Earth's motion is not purely inertial. It is rotating and is acted upon by various forces; but given the quantity of the Earth's inertia, the velocity of its motion, and the strength of the forces acting upon it, the dynamic effects of such forces are for the most part difficult to detect and go unnoticed.[39] In general, the weaker the forces acting upon a body in comparison to its inertia, the nearer such a motion will approach the purely inertial.

The use of the equivalence of rest and inertial motion for physical explanations is also apparent in the specialized case of a body with zero *net* force acting upon

[38]*BP* 9–10.

[39]With respect to the Earth's rotation, the Earth's parts undergo a centripetal acceleration which varies with geographical latitude. One consequence of it is the Earth's equatorial bulge. For most purposes, however, the quantity of this acceleration and the force causing it are relatively small and are hidden by the effects of the Earth's gravity. At the equator, for example, the centripetal acceleration is only about 1/300 the gravitational acceleration. Also, as a result of the Earth's rotation, there are various inertial effects or "fictitious" forces, such as coriolis and centrifugal forces. These are also not readily detected in ordinary experience.

The Sun (as well as other celestial bodies) also acts gravitationally on the Earth. But since the Earth is in free fall towards the Sun, it is weightless, like astronauts in an orbiting space-station. Consequently, the dynamic effects of gravity are not apparent locally—where "locally" means "at a point." Because gravitational fields are naturally non-uniform, the Sun does produce tides on the Earth, and therefore the effects of its gravity are in this way detectable dynamically. The Earth's free fall does not carry it into the Sun because it is moving inertially in a direction perpendicular to the line of fall towards the Sun. The composite motion is an orbit in which the direction of the Earth's motion continually changes. This change in direction, measured in angular terms, is about one degree per day. In addition, the Earth's gravitational acceleration towards the Sun is about 1660 times less than the gravitational acceleration which the Earth produces on an object near its surface.

The Earth is moved in other ways as well, but these motions are also not easily detected. Ohanian, pp. 93–95, 327; *BP* 178–80, 222; A. P. French, *Newtonian Physics* (New York: W. W. Norton, 1971) pp. 507–42.

it. In such cases the various forces on a body are of equal magnitude but of opposite direction and so balance each other. For example, the net force acting on an airplane which is flying smoothly at a constant velocity is zero. The passengers in the airplane can eat and move about as if the plane were at rest on the ground. Even on a Concorde traveling at supersonic speeds, a passenger can easily pop peanuts into his mouth. But such is not the case if the forces acting upon the plane become imbalanced and the plane changes its velocity. One quickly becomes aware of changes in the plane's motion.

Indeed, the inertial properties of bodies are most useful. Inertial stabilizers on cruise-liners keep them steady and comfortable as they sail across oceans and seas; their passengers can play tennis as if they were on land. Submarines use inertial navigation to sail underwater or under the polar icecap. Rockets also use inertial navigation. These and other applications strongly suggest that inertia is a real, physical, and quantifiable property of bodies.

The problem mentioned earlier must now be addressed. If there is no reduction of potency to act in a purely inertial motion, how can the principle of inertia apply to real *per se* motions when such motions are reductions from potency to act? The solution to this problem is twofold. First, inertial motion must be regarded as a principle of motion and not as a particular type of real motion which occurs in the universe. Second, it must be acknowledged that no real motions are *purely* inertial. All real motions are a composite of inertial and other principles, for in the actual universe a body in inertial motion is always also being acted upon by forces such as gravity.

With respect to the first part of the solution, inertia is a principle. A principle is that in an object in virtue of which it acts in certain characteristic ways. Thus, like other principles such as matter, form, or privation, inertia is not a thing or entity to which we can point.[40] Instead, a principle such as inertia must be understood in terms of what comes forth from it. For some philosophers this presents serious difficulties. The impossibility of observing purely inertial motions occurring in the actual universe seems incompatible with the view that the principle of inertia is a physical law which is true of real bodies.[41] But this is not a serious difficulty if inertia is regarded as a principle and is not reified into some kind of thing. We do not observe actual motions which are purely or only gravitational or electromagnetic. These forces are not observed to act alone or in isolation, yet we do not doubt that they are actual physical forces. Thus one should no more expect to observe a purely inertial motion than one should expect to see prime matter or purely gravitational motion.

Purely inertial motion is admittedly an idealization and a counterfactual. But for Aquinas a counterfactual conclusion may follow from a hypothetical conditional. His example is well-known: "if man is an ass he is an irrational animal."[42] Count-

[40]On the concept of a "principle" as distinct from an entity or a thing, see James A. Weisheipl, O.P., *The Development of Physical Theory in the Middle Ages* (Ann Arbor: Univ. of Michigan Press, 1971) pp. 37–40.

[41]For statements of this problem and various responses to it, see for example, Norwood Russell Hanson, "The Law Of Inertia: A Philosopher's Touchstone," *Philosophy of Science* 30 (1963) 107–21; G. J. Whitrow, "On The Foundations Of Dynamics," *British Journal for the Philosophy of Science* 1 (1950) 92–107; and Antonio Moreno, O.P., "The Law of Inertia and the Principle *Quidquid Movetur Ab Alio Movetur*," *The Thomist* 38 (1974) 306–31.

[42]*CP* VII.1.889.

erfactual conditionals and idealized conditions such as force-free motion are sometimes useful for understanding what comes forth from a principle. The practice is not uncommon in the sciences.[43] Matter and form are also often spoken of in a similar way—so much so that they were once misunderstood as occult causes.

Treating inertial motion as a principle is one part of an explanation showing how all real motions involve an actualization of a potency even though there is no such actualization in a purely inertial motion. With respect to the second part of the solution, it must be acknowledged that *purely* inertial motions do not occur in the actual universe and that all real motions involve an actualization of a potency. Physical objects of all known kinds are always and necessarily being acted upon by some force. In the words of Richard Feynman, a Nobel Prize winning physicist:

> Galileo . . . discovered the principle of inertia: if an object is left alone, is not disturbed, it continues to move with a constant velocity in a straight line if it was originally moving, or it continues to stand still if it was just standing still. Of course this never appears to be the case in nature, for if we slide a block across a table it stops, but that is because it is *not* left to itself—it is rubbing against the table.[44]

Even if one could eliminate friction and air resistance, no place in the universe is gravity-free, and thus a moving body is always being acted upon. Newton's universal law of gravitation indicates that no body would be entirely free from gravity, so that no body would ever move in the complete absence of impressed forces.[45] Also, according to Einstein's general theory of relativity, bodies are always in a gravitational field and are inseparable from the space-time continuum.[46] All bodies, from atoms and pebbles to planets and galaxies, are in gravitational fields. Thus a body is never left completely to itself and is always being acted upon.

As Feynman's block-example illustrates, the principle of inertia involves two parts. One part ("Every body continues in its state of rest, or of uniform motion in a right line") explains the block's continued motion after being released from the hand which threw it, and another part ("unless it is compelled to change that state by forces impressed upon it") explains why the block slows down and eventually stops. Both parts are required, and in practice physicists usually emphasize both parts and their operation together. Thus the actual motions of bodies are composite. One component of a motion arises from a body's inertia, but the other component (or components) of a motion comes from a body's being acted upon.[47]

Since real motions are composites of inertial and other principles, all real motions will involve a continuous actualization of a potency. This continuous actualization of a potency comes to a body from without, as a result of being acted upon. The action of a force indicates a potency in the moveable body. The force acts in

[43]See, for example, Harré, pp. 10–29.

[44]Feynman, *FL* I.9-1.

[45]Newton's universal law of gravitation states that given two masses, m_1 and m_2, the gravitational force between the two bodies is directly proportional to the product of the two masses and inversely proportional to the square of the distance between them. No matter how great the (finite) distance separating two bodies, Newton's law predicts at least some force between them.

[46]Einstein and Infeld, pp. 256–60.

[47]*BP* 109–17. For a detailed Aristotelian analysis of motion as composite, see James Bogen, "Fire in the Belly: Aristotelian Elements, Organisms, and Chemical Compounds," *Pacific Philosophical Quarterly* 76 (1995) 390–95.

a given direction and is ordered to causing a certain resultant state or actuality in the moveable by which it is moved. In accordance with the principle of inertia, forces such as gravity or friction change a moving (or resting) body; but insofar as a body moves in virtue of its inertia, no further potency is actualized, and the body continues moving in virtue of an already actualized potency. Therefore, even though a moving body is changing in some respects, no constant conjoined mover is required to explain the continued motion of bodies once they are separated from the movers which set them in motion. They continue moving in virtue of a previously generated state.

In Aristotelian terminology this state would be called an accidental form. A body in a certain state moves in virtue of an accidental form which has been generated in it. This form, however, is not a mover or some sort of force which makes the body move. Only in living beings is a form a mover. In inanimate bodies it is simply the actuality by which a body immediately and spontaneously acts in characteristic ways.[48] In this way motion is analogous to texture or shape, and as a consequence, no additional conjoined mover is required to keep a body moving throughout its motion. Of course, the analogy is not perfect because motion, unlike texture or shape, is an incomplete form or actuality.[49]

Moving bodies are indeed changing. But insofar as a body is moving in virtue of its inertia, no potency is actualized and thus no mover is required. In those respects, however, in which a moving body is actually changing (*i.e.*, is having some potency reduced to actuality), it is then being acted upon by a force from something else. In any real motion a body's inertia and the efficient causality of other bodies operate together. Thus to require a continuous, conjoined mover would be like requiring an efficient cause continuously to do what has already been done. It would be as if someone always had to be building the first floor of a house while the second and third floors, the roof, and other sections were being built.

Inertia is not to be understood as a mover. If the principle of inertia were interpreted to mean that a body moves itself, then a contradiction would exist between the mover-causality principle and the principle of inertia. But according to Newton, insofar as a body is moving inertially, or in virtue of its state, it is not moving itself. Newton thought that "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."[50]

Newton more fully explains what he means by inertia in a series of definitions and clarifications of key terms which appear in the *Principia* prior to the statement of the first law. According to Newton "The *vis insita*, or inherent force of matter, is a power of resisting, by which every body, as much as in it lies, perseveres in its present state, whether it be of rest, or of moving uniformly forward in a right line."[51] Thus every body possesses an inner, inherent, and natural power by which

[48]For a discussion of motion proceeding spontaneously from form as an active principle, see *NG* 24–28.

[49]Aristotle, *Phys.* III.2.201b31–32.

[50]Newton, *Opticks*, L.III, Q.31, p. 397.

[51]Newton, *Principia*, Def. III, p. 2. I have taken the liberty to alter Motte's translation of "*vis insita*" from "innate" to "inherent." "Inherent" is the translation recommended by I. Bernard Cohen, *Introduction to Newton's 'Principia'* (Harvard Univ. Press, 1971) p. 28 n5.

it naturally continues in and resists changes to its motion or rest.[52] Yet the *vis insita* is a passive power and "differs nothing from the inactivity of mass."[53] Newton identifies this power with the "inert nature of matter" and somewhat paradoxically calls it "inertia (*vis inertiae*) or force of inactivity."[54] Thus a body maintains or preserves its motion or rest in virtue of its inertia, but inertia is not an efficient cause of a body's own motion and does not make a body self-moving.

Like Newton, most physicists would deny that inertial motion is self-motion. According to modern physics movers tend to accelerate, not to preserve, uniform motion. In modern physics inertia is not a self-mover but that property by which a body continues in either motion or rest.[55] Thus physicists use words like drift, coast, and glide to describe a body in inertial motion. If inertia were a mover, then merely to continue moving, as opposed to overcoming resistant objects, would require an expenditure of energy and a change in velocity. A spacecraft (such as Voyager II) moving through space would slow down and eventually come to rest unless it continually fired its rockets. But this is not the case. The spacecraft continues moving year after year with no expenditure of energy.

Since inertia is passive and does not move a body, a body cannot set itself in motion out of its own inertia. Thus its motion must be caused by another. It must be set in motion by another; when it stops, its motion must be halted by another; and any changes in its motion must be effected by another. For example, consider a boy throwing a baseball. The boy throws the ball and thus sets it in motion. Throwing the ball puts it in a certain state in virtue of which it continues moving. In virtue of this state, the ball, once set in motion, continues to move without a continuous, conjoined mover to sustain its motion. Because of its inertia, the ball will tend to persist in its state, to resist changes to its state, and to act and re-act upon impressed forces. Because of these forces (for example, effects of the air) this state—and so the motion of the ball—is continuously altered by a variety of causes and will eventually be eliminated when the ball is stopped by the person who catches it. If the ball is imagined to move up and down like a pop-fly, the omnipresence of forces and the continuous reduction of potency to act is perhaps even clearer. In this example the boy moves the ball; the air moves the ball; the catcher moves the ball; and the Earth's gravity moves the ball. The ball, however, does not move itself, or reduce itself from potency to act. Insofar as it is in a certain state, the ball does act upon the air, the catcher, the boy, and even the Earth. Yet this does not mean that the ball moves itself. It is not self-propelled. It is simply in act, albeit an incomplete act.

[52]By the phrase "as much as in it lies" (*quantum in se est*), Newton meant, among other things, that inertia and inertial motion are natural. See I. B. Cohen, "Newton's Concept of Inertia in Relation to Descartes and Lucretius," *Royal Society of London, Notes and Records* 19 (1964) 148. Newton also calls inertial motion natural. See for example, *Principia*, Def. V, p. 4. That inertia is natural may be seen in a more contemporary example. Even in the weightless environment of an orbiting spacecraft, objects not only persevere in their motions but also still resist efforts to move them. Also, a space-station such as the Mir is easily damaged by a massive but weightless coasting supply-ship. The supply-ship, in virtue of its inertia, acts of itself in certain definite and characteristic ways.

[53]Newton, *Principia*, Def. III, p. 2.

[54]*Ibid.* The sense in which inertia may be said to be a mover or force is that, in persisting in its state, a body resists the actions of impressed forces and acts or reacts upon whatever is acting upon it. For a discussion of the meaning of "vis" in *vis inertiae*, see Cohen, *Newtonian Revolution*, pp. 182–93.

[55]Ohanian, pp. 91–93, 122–23.

In scientific practice, with the exception of quantum mechanics, scientists use the principle of inertia in this threefold way. First, they treat motions as having an efficient, generating cause. Thus, for example, theories of the Moon's origin must account for the inertial component of the Moon's orbit.[56] Second, departures from purely inertial motion are ascribed to some efficient cause. For example, perturbations in Uranus's orbit led to the discovery of Neptune; and in the case of the precession of Mercury's orbit, a new theory of gravity led to the discovery that the Sun—not the hypothetical planet Vulcan—is the cause of this precession. Third, when a motion is stopped, it is considered to be stopped by some efficient cause. This is seen in various explanations for the decay of orbiting satellites and other bodies.

Therefore the principle of inertia is compatible with the mover-causality principle, "whatever is moved is moved by another." Inertial motion requires a mover to initiate a motion but does not require a continuous, conjoined mover throughout a motion. A moving body does not require a continuous, conjoined mover because, insofar as its motion is inertial, it does not involve a reduction from potency to act. Inertial motion is one principle of the real motions that can and do occur in the universe. These motions are composite, and other principles such as gravity and electromagnetism account for the reduction of potency to act in them. Thus, for every reduction from potency to act, there is a mover in accordance with the principle "whatever is moved is moved by another."

[56]John A. Wood, "Moon Over Mauna Loa: A Review of the Hypotheses of the Formation of Earth's Moon" in *The Origin of the Moon*, ed. W. K. Hartmann, R. J. Phillips, and G. J. Taylor (Houston: Lunar and Planetary Institute, 1986) pp. 19–38.