Isaac Newton, *Principia* (1687), "Scholium to Definitions"[1]

Isaac Newton (1642–1727) was the foremost mathematician and natural philosopher of the late seventeenth century. He attended Trinity College, Cambridge, was elected a Fellow in 1667, and succeeded Isaac Barrow as Lucasian Professor of Mathematics in 1669. Newton's great work, The Mathematical Principles of Natural Philosophy *(or* Principia*), published in 1687, was a revision and expansion of several treatises he had previously composed but did not publish. He was elected President of the Royal Society in 1703 and knighted in 1705. During his life he engaged in several bitter priority disputes about scientific and mathematical discoveries—for example, with Robert Hooke in 1686–88 over the inverse square law, and with Leibniz in 1703–15 over the calculus. His influence in the history of science is unequaled and extends well beyond science; of particular consequence are his cosmological remarks from the* Principia.[2]

1. Translated from the Latin by A. Motte in *The Mathematical Principles of Natural Philosophy* . . . (London, 1729), modified.
2. For more on Newton, see Richard W. Westfall, *Never at Rest* (Cambridge: Cambridge University Press, 1980); I. Bernard Cohen, *The Newtonian Revolution* (Cambridge: Cambridge University Press, 1980); or B. J. Dobbs, *The Janus Faces of Genius: The Role of Alchemy in Newton's Thought* (Cambridge: Cambridge University Press, 1991). For an account of the dispute between Newton and Leibniz on the calculus, see A. Rupert Hall, *Philosophers at War* (Cambridge: Cambridge University Press, 1980).

Scholium

Up to now I have defined terms that are less known and explained the sense I would have them understood in the following discourse. I do not define time, space, place, and motion, since they are well known to all. Only I must observe that the common people conceive those quantities under no other notions than from their relation to sensible objects. And from this certain prejudices arise, for the removing of which it will be convenient to distinguish the terms into absolute and relative, true and apparent, mathematical and common.

I. Absolute, true, and mathematical time, of itself, and from its own nature, flows uniformly without relation to anything external, and by another name is called *duration*. Relative, apparent, and common time is some sensible and external (whether accurate or varying in rate) measure of duration by the means of motion, which is commonly used instead of true time, such as an hour, a day, a month, a year.

II. Absolute space, in its own nature, without relation to anything external, always remains similar and immovable. Relative space is some movable dimension or measure of the absolute spaces, which our senses determine by its position to bodies and is commonly taken for immovable space, such as the dimension of subterraneous, aerial, or celestial space, determined by its position with respect to earth. Absolute and relative space are the same in form and magnitude, but they do not always remain numerically the same. For if the earth, for instance, moves, a space of our air, which relatively and with respect to the earth always remains the same, will at one time be one part of the absolute space into which the air passes, at another time it will be another part of the same, and so, absolutely understood, it will be continually changed.

III. Place is a part of space which a body takes up, and is absolute or relative according to the space. I say, a part of space, not the situation nor the external surface of the body. For the places of equal solids are always equal, but their surfaces, by reason of their dissimilar figures, are often unequal. Positions properly have no quantity, nor are they so much the places themselves as the properties of places. The motion of the whole is the same as the sum of the motions of the parts; that is, the translation of the whole out of its place is the same thing as the sum of the translations of the parts out of their places; and therefore the place of the whole is the same as the sum of the places of the parts, and for that reason it is internal and in the whole body.

IV. Absolute motion is the translation of a body from one absolute place into another, and relative motion the translation from one relative place into another. Thus in a ship under sail, the relative place of a body is that part of the ship the body possesses, or that part of the cavity the body fills, and which therefore moves together with the ship; and relative rest is the continuance of the body in the same part of the ship or of its cavity. But real, absolute rest is the continuance of the body in the same part of that immovable space, in which the ship itself, its cavity, and all that it contains, is moved. For that reason, if the earth is really at rest, the body which relatively rests in the ship will really and absolutely move with the same velocity which the ship has on the earth. But if the earth also moves, the true and absolute motion of the body will arise, partly from the true motion of the earth in immovable space, partly from the relative motion of the ship on the earth; and if the body moves also relatively in the ship, its true motion will arise, partly from the true motion of the earth in immovable space, and partly from the relative motions as well of the ship on the earth as of the body in the ship; and from these relative motions will arise the relative motion of the body on the earth. As if that part of the earth, where the ship is, was truly moved towards the east with a velocity of 10,010 units, while the ship itself, with a fresh gale and full sails, is carried towards the west with a velocity expressed by ten of those units, while a sailor walks in the ship towards the east, with one unit of the said velocity, then the sailor will be moved truly in immovable space towards the east with a velocity of 10,001 units, and relatively on the earth towards the west with a velocity of nine of those units.

Absolute time is distinguished from relative in astronomy by the equation or correction of the apparent time. For the natural days are truly unequal, though they are commonly considered as equal and used for a measure of time; astronomers correct this inequality that they may measure the celestial motions by a more accurate time. It may be that there is no such thing as a uniform motion by which time may be accurately measured. All motions may be accelerated and retarded, but the flowing of absolute time is not liable to any change. The duration or perseverance of the existence of things remains the same, whether the motions are swift or slow or none at all; and therefore this duration ought to be distinguished from what are only sensible measures of it, and from which we deduce it by means of the astronomical equation. The necessity of this equation for determining the times of a phenomenon is established as well from the experiments of the pendulum clock as by eclipses of the satellites of Jupiter.

As the order of the parts of time is immutable, so also is the order of the parts of space. Suppose those parts to be moved out of their places, and they will be moved (if the expression may be allowed) out of themselves. For times and spaces are, as it were, the places as well of themselves as of all other things. All things are placed in time as to order of succession, and in space as to order of situation. It is from their essence or nature that they are places, and it is absurd that the primary places of things should be movable. These are therefore the absolute places, and translations out of those places are the only absolute motions.

But because the parts of space cannot be seen or distinguished from one another by our senses, we use sensible measures of them in their stead. For from the positions and distances of things from any body considered as immovable, we define all places, and then with respect to such places, we estimate all motions, considering bodies as transferred from some of those places into others. And so, instead of absolute places and motions, we use relative ones, and that without any inconvenience in common affairs; but in philosophical disquisitions, we ought to abstract from our senses and consider things themselves, distinct from what are only sensible measures of them. For it may be that there is no body really at rest to which the places and motions of others may be referred.

But we may distinguish rest and motion, absolute and relative, one from the other by their properties, causes, and effects. It is a property of rest that bodies really at rest do rest in respect to one another. And therefore as it is possible that in the remote regions of the fixed stars, or perhaps far beyond them, there may be some body absolutely at rest, but impossible to know, from the position of bodies to one another in our regions, whether any of these do keep the same position to that remote body, it follows that absolute rest cannot be determined from the position of bodies in our regions.

It is a property of motion that the parts, which retain given positions to their wholes, do partake of the motions of those wholes. For all the parts of revolving bodies endeavor to recede from the axis of motion, and the impetus of bodies moving forwards arises from the joint impetus of all the parts. Therefore, if surrounding bodies are moved, those that are relatively at rest within them will partake of their motion. Because of this, the true and absolute motion of a body cannot be determined by the translation of it from those which only seem to rest; for the external bodies should not only appear at rest, but be really at rest. For otherwise, all included bodies, besides their translation from near the surrounding ones, partake likewise of their true motions; and though that translation were not made, they would not be really at rest, but only seem to be so. For the surrounding bodies stand in the like relation to the surrounded as the exterior part of a whole does to the interior, or as the shell does to the kernel; but if the shell moves, the kernel will also move, as being part of the whole, without any removal from near the shell.

A property related to the preceding is that if a place is moved, whatever is placed in it moves along with it; and therefore a body which is moved from a place in motion partakes also of the motion of its place. Upon which account, all motions, from places in motion, are no other than parts of entire and absolute motions, and every entire motion is composed of the motion of the body out of its first place, and the motion of this place out of its place, and so on, until we come to some immovable place, as in the aforementioned example of the sailor. Because of this, entire and absolute motions can be no otherwise determined than by immovable places; and for that reason I did before refer those absolute motions to immovable places, but relative ones to movable places. Now no other places are immovable but those that, from infinity to infinity, do all retain the same given position one to another, and upon this account must ever remain unmoved, and do as a result constitute immovable space.

The causes by which true and relative motions are distinguished from one another are the forces impressed upon bodies to generate motion. True motion is neither generated nor altered, but by some force impressed upon the body moved; but relative motion may be generated or altered without any force impressed upon the body. For it is sufficient only to impress some force on other bodies with which the former is compared, that by their giving way, that relation in which the relative rest or motion of this other body did consist may be changed. Again, true motion always suffers some change from any force impressed upon the moving body; but relative motion does not necessarily undergo any change by such forces. For if the same forces are likewise impressed on those other bodies, with which the comparison is made, that the relative position may be preserved, then that condition will be preserved in which the relative motion consists. And therefore any relative motion may be changed when the true motion remains unaltered, and the relative may be preserved when the true suffers some change. Thus, true motion by no means consists in such relations.

The effects which distinguish absolute from relative motion are the forces of receding from the axis of circular motion. For there are no such forces in a circular motion purely relative, but in a true and absolute circular motion, they are greater or less, according to the quantity of the motion. If a vessel hung by a long cord is so often turned about that the cord is strongly twisted, then filled with water and held at rest together with the water, at once, by the sudden action of another force, it is whirled about the contrary way, and while the cord is untwisting itself, the vessel continues for some time in this motion, the surface of the water will at first be even, as before the vessel began to move; but after that the vessel, by gradually communicating its motion to the water, will make it begin to revolve sensibly and recede gradually from the middle, and ascend to the sides of the vessel, forming itself into a concave figure (as I have experienced); and the swifter the motion becomes, the higher will the water rise, until at last, performing its revolutions in the same times with the vessel, it becomes relatively at rest in it. This ascent of the water shows its endeavor to recede from the axis of its motion, and the true and absolute circular motion of the water, which is here directly contrary to the relative, becomes known and may be measured by this endeavor. At first, when the relative motion of the water in the vessel was greatest, it produced no endeavor to recede from the axis; the water showed no tendency to the circumference, nor any ascent towards the sides of the vessel, but remained of an even surface, and therefore its true circular motion had not yet begun. But afterwards, when the relative motion of the water had decreased, its ascent towards the sides of the vessel proved its endeavor to recede from the axis; and this endeavor showed the real circular motion of the water continually increasing, until it had acquired its greatest quantity when the water rested relatively in the vessel. And therefore this endeavor does not depend upon any translation of the water in respect of the ambient bodies, nor can true circular motion be defined by such translation. There is only one real circular motion of any one revolving body corresponding to only one power of endeavoring to recede from its axis of motion as its proper and adequate effect; but relative motions in one and the same body are innumerable, according to the various relations it bears to external bodies, and like other relations are altogether destitute of any real effect, except insofar as they may perhaps partake of that unique true motion. And therefore in the system of those who suppose that our heavens revolving below the sphere of the fixed stars carry the planets along with them, the several parts of those heavens and the planets, which are indeed relatively at rest in their heavens, do yet really move. For they change their position one to another (which never happens to bodies truly at rest), and being carried together with their heavens, partake of their motions, and as parts of revolving wholes, endeavor to recede from the axis of their motions. For that reason relative quantities are not the quantities themselves, whose names they bear, but those sensible measures of them (either accurate or inaccurate), which are commonly used instead of the measured quantities themselves. And if the meaning of words is to be determined by their use, then by the names time, space, place, and motion, their sensible measures are properly to be understood; and the expression will be unusual, and purely mathematical, if the measured quantities themselves are meant. On this account, those who interpret these words for the measured quantities violate the accuracy of language, which ought to be kept precise. Nor do those who confound real quantities with their relations and sensible measure defile the purity of mathematical and philosophical truths any less.

It is indeed a matter of great difficulty to discover and effectually to distinguish the true motions of particular bodies from the apparent, because the parts of that immovable space in which those motions are performed do by no means come under the observation of our senses. Yet the thing is not altogether desperate; for we have some arguments to guide us, partly from the apparent motions, which are the differences of the true motions, partly from the forces, which are the causes and effects of the true motions.

For instance, if two globes, kept at a given distance one from the other by means of a cord that connects them, were revolved about their common center of gravity, we might, from the tension of the cord, discover the endeavor of the globes to recede from the axis of their motion, and from thence we might compute the quantity of their circular motions. And then if any equal forces should be impressed at once on the alternate faces of the globes to augment or diminish their circular motions, from the increase or decrease of the tension of the cord, we might infer the increment or decrement of their motions; and hence would be found on what faces those forces ought to be impressed, that the motions of the globes might be most augmented; that is, we might discover their hindmost faces, or those which do follow in the circular motion. But the faces which follow being known, and consequently the opposite ones that precede, we should likewise know the determination of their motions. And thus we might find both the quantity and the determination of this circular motion, even in an immense vacuum, where there was nothing external or sensible with which the globes could be compared. But now, if some remote bodies that kept always a given position one to another were placed in that space, as the fixed stars do in our regions, we could not indeed determine from the relative translation of the globes among those bodies, whether the motion did belong to the globes or to the bodies. But if we observed the cord and found that its tension was that very tension which the motions of the globes required, we might conclude the motion to be in the globes and the bodies to be at rest; and then, lastly, from the translation of the globes among the bodies, we should find the determination of their motions. But how we are to obtain the true motions from their causes, effects, and apparent differences, and the converse, shall be explained more at large in the following treatise. For to this end it was that I composed it.