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ISAAC NEWTON



THE *PRINCIPIA*

Mathematical Principles of Natural Philosophy



A New Translation

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Preceded by

A GUIDE TO NEWTON'S *PRINCIPIA*

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GENERAL SCHOLIUM^a



The hypothesis of vortices is beset with many difficulties. If, by a radius drawn to the sun, each and every planet is to describe areas proportional to the time, the periodic times of the parts of the vortex must be as the squares of the distances from the sun. If the periodic times of the planets are to be as the $\frac{3}{2}$ powers of the distances from the sun,^b the periodic times of the parts of the vortex must be as the $\frac{3}{2}$ powers of the distances. If the smaller vortices revolving about Saturn, Jupiter, and the other planets are to be preserved and are to float without agitation in the vortex of the sun, the periodic times of the parts of the solar vortex must be the same. The axial revolutions [i.e., rotations] of the sun and planets, ^bwhich would have to agree with the motions of their vortices,” differ from all these proportions. The motions of comets are extremely regular, observe the same laws as the motions of planets, and cannot be explained by vortices. Comets go with very eccentric motions into all parts of the heavens, which cannot happen unless vortices are eliminated.

The only resistance which projectiles encounter in our air is from the air. With the air removed, as it is in Boyle’s vacuum, resistance ceases, since a tenuous feather and solid gold fall with equal velocity in such a vacuum. And the case is the same for the celestial spaces, which are above the atmosphere

a. Ed. 1 lacks the General Scholium, which includes Newton’s famous discussions of God and of hypotheses. This scholium is first printed in ed. 2 but is documented further by its changing versions in five extant earlier holograph drafts and is treated also in contemporaneous correspondence between Newton and Roger Cotes, editor of ed. 2. For details see *Unpublished Scientific Papers of Isaac Newton*, ed. A. Rupert Hall and Marie Boas Hall (Cambridge: Cambridge University Press, 1962), pp. 348–364; I. Bernard Cohen, *Introduction to Newton? “Principia”* (Cambridge, Mass.: Harvard University Press; Cambridge: Cambridge University Press, 1971), pp. 240–245.

bb. Ed. 2 lacks this.

of the earth. All bodies must move very freely in these spaces, and therefore planets and comets must revolve continually in orbits given in kind and in position, according to the laws set forth above. They will indeed persevere in their orbits by the laws of gravity, but they certainly could not originally have acquired the regular position of the orbits by these laws.

The six primary planets revolve about the sun in circles concentric with the sun, with the same direction of motion, and very nearly in the same plane. Ten moons revolve about the earth, Jupiter, and Saturn in concentric circles, with the same direction of motion, very nearly in the planes of the orbits of the planets. And all these regular motions do not have their origin in mechanical causes, since comets go freely in very eccentric orbits and into all parts of the heavens. And with this kind of motion the comets pass very swiftly and very easily through the orbits of the planets; and in their aphelia, where they are slower and spend a longer time, they are at the greatest possible distance from one another, so as to attract one another as little as possible.

This most elegant system of the sun, planets, and comets could not have arisen without the design and dominion of an intelligent and powerful being. And if the fixed stars are the centers of similar systems, they will all be constructed according to a similar design and subject to the dominion of *One*, especially since the light of the fixed stars is of the same nature as the light of the sun, and all the systems send light into all the others. “And so that the systems of the fixed stars will not fall upon one another as a result of their gravity, he has placed them at immense distances from one another.”^c

He rules all things, not as the world soul but as the lord of all. And because of his dominion he is called Lord God *Pantokrator*^d. For “god” is a relative word and has reference to servants, and godhood^e “is the lordship of God, not over his own body^f as is supposed by those for whom God is the world soul^f, but over servants. The supreme God is an eternal, infinite, and absolutely perfect being; but a being, however perfect, without dominion is

cc. Ed. 2 lacks this.

d. Newton’s note a: “That is, universal ruler.”

e. Newton here uses the word “deitas,” a nonclassical term which signifies the essential nature of the divinity or “god-ness.” Although “Godhead” does fit, the term “godhood” (which is more abstract) may more accurately convey the sense of Newton’s “deitas.”

ff. Ed. 2 lacks this.

not the Lord God. For we do say my God, your God, the God of Israel, the God of Gods, and Lord of Lords, but we do not say my eternal one, your eternal one, the eternal one of Israel, the eternal one of the gods; we do not say my infinite one, or my perfect one. These designations [i.e., eternal, infinite, perfect] do not have reference to servants. The word “god” is used far and wide to mean “lord,”^g but every lord is not a god. The lordship of a spiritual being constitutes a god, a true lordship constitutes a true god, a supreme lordship a supreme god, an imaginary lordship an imaginary god. And from true lordship it follows that the true God is living, intelligent, and powerful; from the other perfections, that he is supreme, or supremely perfect. He is eternal and infinite, omnipotent and omniscient, that is, he endures from eternity to eternity, and he is present from infinity to infinity; he rules all things, and he knows all things that happen or can happen. He is not eternity and infinity, but eternal and infinite; he is not duration and space, but he endures and is present. He endures always and is present everywhere, and by existing always and everywhere he constitutes duration and ^hspace.^h Since each and every particle of space is *always*, and each and every indivisible moment of duration is *everywhere*, certainly the maker and lord of all things will not be *never* or *nowhere*.

‘Every sentient soul, at different times and in different organs of senses and motions, is the same indivisible person. There are parts that are successive in duration and coexistent in space, but neither of these exist in the person of man or in his thinking principle, and much less in the thinking substance of God. Every man, insofar as he is a thing that has senses, is one and the same man throughout his lifetime in each and every organ of his senses. God is one and the same God always and everywhere.’ He is omnipresent not only *virtually* but also *substantially*; for action requires substance [*lit.* for active power [virtus] cannot subsist without substance]. In him all things are contained and move,] but he does not act on them nor they on him. God

g. Newton’s note b, which ed. 2 lacks: “Our fellow countryman Pocock derives the word ‘deus’ from the Arabic word ‘du’ (and in the oblique case ‘di’), which means lord. And in this sense princes are called gods, Psalms 82.6 and John 10.35. And Moses is called a god of his brother Aaron and a god of king Pharaoh (Exod. 4.16 and 7.1). And in the same sense the souls of dead princes were formerly called gods by the heathen, but wrongly because of their lack of dominion.”

hh. Ed. 2 has “space, eternity, and infinity.”

ii. Ed. 2 lacks this.

j. Newton’s note c: “This opinion was held by the ancients: for example, by Pythagoras as cited in Cicero, *On the Nature of the Gods*, book 1; Thales; Anaxagoras; Virgil, *Georgics*, book 4, v. 221, and *Aeneid*,

experiences nothing from the motions of bodies; the bodies feel no resistance from God's omnipresence.

It is agreed that the supreme God necessarily exists, and by the same necessity he is *always* and *everywhere*. It follows that all of him is like himself: he is all eye, all ear, all brain, all arm, all force of sensing, of understanding, and of acting, but in a way not at all human, in a way not at all corporeal, in a way utterly unknown to us. As a blind man has no idea of colors, so we have no idea of the ways in which the most wise God senses and understands all things. He totally lacks any body and corporeal shape, and so he cannot be seen or heard or touched, nor ought he to be worshiped in the form of something corporeal. We have ideas of his attributes, but we certainly do not know what is the substance of any thing. We see only the shapes and colors of bodies, we hear only their sounds, we touch only their external surfaces, we smell only their odors, and we taste their flavors. But there is no direct sense and there are no indirect reflected actions by which we know innermost substances; much less do we have an idea of the substance of God. We know him only by his properties and attributes and by the wisest and best construction of things and their final causes,^k and we admire him because of his perfections;^k but we venerate and worship him because of his dominion. 'For we worship him as servants, and a god' without dominion, providence, and final causes is nothing other than fate and nature. "No variation in things arises from blind metaphysical necessity, which must be the same always and everywhere. All the diversity of created things, each in its place and time, could only have arisen from the ideas and the will of a necessarily existing being. But God is said allegorically to see, hear, speak, laugh, love, hate, desire, give, receive, rejoice, be angry, fight, build, form, construct. For all discourse about God is derived through a certain similitude

book 6, v. 726; Philo, *Allegorical Interpretation*, book 1, near the beginning; Aratus in the *Phenomena*, near the beginning. Also by the sacred writers: for example, Paul in Acts 17.27, 28; John in his Gospel 14.2; Moses in Deuteronomy 4.39 and 10.14; David, Psalms 139.7, 8, 9; Solomon, 1 Kings 8.27; Job 22.12, 13, 14; Jeremiah 23.23, 24. Moreover idolators imagined that the sun, moon, and stars, the souls of men, and other parts of the world were parts of the supreme god and so were to be worshiped, but they were mistaken." In ed. 2 this note reads: "This opinion was held by the ancients: Aratus in the *Phenomena*, near the beginning; Paul in Acts 7.27, 28; Moses, Deuteronomy 4.39 and 10.14; David, Psalms 139.7, 8; Solomon, Kings 8.27; Job 22.12; the prophet Jeremiah, 23.23, 24."

kk. Ed. 2 lacks this.

ll. Ed. 2 has: "For a god."

mm. Ed. 2 lacks this.

from things human, which while not perfect is nevertheless a similitude of some kind.” This concludes the discussion of God, and to treat of God from phenomena is certainly a part of ⁿnaturalⁿ philosophy.

Thus far I have explained the phenomena of the heavens and of our sea by the force of gravity, but I have not yet assigned a cause to gravity. Indeed, this force arises from some cause that penetrates as far as the centers of the sun and planets without any diminution of its power to act, and that acts not in proportion to the quantity of the *surfaces* of the particles on which it acts (as mechanical causes are wont to do) but in proportion to the quantity of *solid* matter, and whose action is extended everywhere to immense distances, always decreasing as the squares of the distances. Gravity toward the sun is compounded of the gravities toward the individual particles of the sun, and at increasing distances from the sun decreases exactly as the squares of the distances as far out as the orbit of Saturn, as is manifest from the fact that the aphelia of the planets are at rest, and even as far as the farthest aphelia of the comets, provided that those aphelia are at rest. I have not as yet been able to deduce from phenomena the reason for these properties of gravity, and I do not “feign” hypotheses. For whatever is not deduced from the phenomena must be called a hypothesis; and hypotheses, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy. In this experimental philosophy, propositions are deduced from the phenomena and are made general by induction. The impenetrability, mobility, and impetus of bodies, and the laws of motion and the law of gravity have been found by this method. And it is enough that gravity really exists and acts according to the laws that we have set forth and ‘is sufficient to explain all the motions of the heavenly bodies and of our sea.

PA few things could now be added concerning a certain very subtle spirit pervading gross bodies and lying hidden in them; by its force and actions, the particles of bodies attract one another at very small distances and cohere when

nn. Ed. 2 has “experimental.”

oo. The word “fingo” in Newton’s famous declaration, “Hypotheses non fingo,” appears to be the Latin equivalent of the English word “feign.” Andrew Motte translated “fingo” by “frame,” a verb which at that time could have a pejorative sense. For details see the Guide, §9.1.

pp. The final paragraph of the General Scholium has attracted much scholarly attention, notably in an effort to discern what Newton intended (in the opening and closing sentences) by a “spirit” which may

they become contiguous; and electrical [i.e., electrified] bodies act at greater distances, repelling as well as attracting neighboring corpuscles; and light is emitted, reflected, refracted, inflected, and heats bodies; and all sensation is excited, and the limbs of animals move at command of the will, namely, by the vibrations of this spirit being propagated through the solid fibers of the nerves from the external organs of the senses to the brain and from the brain into the muscles. But these things cannot be explained in a few words; furthermore, there is not a sufficient number of experiments to determine and demonstrate accurately the laws governing the actions of this spirit.^p

be operative in various types of phenomena. It might even appear that Newton was here introducing a speculation—we dare not call it a hypothesis—although Newton’s actual language indicates that for him there was no question about whether this spirit “really” exists, only about the laws according to which this spirit acts.

A puzzle relating to the interpretation of this “spirit” is the appearance of the qualifying adjectives “electric and elastic,” introduced in the original Motte translation and retained in the Motte-Cajori version. Although these words are not found in either the second or the third Latin editions, they have a Newtonian provenience since they occur in Newton’s personal interleaved copy of the second edition as one of the proposed emendations. Furthermore, thanks to the research of A. Rupert Hall and Marie Boas Hall, we know that the spirit in question is indeed “electrical.” In particular, as Newton worked toward the second edition of the *Principia*, he composed various drafts of proposed conclusions which, together with other manuscripts, provide evidence for the importance of electrical phenomena in his thinking about gravity during the years 1711–1713. For details see the Guide to the present translation, §9.3.

One possible reason why Newton decided not to insert the qualifying phrase “electric and elastic” into the text of the third edition (1726) is that in his interleaved copy of the second edition he has finally drawn a line through the whole paragraph, showing his intention of deleting it in a third edition. The reason for this decision seems to be that some time after 1713 Newton lost his enthusiasm for electricity as a possible agent in gravitation.

We may readily understand why Newton omitted to carry out either the revision or the proposed cancellation of the final paragraph. By the time that the third edition was fully printed, in about February 1726, Newton and Pemberton had spent several years revising the text and reading the proofs and Newton was within a little more than a year of his death. When Newton reached the last paragraph he was probably so weary that he overlooked his proposed alteration of the conclusion.

The third edition concludes with an “Index Rerum Alphabeticus” (pp. 531–536) and an advertisement of books sold by William and John Innys (pp. 537–538).