The New Physics

Roger Cotes

English astronomer and mathematician Roger Cotes (1682-1716) wrote the preface to the second edition of Newton's Principia in 1713, *from which this section is taken.*

Those who have treated of natural philosophy may be nearly reduced to three classes. Of these some have attributed to the several species of things specific and occult qualities, on which, in a manner unknown, they make the operations of the several bodies to depend. The sum of the doctrine of the Schools derived from Aristotle and the Peripatetics is herein contained. They affirm that the several effects of bodies arise from the particular natures of those bodies. But whence it is that bodies derive those natures they don't tell us; and therefore they tell us nothing. And being entirely employed in giving names to things, and not in searching into things themselves, we may say that they have invented a philosophical way of speaking, but not that they have made known to us true philosophy....

There is left then the third class, which profess experimental philosophy. These indeed derive the causes of all things from the most simple principles possible; but then they assume nothing as a principle that is not proved by phenomena. They frame no hypotheses, nor receive them into philosophy otherwise than as questions whose truth may be disputed. They proceed therefore in a twofold method, synthetical and analytical. From some select phenomena they deduce by analysis the forces of nature, and the more simple laws of forces; and from thence by synthesis show the constitution of the rest. This is that incomparably best way of philosophizing, which our renowned author most justly embraced before the rest; and thought alone worthy to be cultivated and adorned by his excellent labors. Of this he has given us a most illustrious example, by the explication of the System of the World, most happily deduced from the Theory of Gravity. That the virtue of gravity was found in all bodies, others suspected, or imagined before him; but he was the only and the first philosopher that could demonstrate it from appearances, and make it a solid foundation to the most noble speculations.

Therefore that we may begin our reasoning from what is most simple and nearest to us, let us consider a little what is the nature of gravity with us on Earth, that we may proceed the more safely when we come to consider it in the heavenly bodies that lie at so vast a distance from us. It is now agreed by all philosophers

that all circumterrestrial bodies gravitate towards the Earth. That no bodies really light are to be found is now confirmed by manifold experience. That which is relative levity is not true levity, but apparent only, and arises from the preponderating gravity of the contiguous bodies.

Moreover, as all bodies gravitate towards the Earth, so does the Earth again towards bodies. That the action of gravity is mutual, and equal on both sides, is thus proved....

This is the nature of gravity upon Earth; let us now see what it is in the Heavens.

That every body perseveres in its state either of rest, or of moving uniformly in a right line, unless insofar as it is compelled to change that state by forces impressed, is a law of nature universally received by all philosophers. But from thence it follows that bodies which move in curve lines, and are therefore continually going off from the right lines that are tangents to their orbits, are by some continued force retained in those curvilinear paths. Since then the planets move in curvilinear orbits, there must be some force operating by whose repeated actions they are perpetually made to deflect from the tangents....

From what has been hitherto said, it is plain that the planets are retained in their orbits by some force perpetually acting upon them; it is plain that that force is always directed towards the centers of their orbits; it is plain that its efficacy is augmented with the nearness to the center, and diminished with the same; and that it is augmented in the same proportion with which the square of the distance is diminished, and diminished in the same proportion with which the square of the distance is augmented....

Because the revolutions of the primary planets about the Sun, and of the secondary about Jupiter and Saturn, are phenomena of the same kind with the revolution of the Moon about the Earth; and because it has been moreover demonstrated that the centripetal forces of the primary planets are directed towards the center of the Sun, and those of the secondary towards the centers of Jupiter and Saturn, in the same manner as the centripetal force of the Moon is directed towards the center of the Earth; and since besides, all these forces are reciprocally as the squares of the distances from the centers, in the same manner as the centripetal force of the Moon is as the square of the distance from the Earth; we must of course conclude that the nature of all is the same. Therefore as the Moon gravitates towards the Earth, and the Earth again towards the Moon; so also all the secondary planets will gravitate towards their primary, and the primary planets again towards their secondary; and so all the primary towards the Sun; and the Sun again towards the primary.

Therefore the Sun gravitates towards all the planets, and all the planets towards the Sun....

That the attractive virtue of the Sun is propagated on all sides to prodigious

distances, and is diffused to every part of the wide space that surrounds it, is most evidently shown by the motion of the comets; which coming from places immensely distant from the Sun, approach very near to it; and sometimes so near, that in their perihelia they almost touch its body. The theory of these bodies was altogether unknown to astronomers, till in our own times our excellent author most happily discovered it, and demonstrated the truth of it by most certain observations. So that it is now apparent that the comets move in conic sections having their foci in the Sun's center, and by radii drawn to the Sun describe areas proportional to the times. But from these phenomena it is manifest, and mathematically demonstrated, that those forces, by which the comets are retained in their orbits, respect the Sun, and are reciprocally proportional to the squares of the distances from its center. Therefore the comets gravitate towards the Sun; and therefore the attractive force of the Sun not only acts on the bodies of the planets, placed at given distances and very nearly in the same plane, but reaches also to the comets in the most different parts of the heavens, and at the most different distances. This therefore is the nature of gravitating bodies, to propagate their force at all distances to all other gravitating bodies.

The foregoing conclusions are grounded on this axiom which is received by all philosophers; namely that effects of the same kind, that is, whose known properties are the same, take their rise from the same causes and have the same unknown properties also. For who doubts, if gravity be the cause of the descent of a stone in Europe, but that it is also the cause of the same descent in America? ...

Since then all bodies, whether upon Earth or in the heavens, are heavy, so far as we can make any experiments or observations concerning them; we must certainly allow that gravity is found in all bodies universally. And in like manner as we ought not to suppose that any bodies can be otherwise than extended, moveable or impenetrable, so we ought not to conceive that any bodies can be otherwise than heavy. The extension, mobility, and impenetrability of bodies become known to us only by experiments; and in the very same manner their gravity becomes known to us. All bodies we can make any observations upon are extended, moveable, and impenetrable; and thence we conclude all bodies, and those we have no observations concerning, to be extended and moveable and impenetrable. So all bodies we can make observations on we find to be heavy; and thence we conclude all bodies, and those we have no observations of, to be heavy also. If anyone should say that the bodies of the fixed stars are not heavy because their gravity is not yet observed; they may say for the same reason that they are neither ex,tended nor moveable nor impenetrable, because these affections of the fixed stars are not yet observed. In short, either gravity must have a place among the primary qualities of all bodies, or extension, mobility and impenetrability must not.