NEWTON AND THE NEW DIRECTION IN SCIENCE

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GOD IN THE PROJECT OF NEWTONIAN MECHANICS

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Professor Edward Strong of the University of California at Berkeley represented a lengthy tradition in Newtonian scholarship when he maintained that a significant division exists between the mechanical inquiry of the *Philosophiae Naturalis Principia Mathematica* and those texts in its later redactions which introduce theological considerations. God is only brought into its later editions, contended Strong, probably at the suggestions of the editor of its second edition, Roger Cotes. This "religious addendum" to the *Principia* and also to the subsequent Queries of the *Opticks* should not be confused with the project of mechanics. They are and remain separate *genres* which Newton himself did not confuse.[1] That extraordinary metaphysical genius to whom Newton was in so many ways indebted, Dr. Samuel Clarke, "might have prompted Newton to relax his caution as scientist to the extent of including ideas about God in a work on optics, albeit under the heading of Queries," while the General Scholium takes up the existence of god at the end of the *Principia* to ward off the suspicion of atheism.[2] "Theological speculation does not come within the compass of scientific knowledge," wrote Strong, agreeing with G. S. Brett that the divine activity described in the General Scholium issues out of faith, not out of the knowledge proper to mechanics.[3] Professor Strong's challenging essay provides the two questions for the brief reflections of the following pages: [1] With what legitimacy does the theological question emerge in Newtonian mechanics? [2] How does Newton move methodologically to its resolution?

The Theological Question in Newton's Mechanics

A study of the gradual formation of the text of the *Principia* will indicate that Newton did not introduce the notion of god or of divine providence only into later editions of the *Principia*.[4] As early as the review of the first edition of the *Principia* in the *Acta Eruditorum*, June 1688, an anonymous critic had singled out Newton's introduction of god as responsible for the mathematical exactitudes of the system of the Universe: "From which he [Newton] concludes that God placed the Planets at different distances from the Sun, so that they would receive heat from the Sun according to the proportion of their densities."[5] Far from being a later introduction into the *Principia* as Strong contends, or an interest evoked only in later life as Laplace and J.-B. Biot have asserted, the

theological issue was with the *Principia* even before its first edition, and it figured among Newton's interests precisely as appropriate within an elaboration of the system of the universe. It was of the first edition that Newton assured Bentley: "When I wrote my treatise about our *Systeme* I had an eye upon such Principles as might work with considering men for the beliefe of a Deity." [6] Whatever would occur by way of General Scholium in the second edition or by way of Queries in the *Opticks*, the link between the System of the World and the theological interests of Newton was long since established from the very beginning.

The Third Book of the *Principia* had brought the astronomical embodiment of the new mechanics to an end, but to an end which did not read completion. Two critical problems still pressed for treatment: One emerged out of the structure or pattern which marked Newtonian method, a system of the universe had been logistically constructed; the other was born with the mechanical enterprise itself, with the imperative of differentiating true from false motions within their conditions of absolute space and absolute time. The first of these problems appeared only after the system of the world had been established. The second presented itself as prior, lying at the basis of any true mechanics and antecedent to any systematization of celestial mechanics. The first was that of system; the second was that of absolute space and absolute time. The two together spelled out the problematic of the General Scholium which was appended to the second and third editions of the *Principia*.

Mechanics had distinguished two types of force: the inertial force which was identified with mass and the impressed force which effected change. Inertial force was the power of resisting change. It was the power by which a body would persevere (*perseverat*) in its state of rest or of moving uniformly in a straight line. Impressed told upon inertial forces; they compelled an alteration in velocity or a change in direction. What was more, inertial force would only reveal itself as it resisted impressed force. Force was the key to all movement.

The parallelogram of forces had provided the means by which this key could be used. Complex motions could be broken down into the simple motions. These motions, in turn, could be understood only by reducing them to the impressed or motive forces which gave them birth. Inertial forces could explain continuance; impressed forces explained the motion which inertial force conserved and the direction which it kept. Further, the composition of forces allowed for a self-sustaining system of bodies to emerge, one in which the momentum would be constant and in which a common center of gravity would exist around which the mass-units would revolve. This center of gravity gives such unity to these masses with their varied movements that "*est igitur systematis corporum plurium lex eadem, quae corporis solitarii, quoad perseverantiam in statu motus vel quietis*, there is the same law in a system of many bodies as there is in a single body, regarding its perseverance in a state of motion or of rest." [7] In a system, all of the forces which keep the structure in its present state, whether of rest or of rectilinear motion, are now inertial forces.

Thus what constitute impressed or motive force within the Newtonian system, now become inertial forces which sustain the system as a whole from outside and countered alien impressed forces. The gravitational attraction of the sun, for example, is a motive force on the planets, consistently pulling the great masses into an orbit around it. But when the solar system is looked at as a whole, gravitational attractions as well as the inertial forces of each of the planets, all are assimilated into the inertial forces which sustain the system in its continuance. Therefore the question which a system poses is the same as the problem which any movement of any body raises: what lies at the origin of its compound movements?

When Professor Strong maintained that the theological inquiry indicated a shift from the scientific mechanics of Newton into an acceptable but essentially different concern, his assertion failed to reckon that the consistency of the mechanical methodology is involved.[8] The intelligibility of a compound movement is found through analytic resolution into its causes and these causes or forces are generalized through induction. Newtonian mechanics never maintained that mechanics had to reduce everything to mechanical causes; on the contrary, it explicitly repudiated this Cartesian procedure. It did demand a coherence of procedure that one should not cut off the analytic method arbitrarily through hypotheses. In fact, for Newton these two inconsistencies coalesce: the arbitrary termination of analysis and synthesis and the elaboration of simply mechanical causes. The only way that one can arbitrarily terminate the process of mechanical analysis is by the fabrication of a gratuitous mechanical cause. Newton understood this as the cardinal sin of Cartesian mechanics. The ancients allowed for atoms, and the void, and for the gravity of atoms as the principles of their physics, while "tacitly attributing Gravity to some other Cause than dense Matter. Later Philosophers banished the Consideration of such a Cause out of natural Philosophy, *feigning Hypotheses for explaining all things mechanically*, and referring other Causes to Metaphysicks." These later philosophers are the Continental Cartesians, and they are wrong on both counts: "the main Business of natural Philosophy is to argue from Phaenomena without feigning Hypotheses, and to deduce Causes from Effects, till we come to the very first Cause, which certainly is not Mechanical."[9] This assertion is repeated too many times during those discussions which Newton entertains about the proper methodology of experimental philosophy to doubt its authenticity. Mechanics, for Newton, does not end finally in a mechanical principle, but in one "very well skilled in Mechanicks and Geometry."[10] This is not an arbitrary statement. It issues from the intrinsic needs of consistent method.

The problem about the origins of system could only emerge at the end of the *Principia*, but the problem about absolute space and absolute time was with Newtonian mechanics from its initial pages. Newton had distinguished absolute motion from relative motion as the translation of a body from one absolute place to another. Absolute place constituted a part of absolute space and absolute time was the duration — independent of

any measurement — in which this translation took place. If there was absolute motion, there had to be absolute space and time. One could determine that there was absolute motion, one not simply measured by circumferential bodies, by its effect, i.e., by the forces of receding from the axis of circular motion. Newton's experiment with the two globes demonstrated that true motion did exist, which meant that absolute space and absolute time existed in which such a motion would exist. As the final conditions of all motion, absolute space and absolute time could not themselves be changed, i.e., could not be moved. Hence absolute space has a duration that is eternal — there was no time in which it was other than it is; space was also infinite — there was nothing within which it was contained. Immutable space existed "from infinity to infinity." [11] Neither can be determined by observation; both enter definitionally as the conditions for the possibility of absolute motion providing the entire problematic of the *Principia*:

> "But how we are to obtain the true motions from their causes, effects, and apparent difference, and the converse, shall be explained more at large in the following treatise. For to this end it was that I composed it." [12]

Not only was Newtonian mechanics beginning its inquiry, it was also eliciting a row — and a row about theology at that. In 1710, George Berkeley, fellow and lecturer of Trinity college, launched his massive attack on the materialists, *A Treatise concerning the Principles of Human Knowledge*. He takes up the basic doctrine of the *Principia*, "a certain celebrated treatise of *mechanics*: in the entrance of which justly admired treatise, time, space, and motion, are distinguished into *absolute* and *relative*, *true* and *apparent*, *mathematical* and *vulgar*; which distinction, as it is at large explained by the author, doth suppose those quantities to have an existence without the mind; and that they are ordinarily conceived with relation to sensible things, to which nevertheless, in their own nature, they bear no relation at all." [13] Berkeley's reservations about these Newtonian coordinates issued both from his own philosophy and from the implications of Newton's. The "New Principle" of Berkeley's treatise collapsed the distinction between *esse* and *percipi*. Newton's distinction between the absolute and relative space, then, would make no sense. What is imperceptible has no reality. But theologically, the issue can be lodged even on Newtonian terms. The *Principia* is left with a dangerous dilemma: "to wit, of thinking either that real space is God, or else that there is something beside God which is eternal, uncreated, infinite, indivisible, immutable. Both of which may just be thought pernicious and absurd notions." [14] What Bishop Berkeley is saying is this: If space is unchangeable and thus eternal, uncontained and thus infinite, then you have a radical theological issue. Either space is god, since it shares the predicates which are classically reserved to god, or you have something other than god which possesses these divine attributes.

To have a true mechanics, there must be true motions, absolute movements whose causative forces can be analyzed and whose subsequent orbits can be charted. There must be absolute space in which these occur. Otherwise locomotion is a contradiction in terms or is always simply relative to the perceiver. If this space is final and uncontained, then it is infinite; if it is immobile, then it is eternal. Then, says Berkeley, the conditions for this mechanics is either god reduced to space or space exalted to god. This was the theological issue which emerges ineluctably from the Newtonian attempt to treat absolute movement as the subject-matter of a true mechanics.

The consistency of Newtonian method, that all complex movement must be analyzed back to aboriginal forces, made it inevitable that the system of the world would be analyzed back to the forces out of which its movements came; the intelligibility of the Newtonian subject-matter, true or absolute motion, made it inevitable that the infinity and eternality of space and time would ask the question how such realities differed from the divine. Either in its completion or in its inception, the *Principia* ineluctably posed problems about god. It is certainly a legitimate position that mechanics must reduce all phenomena to mechanical principles. Indeed, it was the opinion of Descartes and of many of the later Newtonians. But it is not the position of Newton, and to assert that it is the only possible one is to ignore the several times in which he explicitly repudiated it.

Nor is it particularly strange to find Newton engaged in these questions, irrespective of how organically they arose from his project. Certainly the coordination between scientific inquiry and religious belief was part of the air which England breathed. "Who can better magnify the arm that expanded he heavens," asked Christopher Wren in his inaugural oration as Gresham Professor of Astronomy, "than he who tells you that seven thousand miles will fall short of the diameter of this earth, and yet that this diameter repeated a thousand times will not reach the sun, or this distance between the sun and us repeated a thousand times reach the nearest fixed star?" [15] In his *Discourse Concerning a New Planet*, John Wilkins urged that the positive religious value of astronomy be understood: "It proves a God and a providence and incites our hearts to a greater admiration and fear of His omnipotency." [16] Perhaps even more busy about this issue than any of his colleagues, if that be possible, the great Robert Boyle insisted that the scientific and religious intellect were one: "... the knowledge of the works of God proportions our admiration of them, they participating and disclosing so much of the unexhausted perfection of their Author, that the further we contemplate them, the more footsteps and impressions we discover of the perfections of their Creator; and our utmost can but give us a just veneration of His omniscience." [17] It was a heady time in England in which "footsteps and impressions" were imprinted large over all natural phenomena, but over none so emphatically and irresistibly as over the heavens.

It was both systematically necessary and historically understandable that Isaac Newton would entertain in his mechanics the great questions of the divine existence: first, to deal with the further problems posed by the

system of the world he had elaborated; and second to respond to the objections lodged at the conditions in space and time for absolute motion, the subject-matter of the *Principia.*

Newton's Methodical Resolution of the Theological Question

System, then, is the first of these problems which the General Scholium engages. System is a problem of the one and the many. The many are the diverse masses, their individual locations, the velocity of their movements; the unity came from the common center of gravity, some geometric focus and the laws of gravitation by which this focus was enabled to give structure to the diversity. When system became the "System of the World," the mass objects became the sun, the six primary planets, the ten moons which revolved around the earth, Jupiter and Saturn, and the comets which ranged eccentrically over all part of the heavens. Their locations were such that the planets moved almost in the same plane in their revolutions, and the moons almost in the planes of their planets. The comets pass through extended ellipses with the sun as one focus; but in their aphelions, they proceed at their slowest as they move at the greatest distance from one another. The larger orbits of Jupiter and Saturn prevent these greater bodies from significantly disturbing the movement of the lesser. The mathematical balance among them is such as to form "this most beautiful system of the sun, planets, and comets." [18] This is the phenomenon which demands explanation.

Masses, location, velocity also figure in Newton's further specification of the factors within this system whose intelligibility looks for a cause beyond the mechanical ones which had been provided. Bentley had posed to Newton the classical Epicurean hypothesis: an even distribution of matter throughout space and a descending movement by which these particles endowed with gravity, came together to form the masses and the motions which compose the solar system. If the space was finite, counters Newton, the internal gravitational pull would have collapsed one body into another until there was left only one great spherical mass. But if the space was infinite and matter was evenly disposed throughout an infinite space, some of the particles would have formed one body and others would have composed another, "so as to make an infinite number of great masses scattered at great distances from one to another throughout all of infinite space." But even with this assumption, one would have to account for the formation and the content of these great masses, e.g. that those elemental units coalesce to make up the huge, light-giving sun, and those other elements come together to form the many opaque planets. This composition and division of primordial matter "I do not think explicable by mere natural causes but am forced to ascribe it to ye counsel and contrivance of a voluntary Agent." Further, one must account for the fact that these masses were placed at such locations that the Sun could give system to the others by its massive gravity and light and heat because of its composition. Jupiter and Saturn revolve last among the planets, so that

their great masses would not seriously perturb the orbits of the lesser bodies. The intricate balance of the mass objects and the careful correlation of their composition, their distances, and their gravitational attractions would have been impossible "had this cause been a blind one without contrivance." [19]

If one move the consideration further, from the mass objects and their distances to the kinematics of motions and the dynamics of their velocity, the evidence increases proportionally. The comets descend into the area of the planets and move among them in vastly different ways, sometimes to move in the same manner as the planets, sometimes to cross their planes while the solar system is undamaged by these eccentric visitors. The primary planets and their moons move in the same way and in the same plane without any considerable variation, a phenomenon so exact in its multiple proportions that "no natural cause" can reasonably explain it.

Take the degree of velocity of each of these planets and comets: If the planets had been as swift as the comets, they would have described not concentric orbits around the sun but such excentric ones that a life supporting solar system would have been impossible. If all the planets were as swift as Mercury or as slow as Saturn or were their velocities much different from what they are now; or had their velocities remained what they are now and their distances from the sun had changed; or had their velocities and distances been what they are now and their masses significantly different with proportional changes in their mutual gravitational attraction — in any of these assumptions, the present system could not have existed. The mass objects would have described hyperbolic or parabolic or very eccentric elliptical movement. Everything which Newtonian Mechanics found essential for its investigations and which it specified in its initial definitions had to be harmonized to form the system which now exists. This very complicated, mathematically intricate structure demands to be explained if any motion demands explanation: "To make this systeme therefore with all its motions, required a Cause which understood and compared together [1] the quantities of matter in ye several bodies of ye Sun and Planets and [2] ye gravitating powers resulting from thence, [3] the several distances of the primary Planets from ye Sun and secondary ones from Saturn, Jupiter and ye earth, and [4] ye velocities with which these Planets could revolve at those distances about those quantities of matter in ye central bodies." These factors that make up the "harmony of ye systeme" are the same factors which are comprised in the initial definitions of the *Principia*: mass, the velocity added to mass which gave the quantity of motion, the gravitational powers which now translated motive force, and the distances through which they operated. But these initial and abstract concepts are now concretized in this massive "harmony of ye systeme," and their concrete realization made the theological question one which was native to the mechanics: "And to compare and adjust all these things together in so great a variety of bodies argues that cause to be not blind and fortuitous, but very well skilled in Mechanicks and Geometry." [20]

Just as masses could be broken down into composition and size, so each of the velocities of the planets, moons and comets could be resolved into the gravitational attraction and the inertial force which gave them a transverse motion. It was the delicate balance of these two forces which gave the planets their orbits and the moons their revolutions around their several planets. As the parallelogram of forces indicated that mechanics should resolve compound movements into original forces, so the orbit of each of these masses demanded a similar analysis. Gravity could account for the decline or divergence of the body from rectilinear movement, but it could not account for its balancing transverse motion. "Gravity may put ye planets into motion but without ye divine power it could never put them into such a Circulating motion as they have about ye Sun, and therefore for this as well as other reasons I am compelled to ascribe ye frame of this Systeme to an intelligent agent." [21] The compound movement of the earth in its orbit originates in the balancing of gravity with a transverse motion which will be conserved by inertia. The mathematical adjustment of these two forces indicates the presence of a calculating intelligence.

But this annual movement about the sun is only one of the three motions of the earth. There is also the diurnal movement on its axis which yields night and day and the precessional movement of the equinoxes. The diurnal movements of the planets are not caused by gravity. The earth rotates on its axis such that the surface velocity at the equator is about 1000 miles an hour. If, for example, it turned at 100 miles an hour, the days and nights would each be ten times as long. The hot sun would annihilate vegetation or in the long nights any surviving living thing would freeze. Conserved by inertial force, these movements "required a divine power to impress them." [22] The inclination of the axis of the earth may be urged "as a contrivance for winter and summer and for making the earth habitable towards ye poles, and that ye diurnal rotations of ye Sun and Planets as they could hardly arise from any cause purely mechanical, so by being determined all the same way with the annual and menstrual motions they seem to make up that harmony of ye systeme wich ... was the effect of choice rather than of chance." [23] The axis of the earth is tilted at an angle of 23.5 degrees to the plane of its motion around the sun. Not only does this ensure the rhythm of the seasons, but had it not been so tilted, vapors from the ocean would move north and south, piling up into continents of ice. Everything within the structure of the system of the world was a function of everything else: masses, gravitational attractions, distances, and velocities. Each of these could be broken down further to its component units. In the presence of these units and in their combination, a mathematical exactitude was discovered which drove Newton's mechanics to a cause that was not mechanical. This was not a new step in physics: Aristotelian inquiry into nature uncovered an eternality of movement which indicated the causality of some principle which was beyond nature. A similar path was being traced by the new mechanics.

But the phenomenon at hand was more than the planetary system of the world. There was the universe, with the fixed stars and with the possibility that each of these was the center of another such system. Each of these stars possesses a unity with the other stars since the light from one passes into the light of another. But while they mutually illumine each other, the stars do not draw one another into a single mass by their gravity. Their immense distances, one from another, prevent this as they also hinder their coalescence with the sun of this solar system. The universe is a system of systems.

Granted this phenomenon, i.e. that so many exacting conditions that human life could exist on this planet or that this system would emerge, what does it indicate for the inquiry of mechanics? Another kind of force, one not mechanical, one which can compare and dispose of great masses, immense distances, gravitational attractions, velocities, diurnal and annual revolutions. In the first Book of the *Principia*, impressed force had been counted as motive force; in the system of the world, this motive force became gravity. Now all of these forces which compose and conserve the universe are equivalently inertial forces, continuing what is the structure of the multiple units. What, then, is this force which gave it origin and structure to so immense a composition, a force which must be both intelligent and powerful?

It is dominion. *Vis impressa* is now *dominium* or *dominatio*. What is critical to note is that Newton does not have to go beyond the notion of "force" in order to account for the universe, any more than he had to transcend the notion of "motive force" in order to grasp gravity. Gravity is a particular form of motive force. Dominion is the primordial form of impressed force.

It is dominion which makes god to be god. The researches of Edward Pococke, the English orientalist and biblical scholar who had first introduced the study of Arabic at Oxford and who had served as the University's first professor of Arabic, had convinced Newton that the Latin word "Deus" comes from the Arabic "du," which means Lord, in Latin "Dominus". *Deus* is a relative word, relative to that which is ruled by him, and this rule is his *dominium* or *dominatio*. What makes god to be god, his *deitas*, is this dominium: "Deitas est dominatio Dei." Dominion constitutes the crucial attribute for Universal Mechanics. Dominion holds a position in Newtonian theological inference similar to the infinite or perfect in Descartes: Dominion is that out of which all of the divine attributes will be inferred and by which their intelligibility will be governed. In fact, even here Newton makes his disagreement with Descartes sharp: "The supreme God is a being eternal, infinite, absolutely perfect; but a being, *even a perfect one*, without dominion is not the Lord God [*Dominus Deus*]." The relativity of the word god emerges in ordinary speech. It makes sense and is common practice to speak of "my god" or "your God." It makes no sense nor is it anyone's practice to speak of "my Eternal" or "my Infinite" or "my Perfect." Just as force is known and designated by the change which it can author and in this way is a relative word, so god is known and designated by the rule which He exercises.

There are many Lords, and the title is given them in accordance with the area of their rule. There is only one Lord god, and it is the dominion [*dominatio*] of the spiritual being which constitutes god to be what he is. As his dominion, so is his divinity. "A true, supreme, or imaginary dominion makes a true, supreme or imaginary God." [24]

The system of the universe has yielded the existence and power of god, but this handles only one of the problems with which the *Principia* ends. There was a prior one, a problem which had been with the mechanics from its beginning and which Bishop Berkeley had pointed out as an inescapable dilemma: "to wit, of thinking either that real space is God, or else that there is something beside God which is eternal, uncreated, infinite, indivisible, immutable. Both of which may justly be thought pernicious and absurd notions." [25] That space was absolute, that it was unchangeable and consequently eternal, was essential for Newtonian mechanics. Without this, there would be no true or absolute motion, which was by definition the movement of a body from one absolute place to another. Descartes' relative motion did not necessitate absolute space and time. In fact, it denied them. Newtonian absolute movement did necessitate absolute space and time, and the theological problem which inescapably emerged — not as an addendum, but at the heart of mechanics — was to indicate that space and time were not already divinized, that one had not been doing theology from the beginning of the *Principia*. Berkeley's dilemma was an essential question within Newton's mechanics.

The establishment of the existence and dominion of god allows the problem of Berkeley to be handled synthetically. The system of the world which functions as the phenomenon for theological analysis has been analytically reduced finally "to a first cause, which certainly is not mechanical." [26] Now can one assume this cause as established and by it handle the data or facts of mechanics which remain unexplained. Thus the movement from the question about system to the question about space and time embodies the two moments of Newtonian method: analysis and synthesis.

Analysis in Newtonian mechanics consisted of four heuristic moments: [1] the assessment of a phenomenon either through the immediacy of observation or the refinements of experimentation; [2] a derivative or deductive movement from this effect to its proximate causes; [3] an inductive or universalizing from these "particular Causes to more general ones, till the Argument end in the most general"; and finally [4] the coordination of these conclusions with objections which may be taken from experiments or from propositions which have already been established. This last moment of verification is a continuation of the movement towards generality, for "if no Exception occur from Phaenomena, the Conclusion may be pronounced generally." Analysis is the resolution of effects into their causes, whether one is dealing with the solution of compounds into ingredients or of movements back to their diverse and originating forces. Analysis is not a movement simply to particularities. It begins with particularity and it moves to particular causes; but it continues this causal resolution until it uncovers the general laws that explain why these particular causes act in this particular way.

Synthesis moves in precisely the opposite manner: from cause to effect. Granted these general laws of mass, distance, and force; granted further these particular forces inherent in this body and impressed by the agency of other influences; synthesis describes the subsequent career they will effect. Synthesis is a movement back to the phenomena, and it "consists in assuming the Causes discover'd and establish'd as Principles, and by them explaining the Phaenomena proceeding from them, and proving the Explanations."[27] Analysis proceeds from effect to cause and from particularity to generality, from phenomena to underlying and universal structure; synthesis proceeds from cause to demonstrate the effect, from general laws to show their instantiation in a particular event, from abstractions to explain and predict the phenomena. The explanation of the possibility of space and time in the General Scholium is a moment of synthesis.

From the domination which marks god to be god and by which the system of the world is explained, it follows that he is intelligent and powerful and living. Indeed these three attributes simply spell out what intrinsically constitutes *dominatio*. If he is dominant, then he is supreme or most perfect [*summe perfectum*]. Within *summe perfectum* is contained the assertions that he is eternal and infinite, omnipotent and omniscient, "that is, he continues [*durat*] from age to age, and is present [*adest*] from infinity to infinity; he rules all things, and he knows what happens and what is able to happen." These attributes are not assigned to god by faith, *pace* Strong and Brett. They are synthetically demonstrated from god's total dominion.

Now Newton can deal with Berkeley. God is not eternity or infinity, but eternal and infinite. By existing eternally, he constitutes the absolute duration that is real time. By being everywhere, he constitutes that infinite extension that is absolute space. It is not so extraordinary that this would be said of god. A particle of space is always, and a moment of time is everywhere. If the supreme being were not both always and everywhere, he would be less than either or both. Then, again, in a line which will echo and reecho in the discussions with the materialists: "It is allowed by all that the Supreme God exists necessarily; and by the same necessity, He exists always and everywhere."[28]

What, then, is this eternal space — if it is not god, but that which is constituted as an infinite extension by the omnipresence of god? Descartes had made it substantial, equating it with matter; Spinoza had made it accidental, one of the two known attributes of the single eternal substance. The fundamental error of both, according to Newton, was to insist that space must fit within the ancient division of all being into substance and accident. It was neither. In his *De gravitatione et a equipondio fluidorum*, which Westfall places at the very end of the 1660's, Newton insisted that space had "its own manner of existing which fitted neither substances nor accidents."[29] It is not a substance because it does not exist absolutely by itself. It is not god nor is it an accident of god for god has no accidents.[30] It is an effect, but a necessary effect of the divine existence. It issues not from his choice, but from his existence everywhere. Newton, following Gassendi, reaches back to the Neo-Platonists for the vocabulary and

distinction he wished: Space is an *effectus emanativus*, an effect that emanates or issues from the divine omnipresence, one which is neither independent of god nor simply a creature produced by the divine choice.[31] Thus it becomes "a disposition of being *qua* being. No being exists or can exist which is not related to space in some way. God is everywhere, created minds are somewhere, and body is in the space it occupies; and whatever is neither everywhere nor anywhere does not exist. And hence it follows that space is an effect arising from the first existence of being, because when any being is postulated, space is postulated." [32] Thus god by being present constitutes as a necessary and emanent effect an infinite space and by being everlasting constitutes an eternal time. It is not that god acts to create space and time. He is, and that constitutes space and time. What is necessary must exist always and everywhere, must constitute time and space, must be that which realizes the Pauline allusion to Epimenides of Cnossos and which Newton rephrases. "In Him all things are contained and moved, but without affecting one another." [33] God constitutes space and time in which all that moves occurs.

What, then, does the mechanics tell us about god? This is a question that presupposes a position on a prior question: What can we know about anything? What do we know about bodies? "We see only their figure and colors, we hear only the sounds, we touch only their outward surfaces, we smell only the smells, and taste the savors; but their inward substances are not to be known either by the senses or by an reflex act of our mind." Mechanics cannot deliver any different knowledge about god. One can know that he exists, that he is characterized primarily by *dominatio*, that his attributes are such and that these exclude others which would be proper to masses or bodily reality. Beyond this, we cannot go: "Much less, have we any idea of the substance of God. We know Him only through his properties and attributes. We know him only by the most wise and excellent structures [*structuras*] of things and final causes. We are in wonder because of his perfections, but we reverence and adore him because of his dominion [*dominium*]." Just as gravity cannot be traced to the inner structure of matter or the cause of its laws determined with certitude, so also the divine dominion cannot be reduced to a grasp of the divine nature itself. It is enough that gravity does exist and that it acts in this way. It is enough that god does exist, a god whose dominion reveals his living presence always and everywhere.

The alternative to his analysis of the system of the world to the divine dominion, for Newton, is not that mechanics would stop its inquiry with mechanical laws. The alternative would be that it would end with fate and nature [*Fatum et Natura*], i.e. with a blind metaphysical necessity [*caeca necessitate metaphysica*] which under the guise of preserving the autonomy of science would posit rather another kind of god, one without dominion, providence and purpose. This would not only be scripturally false — Newton is not arguing from those grounds — it also would fail to account for the diversity seen everywhere in things, whether different masses and their conjunctions, or different velocities and their composing forces or different geometric configurations and the complicated unities which they

form. Whatever is necessary must exist always and everywhere. If this necessity is blind and without choice, it will act, like the laws of gravitation, always and everywhere the same. Diversity comes from ideas and will. The issue, then, for the Newtonian mechanics is not whether or not it will terminate in god. God in the sense of the force out of which the world issues is obvious for Newton and inescapable as the rational consequence of a system of the world. What is crucial is the inference that this dominion is intelligent as well as powerful, i.e. that it is personal. And the mathematical coordination within the system of the world, the structure of unity with such enormous diversity, is the best warrant for this conclusion. It is the evidence that this god is personal. "And thus much, concerning God: to discourse of whom from the phenomena certainly does belong to Natural Philosophy."[34]

Does this leave Newton with the distant god, one who constructed the watch but now leaves it to run on its own? Both of the previous issues, those of systems and space, function in the response to this question. First, god constitutes the space and time in which all takes place by his omnipresence. He is in no sense distant; his presence makes possible the existence and movement of all things. Secondly, the system of the world is not of itself an eternal system. Granted that once formed, it "may continue by these Laws for many Ages," but it is inevitable that the mutual actions of the planets one upon the other will give rise to "some inconsiderable irregularities... and which will be apt to increase, till this System wants a Reformation."[35] Newton held something like a gradual enervation of motion: "It appears that Motion may be got or lost. But by reason of the Tenacity of Fluids, and Attrition of their Parts, and the Weakness of Elasticity in Solids, Motion is much more apt to be lost than got, and is always upon the Decay."[36] There are active principles such as gravity, magnetism, electricity, and fermentation (= heat-producing reactions) which continue to reinvigorate the system, but even with these the system would eventually need reformation. Leibniz was scandalized by this assertion. Clarke, or Newton through Clarke, used it as a mechanical indication of the presence of a continual providence so that "nothing is done without his continued government."[37] For a god without providence would be mere blind fate or nature.[38] Dr. David Kubrin details the various conjectures which Newton entertained about the manner of this periodic reformation, whether the aetherial hypotheses of a perpetual circulation of matter or the conjecture that the comets were the instruments with which god perpetually reconstituted the universe.[39] These remained for Newton hypotheses, though the latter was allowed a place in the System of the World: "So fixed stars, that gradually waste away [*expirant*] into light and vapors, can be renewed by comets that fall upon them; and from this new nourishment those old stars, acquiring new splendor, can pass for new stars."[40]

Whatever the manner in which this reformation of the system of the world was to occur, just as whatever the actual manner in which the harmony of the system itself was achieved through the balancing out of the myriad factors which composed it, that it occurred was an important

indication of the steady influence of divine intelligence and power either to originate or to retrieve the universe. Reformation warranted belief in a continuous providence just as formation gave evidence of an all powerful understanding and choice. Neither of them was magic, but both of them manifested the divine dominion of the one who "rules over all things, not as the world soul, but as the Lord of all things." [41]

Light and the Inner Structure of Natural Bodies

If the *Principia* allowed for a universe to emerge which gave system and consequent intelligibility to the heavens, the *Opticks* proceeded in an almost opposite direction. It began with that which was as universal as motion and as phenomenal as bodies. It began with light. Light was passed on from the stars, it was transmitted from the sun, it was reflected by the planets and by the moons. Light pervaded the entire system of the universe and touched all its parts in one way or another. The *Opticks* proposed an investigation of light, but the final product is not a system of the world, but the inner structure of natural bodies. The developing line of investigation in the *Opticks* is not towards the comprehensive assemblage of everything; it is towards the internal make-up of each. Yet this inquiry also would disclose an arrangement similar to the universe itself, both finally to be read through mathematical proportions of masses and forces. The parallelism between movement and light had been noted early in the *Principia*, and emphatically enough so that either could be the subject of mechanics: "Because of the analogy which exists between the propagation of the rays of light and the motion of bodies, I thought it not amiss to add the following Propositions for optical use; not at all considering the nature of the rays of light or inquiring whether they are bodies or not; but only determining the curves of bodies which are extremely like the curves of rays." [42] The emission of light paralleled the movement of masses. The motions of bodies had allowed one to build to a system of the universe; the light from bodies, whether refracted or reflected, allowed one to discover something of their inner depth and internal constitution.

Initial optical inquiry focused upon the broad questions of its subject-matter: light and its consistent property, color. Color can be analytically reduced through the two mechanical operations which account for it: refraction and reflection. Refraction further reduces compound or heterogeneal color into its simple or primary components. Thus, white light can be analyzed into its component colors just as compound motions could be resolved into simple motions; or, again parallel with procedures of the *Principia*, these simple colors could be conjoined into a compound or heterogeneal light. Color itself, in any of its forms, is the yield of either refraction or reflection.

This pushes the examination of light one step further: What is the nature of transparent and opaque bodies? Like white light itself, each of these visible bodies is a compound, a porous composite of least particles or corpuscles and many empty spaces. The connection between the internal

composition of bodies and the basic properties of light is firmly established by the discovery that the opacity of bodies is in indirect relationship to their density. "That this discontinuity of parts is the principal Cause of the opacity of Bodies, will appear by considering, that opake Substances become transparent by filling their Pores with any Substance of equal or almost equal density with their parts. Thus Paper dipped in Water or Oil, the *Oculus Mundi* Stone steep'd in Water, Linnen Cloth oiled or varnish'd, and many other Substances soaked in such Liquors as will intimately pervade their little Pores, become by that means more transparent than otherwise."[43] And the conclusion that emerges: "Hence we may understand that bodies are much more rare and porous than is commonly believed."[44] Just as the free movement of the planets and their moons indicated that the universe was empty of matter with the exception of some very thin vapors or steam or effluvia which rise from the atmosphere of the earth or of possible a medium so rare as to register no resistance, so the refraction and reflection of light indicates myriad spaces among the particles by which the visible bodies are composed.

Thus the phenomenon of color allows for the mechanical activities of refraction and reflection, and these powers have their location in the internal structure as well as surfaces of each body. And each of these bodies is itself a composite of least particles, interstices, and the powers of attraction or cohesion or repulsion. Each body is then a structure, a system. The Questions appended to the *Opticks* allow this reductive analysis to continue. They analyze light finally into the bodies from which it comes and into the corpuscles by which even the rays of light are formed. This section is one of questions, but of essential questions, if the phenomenon of light is to be brought under what Newton had called "Universal Mechanics." The reduction of bodies to least parts and of light to corpuscles allows for this integration. The *Lexicon Technicum* of John Harris had already identified the corpuscular philosophy with the mechanical philosophy.[45] The Queries of Newton allow for light and color to be subsumed into mechanics because light is analyzed as corpuscular and it is through light that one reaches into the corpuscular construction of things.

This corpuscular composition of masses introduces new phenomena into the theological considerations which Newton thought appropriate to mechanics. To the order and beauty of the heavenly composition can be added questions such as: "How came the Bodies of Animals to be contrived with so much Art, and for what ends were their several Parts? Was the Eye contrived without Skill in Opticks, and the Ear without Knowledge of Sounds? How do the Motions of the Body follow from the Will and whence is the Instinct in Animals... And these things being rightly dispatch'd, does it not appear from Phaenomena that there is a Being incorporeal, living, intelligent, omnipresent...."[46] The divine attributes here are similar to those of the *Principia*, but with two notable differences. Dominion does not figure as yet. The comprehensive principle of force has still to be worked into the optical discussion. Secondly, space is now seen not simply as the extension which emanates from god and

which allows for real motion. The citation continues: "... omnipresent, who in Infinite Space, *as it were in his Sensory*, sees the things themselves intimately, and thoroughly perceives them, and comprehends them wholly by their immediate presence to himself." The previous discussion about seeing now allows for a parallel predication about space. Space analytically is the condition for the possibility of movement; space in the synthetic moment of the *Opticks* is that in which god is present to all things consciously. Newton is comparing the *sensorium* of human beings with the space of god. In his representative theory of perception, what human beings perceive directly are not things, but the images of things, brought into the human interiority through sensible experience. In this interiority — the interior senses or the phantasm — these images "are there seen and beheld by that which in us perceives and thinks."[47] Space is that in which god perceives and thinks and is present not to images, but to things.

This was the first point of Leibniz' attack on Newtonian mechanical theology, as if god needed an organ, through which He could perceive what is. Clarke's reply was short and directly to the point: "The word *sensory* does not properly signify the organ but the place of sensation. The eye, the ear, etc., are organs, but not sensoria. Besides, Sir Isaac Newton does not say, that space is the sensory; but that it is, by way of similitude only, *as it were the sensory*."[48] Just as the soul perceives the images by which things are present to it in its sensory, i.e. in its interior sense in which they are represented, so god is present to things directly and, hence, perceives them in themselves, in the way and place that they are, i.e. in space.

The theological argument from the corpuscular composition is basically the same as from the system of the world: Compound bodies are porous, i.e. they consist of parts "which are only laid together," and these parts are conjunctions of similarly smaller parts until one comes to the "simple Particles." What holds the great masses of the system of the universe together is the force of gravitation "which intercedes those Bodies, and almost all the small ones of their Particles." The theological argument can be basically the same because "thus Nature will be very conformable to herself and very simple."[49] In the universe and in any compound body, inertial forces will only account for the perduration in existence. They will not account for the origin and composition of structures. The active forces in the universe can account for some of the composition — forces such as magnetism, gravity, fermentation, and electricity. But the structure of movements in the universe and the system of correlationships which make up a body demand intelligence and power in the ultimate force: "Such a wonderful Uniformity in the Planetary System must be allowed the Effect of Choice. And so must the Uniformity in the Bodies of Animals," i.e. the parallels of the right and left sides, the location of the arms and legs, the relationship between shoulders and neck and backbone and head. Or analyze the body still further into each of its parts and its organic composition. Any and all of these "can be the effect of nothing else than the Wisdom and Skill of a powerful ever-living Agent, who being in all Places, is more able by his Will to move the Bodies within

his boundless uniform *Sensorium*, and thereby to form and reform the Parts of the Universe, than we are by our Will to move the Parts of our own bodies." [50]

The last Query linked the theological reflections of the *Principia* with those of the *Opticks*, for the power which joins the least particles together to constitute a more complex body elicits a consideration of the power by which the structure has come together. This power operates in space, and Newton conjectures a "probable" scenario by which the divine *dominatio* constructed the bodies, both minuscule and finally planetary and astral: "God in the beginning form'd matter in solid, massy, hard, impenetrable, moveable Particles, of such Sizes and Figures, and with such other Properties, and in such Proportion to Space, as most conduced to the End for which he form'd them; and that these primitive Particles being Solids, are incomparably harder than any porous Bodies compounded of them; even so very hard, as never to wear or break into pieces; no ordinary Power being able to divide what God himself made one in the first Creation.... And therefore, that nature may be lasting, the Changes of corporeal Things are to be placed only in the various Separations and new Associations and Motions of these permanent Particles." [51] These particles, then, were the original and perduring building blocks of all corporeal things, and things themselves are associations of these particle.

What was "system" for the universe is now "association" for each body within it, and both demand an intelligent cause: "Now by the help of these Principles, all material Things seem to have been composed of the hard and solid Particles above-mention'd, variously associated in the first Creation by the Counsel of an intelligent Agent. For it became him who created them to set them in order." [52] This last sentence summarizes Newtonian natural theology: where there is an order of masses and gravitational attractions, of orbits and proportional distances, or of the design of bodies and their functions, a proportional force is required to account for so carefully constructed an order, whether it is a system or an association.

All of the data of mechanics and of an optics which is reduced to the principles of mechanics pointed to this intelligent force: "Atheism is so senseless and odious to mankind, that it never had many professors.... Whence arises this uniformity in all their outward shapes but from the counsel and contrivance of an Author." [53] This Author was an inescapable object of inquiry for a Universal Mechanics that would both demand absolute space and absolute time as the conditions for its subject-matter and would analyze any system back to its aboriginal forces.

REFERENCES

[*Prenote*: This paper, delivered in the Crakow Conference in May of 1987, is reworked and incorporated into a much more extensive treatment of Newton's mechanics by the author and published by the Yale University Press to form a section of *At the Origins of Modern Atheism* by Michael J. Buckley, S.J. (Yale University Press). For an early exploration of this same topic, cf. Michael J. Buckley, S.J., *Motion and Motion's God* (Princeton University Press, 1971).]

[1] Edward Strong, "Newton and God," *Journal of the History of Ideas* XIII:2 (April 1952), p. 167 [hereafter: Strong].

[2] Strong, pp. 157 and 149.

[3] Strong, pp. 148-149, 154.

[4] In general, the Latin edition of Newton's works which is used in this book is contained in *Isaaci Newtoni Opera quae exstant omnia*, commentariis illustrabat Samuel Horsley (Londini: Excudebat Joannes Nichols, 1779-1785), and cited as *Newtoni Opera Omnia*. The third and final edition (1726) of Newton's *Philosophiae Naturalis Principia Mathematica* has been assembled and edited by Alexandre Koyre and I. Bernard Cohen with the assistance of Anne Whitman (Cambridge: Harvard University Press, 1972) [henceforth cited as K-C]. All the citations from the *Principia* have either been translated by the author from this edition or checked against it in his use of the English translation of Andrew Motte as revised by Florian Cajori: Sir Isaac Newton's, *Mathematical Principles of Natural Philosophy and His System of the World*. Translated by Andrew Motte, 1729. Translation revised and supplied with historical and explanatory appendix by Florian Cajori (Berkeley: The University of California Press, 1962) [henceforth cited as Cajori]. The edition of Newton's correspondence will be that of *The Correspondence of Isaac Newton*, volumes 1-3 edited by H. W. Turnball, volume 4 edited be J. F. Scott, volumes 5-7 edited by A. R. Hall and L. Tilling. Published for the Royal Society. (Cambridge: Cambridge University Press, 1959-1977). These seven volumes bring the correspondence up to the end of Newton's life [henceforth cited as *Correspondence*].

[5] Cf. I. Bernard Cohen, *Introduction to Newton's 'Principia'*, pp. 155-156. The reference which this review is making is to the first edition of the *Principia*, III, Proposition VIII, Corollary V: "Collocavit igitur Deus Planetas in diversis distantiis a Sole, ut quilibet pro gradu densitatis calore Solis majore vel minore fruatur." It is this laconic statement, touching both upon the divine *dominatio* and the divine providence, which would, under diverse incentives offered by many issues, be expanded into the more complete thesis of the General Scholium. Cohen has pointed out that Newton in the versions of the *Principia* elaborated before the first edition "on at least two occasions turned to discussion of God." Cf. I. Bernard Cohen, "Isaac Newton's *Principia*, the Scripture, and the Divine Providence," in *Philosophy, Science and Method: Essays in Honor of Ernest Nagel*, edited by Sidney Morgenbesser, Patrick Suppes, and Morton White (New York: St. Martin's Press, 1969), pp. 431-522.

[6] Newton to Bentley, December 10, 1692, *Correspondence* III, p. 233.

[7] *Principia*, Corollaries after the Three Laws of Motion, Corollary IV, K-C I, p. 63 [M].

[8] Strong, p. 167: So Strong censures Clarke and Cheyne because "they did depart from his [Newton's] thought, however, in taking the religious addendum to

be fundamental to his science, for therein they did violence to the autonomy of science in methods and results upon which Newton had clearly and vigorously insisted." It seems that Mr. Strong is reading his own sense of the "autonomy of science" into Newton.

[9] Sir Isaac Newton, *Opticks, or a Treatise of the Reflections, Refractions, Inflections and Colours of Light*, III, Query 31. Based on the Fourth Edition, London, 1730. (New York: Dover Publications, Inc., 1952), pp. 404-405 [henceforth cited as *Opticks*] For a history of the various editions of the *Opticks* with the consequent addition of Queries, cf. I. Bernard Cohen's excellent "Preface" to this Dover edition, pp. xxxiii and ff. Cf. also, Cohen, *Introduction to Newton's Principia*, p. 22.

[10] Newton to Bentley, December 10, 1692, *Correspondence* III, p. 235.

[11] *Principia*, Scholium after the Eight Definitions, K-C I, pp. 50-53; Cajori, pp. 10-12. This notion of absolute space as the condition for the possibility of motion finds early and very succinct expression in an early manuscript of Newton's. Though these precise lines are in the hand of Wilkins, the massive bulk of the work is in Newton's handwriting. The editor of the *Correspondence* hypothesizes that Wilkins may have been transcribing at Newton's direction: "There is an uniform extension, space, or expansion continued every way without bounds: in wch all bodyes are, each in severall parts of it: wch parts of space possessed and adequately filled by ym are their places. And their passing out of one place or part of space into another, through all ye intermediate space is their motion." *Correspondence* III, p. 60.

[12] *Principia*, Scholium after the Eight Definitions, K-C I, p. 53; Cajori, p. 12.

[13] George Berkeley, *Principles of Human Knowledge*, #110; Cited in his history of the concept of space, by Alexander Hoyré, *From the Closed World to the Infinite Universe*. Harper Torchbooks. (New York: Harper and Brothers Publishers, 1958), pp. 221-222.

[14] Berkeley, *Principles of Human Knowledge*, #117. Cf. Koyré, *From the Closed World to the Infinite Universe*, p. 222.

[15] As cited in Richard S. Westfall, *Science and Religion in Seventeenth Century England* (New Haven: Yale University Press, 1958), p. 28.

[16] Westfall, *Science and Religion*, p. 34.

[17] Westfall, *Science and Religion*, p. 42.

[18] *Principia* III, "General Scholium," K-C II, p. 760; Cajori, p. 544. Newton uses two words for system in Latin: either *systema* or *compages*. This latter could equally well be translated as "structure."

[19] Newton to Bentley, December 10, 1692. *Correspondence* III, p. 234. The value of these letters to Bentley lies in their amplifying the demonstration of the existence and attributes of God which Newton outlined in his published works. In so doing, they give an indication of what theological development would follow upon the influence of the *Principia* and the *Opticks*.

[20] Newton to Bentley, December 10, 1692, *Correspondence* III, pp. 235-236 [enumeration added].

[21] Newton to Bentley, January 17, 1692/3, p. 240: "I do not know any power in nature wch could cause this transverse motion without ye divine arm." Cf. Newton to Bentley, February 11, 1692/3, *Correspondence* III, p. 244: "And tho gravity might give the Planets a motion of descent towards the Sun either directly or wth some little obliquity, yet the transverse motions by wch they revolve in their several orbs required the divine Arm to impress them according to ye tangents of their orbs."

[22] Newton to Bentley, February 11, 1692/3, *Correspondence* III, p. 244.

[23] Newton to Bentley, December 10, 1692, *Correspondence* III, p. 236.

[24] *Principia* III, "General Scholium," K-C II, pp. 760-761; Cajori, pp. 544-545 [italics added].

[25] George Berkeley, *Principles of Human Knowledge*, #117, cf: Koyré, *From the Closed World to the Infinite Universe*, pp. 222-3. James Collins nicely summarizes Berkeley's view of the Newtonian theological enterprise with its many successors: "Berkeley greatly admired Newton's combination of reason and observation, in the development of a *natural philosophy*. But he opposed the pretentious claims being made by the Newtonians for this natural or experimental philosophy, whether the claims were made in the interest of religion or of irreligion." Collins cites Berkeley's letter to the American Samuel Johnson: "The true use and end of Natural Philosophy is to explain the phenomena of nature; which is done by discovering the laws of nature, and reducing particular appearances to them. This is Sir Isaac Newton's method; and such method or design is not in the least inconsistent with the principles I lay down." Collins, *A History of Modern European Philosophy*, p. 397. Berkeley has significantly truncated Newton's method.

[26] *Opticks* III, Query 28, p. 369. Cf. Query 31, p. 405: "For so far as we can know by natural Philosophy what is the first Cause, what Power He has over us, and what Benefits we receive from him, so far our Duty towards him, as well as that towards one another, will appear to us by the light of Nature". Note that "Power" is again singled out as the primary and pivotal attribute.

[27] *Opticks* III, Query 31, pp. 404-405.

[28] *Principia* III, "General Scholium," K-C II, p. 762: "Deum summum necessario existere in confesso est: et eadem necessitate semper est et ubique." Cf. Cajori, p. 545. That whatever necessarily exists, whatever cannot not-be, must be everywhere, will form a critical argument of Clarke's against the materialists.

[29] *De gravitatione et a equipondio fluidorum*. Edited with an English translation in *Unpublished Scientific Papers of Isaac Newton*. Edited by A. R. and Marie Boas Hall. (Cambridge: Cambridge University Press, 1962), p. 99. [Henceforth cited as *De gravitatione*]: "[Extensio] habet quemdam sibi proprium existendi modum qui neque substantiis neque accidentibus competit." Cf. R. S. Westfall, *Force in Newton's Physics*, pp. 339 ff. and 403, n. 26.

[30] *Principia* III, "General Scholium," K-C II, p. 762: "Totus est sui similis."

[31] *De gravitatione*, p. 99.

[32] *De gravitatione*, p. 136. Cf. Alexander Koyré, "Newton and Descartes," *Newtonian Studies*, pp. 85-86. For the historical context of this discussion of the nature of space, cf. Koyré, *From the Closed World to the Infinite Universe*, p. 227.

[33] *Principia* III, "General Scholium," K-C II, p. 763; Cajori's version (p. 546) leaves out one of these sentences. See *Acts of the Apostles* xvii, 28: "For in Him we live and move and are." Newton has shifted this statement to a statement about space and the lack of resistance. Thus Koyré can comment that this assertion is not to be taken "metaphorically or metaphysically as St. Paul meant it, but in the most proper and literal meaning of these words. We — that is, the world — are in God; in God's space, and in God's time." Koyré, *From the Closed World to the Infinite Universe*, p. 227.

[34] *Principia* III, "General Scholium," K-C II, p. 764; Cajori, p. 546.

[35] *Opticks* III, Query 31, p. 402. The Queries do *not* assert that God intervenes to reform this system, but only that the system will eventually need a reformation.

[36] *Opticks* III, Query 31, p. 398.

[37] "Dr. Clarke's First Reply," in the *Leibniz-Clarke Correspondence*, edited with introduction and notes by H. G. Alexander (Manchester: Manchester University Press, 1956), p. 14 [henceforth cited as *L-C*].

[38] *Principia* III, "General Scholium," K-C II, p. 763; Cajori, p. 546. Cf. Henry Guerlac and M.C. Jacob, "Bentley, Newton, and Providence," *Journal of the History of Ideas* XXX:3 (July-September, 1969), p. 317.

[39] David Kubrin, "Newton and the Cyclical Cosmos: Providence and the Mechanical Philosophy," *Journal of the History of Ideas* XXVIII:3 (July-September, 1967), pp. 325 ff.

[40] *Principia* III, Proposition XLII, Problem XXII, K-C II, p. 757; Cajori, p. 541 [M].

[41] *Principia* III, "General Scholium," K-C II, p. 760; Cajori p. 544.

[42] *Principia* I, Section xiv, Proposition XCVI, Theorem L, Scholium, K-C I, p. 344; Cajori, pp. 230-231.

[43] *Opticks* II, Part II, Proposition III, pp. 249-250.

[44] *Opticks* II, Part III, Proposition VIII, p. 267.

[45] John Harris, *Lexicon Technicum: or, An Universal English Dictionary of the Arts and Sciences: explaining not only the terms of art, but the arts themselves* (London: Printed for D. Brown etc., 1704), under "Mechanical Philosophy": "*Mechanical Philosophy* is the same with the *Corpuscular*, which endeavours to explicate the Phaenomena of Nature from Mechanical Principles; i.e. from the Motion, Rest, Figure, Position, Magnitude, etc. of the Minute Particles of Matter. And these Principles are frequently called *Mechanical Causes*: And also the *Mechanical Affections* of Matter."

[46] *Opticks* III, Query 28, pp. 369-370.

[47] *Opticks* III, Query 28, pp. 369-370. [Italics added]

[48] "Dr. Clarke's Second Reply," *L-C*, p. 21. Leibniz' attack was stated in his first paper: "Sir Isaac Newton says, that space is an organ, which God makes use of to perceive things by. But if God stands in need of any organ to perceive things by, it will follow, that they do not depend altogether upon him, nor were they produced by him." "Mr. Leibniz' First Paper," *L-C*, p. 11.

[49] *Opticks* III, Query 31, p. 397. [Italics added]

[50] Query 31, pp. 402-403. Cf. p. 389: "I had rather infer from their Cohesion, that their Particles attract one another by some force, which in immediate contact is exceeding strong, at small distances performs the chymical Operations above-mention'd, and reaches not far from the Particles with any sensible Effect."

[51] *Opticks* III, Query 31, p. 400.

[52] *Opticks* III, Query 31, p. 402.

[53] Isaac Newton, "A Short Scheme of the True Religion," quoted by Sir David Brewster, *Memoirs of the Life, Writings, and Discoveries of Sir Isaac Newton* (Edinburgh: Thomas Constable and Company, 1855) II, pp. 347-348: "Did blind chance know that there was light, and what was its refraction, and fit the eyes of all creatures, after the most curious manner to make use of it? These, and such like considerations, always have, and ever will prevail with mankind, to believe that there is a Being who made all things, and has all things in his power, and who is therefore to be feared."