CHAPTER V

NEWTON'S MATHEMATIZATION OF NATURE

5.1. Introduction.

In the previous chapter, we have discussed Newton's view of the relationship between nature, religion and science. Mathematics is an integral part of his natural philosophy, perhaps the most important part of all. In this chapter, we will focus on Newton's mode of mathematization. We will examine his concept of the mathematical content of nature, the concept of God as mathematician and mechanic, mathematics' relation to scientific research and stages of mathematization as an important element in his philosophy of mathematics.

5.2. That Nature Can Be Mathematized

In Newton's "Scheme for Establishing the Royal Society", he states that "Natural Philosophy consists in discovering the frame and operations of Nature, and reducing them, as far as may be, to general Rules or Laws". The reduction process is done through five main branches of natural philosophy, the first of which is "Arithmetic, Algebra, Geometry, and Mechanics", followed by "Philosophy relating to the Heavens, the Atmosphere, and the surface of the Earth", "Philosophy relating to animals", "Philosophy relating to vegetables", and the fifth, "Mineralogy and Chemistry and the knowledge of the nature of Earths". In the first

branch, he includes studies related to:

> the figures, surfaces, magnitudes, forces, motions, resistances, weights, densities, centres of gravity, and other mathematical affections of solids and fluids: the composition of forces and motions; the shocks and reflexions of solids; the centrifugal forces of revolving bodies; the motion of pendulums, projected and falling bodies; the mensuration of time and distance; the efficacy of the five powers, the running of rivers; the propagation of light and sound, and the harmony and discord of tunes and colours.[1]

From the above passage, one might conclude that Newton had listed all the contents of mathematics. However, if we read the content of the other branches of his natural philosophy, we will find that there is an overlapping of the two contents. For example, the second division entitled "Philosophy relating to the Heavens..." is comprised of:

> Opticks, Astronomy, Geography, Navigation and Meteorology; what relates to the magnitudes, distances, motions, and centrifugal forces of the heavenly bodies; and to the weight, height, form, and motions of the Atmosphere, and of the things therein, and to instruments for observing the same; and to the figures and motions of the Earth and Sea.[2]

The third division, "Philosophy relating to animals", embraces "organs of sensation" which he discusses at some length in his Opticks[3] in relation to perception and the fifth division takes into account:

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[1]See Brewster, Memoirs..., Vol.I, pp. 102-103.

[2]Ibid. p.102.

[3]For example, see Query 23, 28, 29, and 30.

> Colours, Gravity, Density, Fixity, Dissolutions, Fermentations, Coalitions, Separations, Congelations, Liquefactions, Volatility, Distillation, Sublimation, Precipitation, Corrosiveness, Electricity, Magnetism...[and] Heats...[4]

Therefore in addition to the fourth division, "Philosophy relating to vegetables", the rest constitute parts of Newton's mathematics because they are mathematically treated in his Principia and Opticks.[5] From Newton's perspective, by and large, mathematical reduction of "the frame and operations of Nature" is possible. And from four out of the five main branches of his natural philosophy, we can infer that the quantitative aspect of mathematics already dominates.

Newton states that mathematization of nature is not a new form of scientific inquiry. The idea of mathematization can be traced back to antiquity whereby the flowering of mathematics was closely related to the development of mechanics. He claims that mathematics evolved as a reaction to the intrusion of "substantial forms and occult qualities". Thus:

> Since the ancients (as we are told by Pappus)[6] esteemed the science of mechanics of greatest importance in the investigation of natural things, and the moderns, rejecting substantial forms and occult qualities, have endeavoured to

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[4]Ibid., p.103.

[5]Newton treats some of these topics, particularly the contents of the fifth branch, in his alchemy too. See Castillejo, Expanding Force..., pp.17-31.

[6]Pappus wrote the Synagoge, a compendia of Alexandrian mathematics, about 320 A.D. The book served as a guide to the study of Greek mathematics.

subject the phenomena of nature to the law of mathematics.[7]

Mathematics deal with both quantities and qualities although in the case of Newton and unlike al-Bīrūnī, it is the quantitative aspect that has the upper hand. We will deal with the qualitative aspect in the ensuing chapter. In so far as dealing with quantities, Newton maintains that mathematics is that branch of knowledge with which the scientist "investigates the quantities of forces with their proportions consequent upon any conditions supposed".[8] In mentioning "quantities", Newton does not give any philosophical treatment on numbers as the foundation of mathematics. Yet in his letter to Hawes containing suggestions as how to improve the curriculum of Christ's Hospital, he accepts arithmetic as the foundation of mathematics. Writes Newton,

> Arithmeticks is set down preposterously in the 12th Article after almost all the rest of Mathematicks. For a man may understand and teach Arithmetick without any other skill in Mathematicks, as writing Masters usually doe, but without Arithmetick he can be skilled in noe other parte of Mathematicks, & therefore Arithmetick ought to have been set downe in the very first place as the foundation of all the rest.[9]

Newton further claims that both geometry and mechanics are equally important. He reminds Hawes of their significance: "If you admit this learning, your school will certainly grow into greater reputation,...for the scheme of learning ....is an entire thing

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[7]See his preface to the first edition of the Principia. Principia, Motte-Cajori, p. xvii.

[8]See Principia, Motte-Cajori, p.192.

[9]See J. Eddleston, Correspondence of Sir Isaac Newton and Professor Cotes, (London, 1969), p.280.

which cannot well want any of it's members, for 'tis nothing but a combination of Arithmetick, Geometry, Perspective and Mechanicks,..."[10]

Mechanics is an important part of geometry. He draws the conclusion that mechanics is that part of geometry which is less "perfectly accurate" by furnishing the following argument.

> The ancients considered mechanics in a twofold respect: as rational, which proceeds accurately by demonstration, and practical. To practical mechanics all manual arts belong, from which mechanics took its name. But as artificers do not work with perfect accuracy, it comes to pass that mechanics is so distinguished from geometry that what is perfectly accurate is called geometrical; what is less so is called mechanical.[11]

The elevation of mechanics to the status of a legitimate tool in the mathematician's quest for knowledge of nature cannot be attributed to either Plato or Aristotle, who believe that manual labour should be performed by slaves.[12] To investigate nature 'manually' is considered beneath the dignity of the mathematician. In our opinion, Newton had in mind neither Plato nor Aristotle but Archimedes or the Muslims who had invented a wealth of mechanical instruments.[13]

The possibility of Newton's acquaintance with the Islamic contribution in mechanics could not be overlooked. The recieved view that European civilisation is the direct descendent of Greece

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[10] Ibid., p.286.

[11] See Principia, Motte-Cajori, p.xvii.

[12] See Plato, Laws V, 743 D; Also vii, 806 D. See Aristotle, Politics, i, 2 (4,5) and 5 (3-10).

[13] An excellent example would be al-Biruni who had made an astrolabe and some instruments to measure density. See Chapter 1.

and Rome has been shown to be misleading, particularly when transfer of technology is concerned. It has been argued that the most of the so called Hellenistic and Roman mechanical contribution to Europe are actually mechanical products invented by Islamic scholars and artisans of Egypt and Syria.[14] An avid reader of history like Newton is very likely to have come across the development of technology, particularly mechanics, in the pre-renaissance period.

Setting these interesting possibilities aside, Newton argues that geometry is the foundation of mechanics. In order for a mathematician to be a mechanic par excellence, he should master geometry. In the mathematician's quest for studying nature, he should work like a mechanic by uniting both his head and hand and not simply deducing 'using his head'. Says Newton concerning the significance of mechanics and geometry:

> He that works with less accuracy is an imperfect mechanic; and if any could work with perfect accuracy, he would be the most perfect mechanic of all; for the description of right lines and circles upon which geometry is founded, belongs to mechanics.[15]

According to Newton, geometry includes the art of inferring from hypotheses, that is, from proven phenomena. The root of mechanical practice lies in geometry. Mechanics is that subject of geometry concerning the art of measuring. For example, Newton

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[14]See A.Y. al-Hassan & D.R. Hill, Islamic Technology: An Illustrated History, (Cambridge Univ. Press, Cambridge; 1986), pp. 31-35.

[15]Principia, Motte-Cajori, p. xvii. All underlined quotations are by authour.

claims that describing 'figures' are not geometrical problems but mechanical. He writes:

> Geometry does not teach us to draw these lines, but requires them to be drawn; for it requires that the learners should first be taught to describe these accurately before he enters upon geometry, then it shows how by these operations problems may be solved. To describe right lines and circles are problems, but not geometrical problems. The solution of these problems is required from mechanics, and by geometry the use of them, when so solved, is shown; and it is the glory of geometry that from those few principles, brought from without, it is able to produce so many things. Therefore geometry is founded in mechanical practice and is nothing but that part of universal mechanics which accurately proposes and demonstrates the art of measuring.[16]

From the above passage, we can trace the general schema of Newton's conception of reducing "the phenomena of nature to the laws of mathematics". Beginning with phenomena, the mathematician applies geometrical principles to the phenomena, yielding some axioms. Mechanical principles are then applied to these axioms in order to explain other phenomena. If the resulting mathematical formulae are successful in explaining and predicting those phenomena, they are elevated to the status of mathematical laws. Thus:

Phenomena of nature---> geometrical principles-----> mechanical principles----> other phenomena------> mathematical laws

Dia. 5.2 Newton's conception of the importance of mechanics and geometry in mathematics.

So far we have not discussed about Newton's conception of the place of numbers in his mathematics. This is so because unlike al-

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[16]See Principia, Motte-Cajori, p. xvii.

Bīrūnī, Newton does not treat numbers per se in any comprehensive or very qualitative way. When he mentions numbers in the Principia, it is usually in terms of "geometric measures" in the sense that everything in the external world is theoretically measureable. Yet to undermine the importance of numbers in his philosophy of mathematics would be misleading because he believes that it is through "sensible measures" that we can study extra sensible objects. For example, his discussion on space leads him to write: "But because the parts of space cannot be seen or distinguished from one another by our senses, therefore in their stead we use sensible measures of them",[17] and elsewhere; "And if the meaning of words is to be determined by their use, then by the names 'time', 'space', 'place', and 'motion', their [sensible] measures are properly understood;..."[18] In Newton's philosophy of mathematics, numbers constitute an integral part of arithmetics and are closely bonded with geometry so much so that it is by way of geometry that they are of tremendous use to the natural philosopher in deciphering God's works.

The significance of geometry and mechanics in shaping Newton's philosophy of mathematics is also evident from his comments concerning the conventional use of those terms. Newton argues that although geometry is "that part of universal mechanics which accurately proposes and demonstrates the art of measuring",

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[17]See H.S. Thayer, ed., Newton's Philosophy of Nature: Selections..., op. cit., p.20.

[18]Principia, Motte-Cajori, p.11.

geometry is not customarily percieved that way. He writes:

> But since the manual arts are chiefly employed in the moving of bodies, it happens that geometry is commonly referred to their magnitude, and mechanics to their motion.[19]

Bearing in mind of the "vulgar" aspect in the usage of the word "geometry" and "mechanics", he gives a definition for his "rational mechanics."

> In this sense rational mechanics will be the science of motions resulting from any forces whatsoever and of the forces required to produce any motions, accurately proposed and demonstrated.[20]

In view of the above passage, Newton's "rational mechanics" includes geometry and arithmetics as well because it is evident that the study of both "motions" and "forces" definitely involves "measures". As a matter of fact in his letter to Hawes, he states:

> Geometry is the foundation of Mechanicks, & Mechanicks the accomplishment & Crown of Geometry, & both are assisted by Arithmetick for computing and perspective for drawing figures: So that any part of this Systeme being taken away the rest remaines imperfect.[21]

Since arithmetics, geometry and mechanics, or to use his terms "rational mechanics", is fundamental to his conception of mathematizing nature, accordingly in Newton's view the foundation of his programme of mathematization is his "rational mechanics". We come to this conclusion because in his discussion on "rational mechanics," he states:

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[19] Ibid., p.xvii.

[20] Ibid., p.xvii.

[21] See J. Eddleston, op.cit., p.286.

> This part of mechanics, as far as it extended to the five powers which relates to manual arts, was cultivated by the ancients, who considered gravity (it not being a manual power) not otherwise than in moving weights by those powers. But I consider philosophy rather than arts, and write not concerning manual but natural powers, and consider chiefly those things which relate to gravity, levity, elastic force, the resistance of fluids, and the like forces, whether attractive or impulsive; and therefore I offer this work as the mathematical principles of philosophy, for the whole burden of philosophy seems to consist in this: from the phenomena of motions to investigate the forces of nature, and then from these forces to demonstrate the other phenomena; and to this end the general propositions in the first and Second Books are directed.[22]

That the foundation of his programme of mathematization rests upon "rational mechanics" can also be discerned from the continuation of the above passage found in the third section of the Principia wherein Newton describes the "geometrical aspects" in order to derive other mathematical laws. Writes Newton:

> In the Third Book, I give an example of this in the explication of the System of the World; for by the propositions mathematically demonstrated in the former books, in the third I derive from the celestial phenomena the forces of gravity with which bodies tend to the sun and the several planets. Then from these forces, by other propositions which are also mathematical, I deduce the motions of the planets, the comets, the moon and the sea. I wish we could derive the rest of the phenomena of Nature by the same kind of reasoning from mechanical principles.[23]

If we take into account what Newton meant by "rational mechanics", mathematics that is built upon it is surely axiomatic but not purely theoretical. It is mathematics resulting from the unity of hand and head, a marriage between the world of sensibles and to some aspects related to the world of intelligibles.

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[22]See Principia, Motte-Cajori, p.xvii.

[23]See ibid., p.xviii.

5.3. God: the Mathematician and Mechanic.

In the previous chapter, we have discussed Newton's concept of God. In this section, we will examine in greater detail the place of God in Newton's scheme of reducing the phenomena of nature to that of mathematics.

The concept of God as a mathematician is not entirely new. We can trace it as far back as to the Greeks. Plato's demiourgos was a mathematician but he could not be a mechanic in Newton's sense of the word. The demiourgos was always constrainted by the eternal Ideas and considers it humiliating to make even a mortal pot.[24] What is new in Newton's conception of God as the mathematician is that God is not only a perfect geometer but also an expert mechanic, Who makes everything and there is no act of creation which is not proper for his "divine arm".[25] Says Newton:

> To make this system therefore, with all its Motions, required a Cause which understood, and compared together, the Quantities of Matter in the several Bodies of the Sun and Planets, and the gravitating Powers resulting from thence; the several distances of the Primary Planets from the Sun, and of the secondary ones from Saturn, Jupiter, and the Earth; and the velocities with which these Planets could revolve about those Quantities of Matter in the central Bodies; and to compare and adjust all these Things together, in so great a Variety of Bodies, argues that Cause to be not Blind and

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[24]See R. Hooykas, Religion and the Rise of Modern Science, (Michigan, USA), p. 10.

[25]Newton uses the phrase "divine arm" at several places. Just to cite two examples, Newton says: "...I do not know any power in nature which would cause this transverse motion without the divine arm". (See Newton's second letter to R. Bentley) and elsewhere, "...the diurnal rotations of the planets could not be derived from gravity, but required a divine arm to impress them". (See his fourth letter, ibid.). It is interesting to note that predating Newton, Kepler and Galileo use the anthromorphic phrase "finger of God" and "hand of God" respectively.

> fortuitous, but very well skilled in Mechanicks and Geometry.[26]

In view of the above statement, an important aspect of Newton's God is that He is "very well skilled in Mechanicks and Geometry". From Newton's point of view, God is not a mathematician in the anthromorphic sense of an arm chair natural philosopher. He is a mathematician in the sense that He deduces and invents aided by the natural causes which are His instruments. "Where natural causes are at hand", states Newton, "God uses them as instruments in his works".[27] By "natural causes", Newton is referring to "gravity, levity, elastic force, the resistance of fluids, and the like forces, whether attractive or impulsive".[28] Just as a mechanic requires specific instruments to do his job, so is Newton's God. Newton's God closely resembles that of a clock maker. God not only creates the world but like a mechanic, He also maintains it occasionally.

> God made the world and governs it invisibly, and hath commanded us to love, honour and worship him and no other God but him, and to do it without making any image of him and not to name him idly and without reverence...[29]

Newton believes that God who is the most perfect mechanic and geometer, governs the world in a particular way. He is not the soul of the universe, yet He dominates everything. Thus:

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[26]See Newton's first letter to R. Bentley, 10th December 1692.

[27]See Newton's letter to Thomas Burnet, January 1680/81, Correspondence, Vol.II, pp.329-334.

[28]See Principia, Motte-Cajori, p.xvii.

[29]See Theological Manuscripts, op. cit., p.54.

> This Being governs all things, not as the soul of the world, but as Lord over all; and on account of his dominion he is wont to be called Lord God παντοκράτωρ or Universal Ruler; for God is a relative word, and has a respect to servants; and Deity is the dominion of God not over his own body, as those imagine who fancy God to be the soul of the world, but over servants. The Supreme God is a Being eternal, infinite, absolutely perfect, without dominion, cannot be said to be Lord God; ... The word God usually signifies Lord; but every Lord is not a God. It is the dominion of a spiritual being which constitutes a God: a true, supreme, or imaginary dominion makes a true, supreme, or imaginary God. And from his true dominion it follows that the true God is a living, intelligent, and powerful Being; and, from his other perfections, that he is supreme, or most perfect.[30]

Accordingly Newton claims that "All that diversity of natural things which we find suited to different times and places could arise from nothing but the ideas and will of a Being necessarily existing".[31] It is with regard to this aspect of God that Newton writes: "Thou shalt love the Lord thy God with all thy heart, and with all thy soul, and with all thy mind:..."[32]

Newton's God who is skilled in mechanics and geometry is omnipresent. We have stated earlier that Newton's God uses natural causes as His instruments. There is yet another aspect of God in Newton's philosophy of mathematics wherein He manages the universe by way of His Sensorium. Newton mentions this aspect in one of his cosmological arguments for the Existence of God.

> Also the first Contrivance of those very artificial Parts of Animals, the Eyes, Ears, Brain, Muscles, Heart, Lungs,

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[30]See Principia, Motte-Cajori, pp.544-45, Principia, Koyre'-Cohen, pp.760-61.

[31]See ibid., Motte-Cajori, p.546; ibid., Koyre'-Cohen, pp.762-3.

[32]See Theological Manuscripts, p.48.

> Midriff, Glands, Larynx, Hands, Wings, swimming Bladders, natural Spectacles, and other Organs of Sense and Motion; and the Instinct of Brutes and Insects, 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.[33]

What is God's Sensorium? Certainly for Newton, God's Sensorium is not an organ of sensation because He has no such need. At least that much is clear to Newton. God's Sensorium is neither the world nor a Part of Him. Says Newton:

> And yet we are not to consider the World as the Body of God, or the several Parts thereof, as the Parts of God. He is a uniform Being void of Organs, Members or Parts, and they are his Creatures subordinate to him, and subservient to his Will; and he is no more the Soul of them than the Soul of man is the Soul of the Species of Things carried through the Organs of Sense into the place of its Sensation, where it percieves them by means of its immediate Presence, without the Intervention of any third thing. The Organs of Sense are not for enabling the Soul to perceive the Species of Things in its Sensorium, but only for conveying them thither; and God has no need of such Organs, he being every where present to the Things themselves.[34]

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[33]See Opticks, pp. 402-3.

[34] Ibid., pp.402-3. According to Samuel Clarke; "Sir Isaac Newton does not say, that space is the Sensorium God; but that it is, by way of similitude only, as it were the sensory, &c." See H.G. Alexander, ed., The Leibniz-Clarke Correspondence, (Manchester & New York, 1956), under the heading "Clarke's Second Reply", p.21. See also Samuel Clarke, ed. A Collection of papers which passed between the late learned Mr. Leibnitz and Dr. Clarke in the years 1715 and 1716 relating to the Principles of Natural Philosophy and Religion, (London, 1717). The extent of Newton's deep involvement with Clarke in the correspondence is discussed at great length by I.B. Cohen, A. Koyre, "Newton and the Leibniz-Clarke Correspondence, with Notes on Newton, Conti, and Des Maizeaus", Archives Internationales d'Historie des Sciences, 15(1962), pp. 63-126.

In view of the above passage, one is inclined to say that God's Sensorium is "the place of its Sensation". But taking into account that Newton's God "perceives them by means of its immediate Presence without the Intervention of any third thing", the word "sensorium" described by Newton as an aspect of God points to nothing save Its Existence. As a point of fact, Newton writes elsewhere:

> God is the same God, always and everywhere. He is omnipresent not virtually only, but also substantially; for virtue cannot subsist without substance. In him are all things contained and moved; yet neither affects the other: God suffers nothing from the motion of bodies; bodies find no resistance from the omnipresence of God. It is allowed that the Supreme God **exists** necessarily; and by the same necessity he **exists** always and everywhere.[35]

God's Sensorium is an aspect of God which only He knows. "As a blind man has no idea of colours", Newton comments, "so have we no idea of the manner by which the all wise God percieves and understands all things",[36] not withstanding the fact that God knows directly without any intermediary. Unlike His creations, God who is a perfect geometer and a mechanic, knows by his Divine Presence and Divine Wisdom. Thus:

> Is not the Sensory of Animals that place to which the sensitive Substance is present, and into which the sensible Species of Things are carried through the Nerves and Brain, that there may be perceived by their immediate presence to

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[35]See Principia, Motte-Cajori, p.545.

[36]See ibid., p.545. It is important to note here that although we are ignorant of how God perceives and understands things, Newton believes that we can know how He does things, that is, by way of mechanics and geometry.

> that Substance? And these things being rightly dispatch'd, does it not appear from the Phenomena that there is a Being incorporeal, living, intelligent, 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;...[37]

We claim that it is this concept of God, as a geometer and a mechanic par excellence who is the sole creator of this world, which functions as the underlying raison d'etre for Newton to reduce the phenomena of nature to mathematical laws.[38] In order to arrive at this conclusion, we will elaborate on Newton's position towards idolatory and consequently his attempt to de-deify nature by mathematizing it.

Newton views idolatory as the greatest evil of mankind. Idolatory is the manifestation of Atheism.[39] Idolatory, says Newton, is "against the principal part of religion, is in scripture condemned and detested above all other crimes".[40] It is the greatest evil for no other reason but because of what it brought

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[37]See Opticks, p.370.

[38]It is worthy to note that in Bentley's lecture sanctioned by Newton, the former states:

> Now that all this Distances and Motions and Quantities of Matter should be so accurately and harmoniusly adjusted in this great Variety of our System, is above the fortuitous Hits of Blind Material Causes, and must certainly flow from that eternal Fountain of Wisdom, the Creator of Heaven and Earth, who always acts Geometrically, by just and adequate numbers and weights and measures.

See R.Bentley, "A Confutation of Atheism (III)," in Papers and Letters, p.364.

[39]See Theological Manuscripts, p.48.

[40] Ibid., p.49.

forth; mediators betweeen men and God. The idols can assume many different names. "Whatever you call them, Dy, or Divi, Gods, or Saints or by any other name is not material",[41] says Newton.

The major problem with idolatory is that it is diametrically opposed to the Qualities of God. God is the One and in Newton's terminology, He "forms and reforms" exclusively by Himself. There is no other being besides Him who shares His power. The idolaters, however, ascribe powers to other than God. In his discussion concerning the sin of idolatory, Newton writes:

> ...in serving false or feigned Gods, that is, Ghosts or Spirits of dead men, or such like beings which you make your Gods, by feigning that they can hear your prayers, do you good or hurt, and praying to them for protection and blessings and trust in them for the same, and which are false gods because they have not the powers which you ascribe to them, and on which you trust.[42]

Now that we have stated Newton's view on false Gods; those things which "have not the powers which you ascribe to them", we will examine his conception of the "natural causes", the essential ingredients which are "God's instruments" explicated earlier. The problem is to find the underlying reason for Newton's effort to mathematize nature. He says that "in philosophical disquisitions, we ought to abstract from our senses and consider things themselves, distinct from what are only sensible measures of them".[43]

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[41] Ibid., p.49.

[42] Ibid., p.49.

[43] See Principia, Motte-Cajori, p.8.

Let us consider Newton's position regarding one of his 'natural causes' in light of his opinion on idolatory, that is his concept of force. Newton speaks of "innate force", "impressed force", and "centripetal force" but what is "force" according to Newton? Desribing what forces are, Newton states:

> These quantities of forces we may, for the sake of brevity, call by the names of 'motive', 'accelerative', and 'absolute forces'; and for the sake of distinction, consider them with respect to the bodies that tend to the center, to the places of those bodies, and to the center of force toward which they tend; that is to say, I refer the motive force to the body as an endeavour and the propensity of the whole toward the center, arising from the propensities of the several parts taken together; the accelerative force to the place of the body, as a certain power diffused from the center to all places around to move the bodies that are in them; and the absolute forces to the center, as endued with some cause, without which those motive forces would not be propagated through the spaces round about; ...For I here design only to give a mathematical notion of those forces, without considering their physical causes and seats.[44]

Therefore from Newton's perspective in studying nature, "forces" are merely mathematical notions irrespective of the powers associated with it. "Forces" are "God's instruments", and as "God's instruments," they are not equivalent to God; anymore than a mechanic's instrument is equivalent to the mechanic himself. Whatever power these instruments may have, they are incomparable to that of God. Newton drives home the point not to ascribe equal powers to them. In his scheme of mathematizing nature, forces could never end up as idols bearing in mind that idols can subsume different names. The only mechanic and geometer "forming and reforming" the universe is God and not "forces".

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[44] Ibid., p.5.

In similar vein, Newton re-emphasizes the de-deification of nature to merely mathematical notions in his comments to the above passsage wherein he reminds the readers of the Principia:

> I likewise call attractions and impulses, in the same sense, accelerative and motive; and uses the words 'attraction,' 'impulse,' or 'propensity' of any sort toward a center, promiscously and indifferently, one for another, considering those forces not physically but mathematically; wherefore the reader is not to imagine by those words I anywhere take upon me to define the kind or the manner of any action, the causes or the physical reason thereof, or that I attribute forces, in a true and physical sense, to certain centers (which are only mathematical points) when at any time I happen to speak of centers as attracting or as endued with attractive powers.[45]

Another example that we have in mind is his concept of gravity. Although Newton uses the phrase "the power of gravity", it is not the case that power is inherent in gravity such that gravity has an equal power to God. He even insists that gravity is not "essential and inherent to matter".[46] To believe that it is so is "so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it",[47] writes Newton.

Newton ventures on explaining the operation of gravity. He speculates in his An Hypothesis Explaining the Properties of Light that the "continual condensation" of ethereal spirit yields "the gravitational attraction of the earth".[48] And in his 1679 Letter to

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[45] Ibid., pp.5-6.

[46] See Newton's second letter to Bentley. See also Correspondence III, p.240.

[47] See Newton's third letter to R. Bentley.

[48] See Papers and Letters, pp. 180-1.

Boyle, Newton considers ether to have varying densities "in such a manner, that from the top of the air to the surface of the earth...the aether is insensibly finer and finer".[49] Consequently, bodies falling to the earth in the same manner as corks rising in water.

Like any other hypotheses on natural causes, gravity has to be understood mathematically and used "in so far as they may furnish experiments".[50] This is Newton's position with respect to the natural causes in his scheme of reducing natural phenomena into mathematical laws. More than anything else, gravity is a mathematical notion, a mathematical entity which can be "deduced from the phenomena" and "rendered general by induction". It is sufficient for Newton that a mathematical entity such as gravity "does really exist and act according to the laws...and abundantly serves to account for all the motions of the celestial bodies, and of our sea".[51] Just as "force" should never be perceived as God or His equal, so is gravity. Gravity is merely a mathematical notion used to describe mathematical relation between mathematical objects in nature such as the inverse square law. Newton's position reflects the increasing importance of quantitative as opposed to the qualitative aspects of his mathematics. Thus:

> Hitherto we have explained the phenomena of the heavens and of our sea by the power of gravity, but have not yet assigned the cause of this power. This is certain, that it must proceed

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[49] Ibid., p.253.

[50] See Newton's letter to Oldenburg in Opera Omnia, IV, p.314.

[51] See Principia, Motte-Cajori, p.547.

> from a cause that penetrates to the very centers of the sun and planets, without suffering the least diminuation of its force; that operates not according to the quantities of the surfaces of the particles upon which it acts (as mechanical causes used to do), but according to the quantity of the solid matter which they contain, and propagates its virtue on all sides to immense distances, decreasing always as the inverse square of the distances.[52]

In addition to his concept of gravity, Newton's distinction between what counts as relative and absolute, apparent and true, common and mathematical, likewise reflects his positon on the need for the de-deification of nature. It is worthy to note that, by and large, Newton equates that which is absolute to that which is true and mathematical; and that which is apparent as equal to that which is relative and common. In other words, in the final vertical analysis and within the hiearchy of reality, nature and all its furniture could be described as mathematical. In more specific terms, Newton embraces the view that mathematics can function as a ladder from the sensibles to some aspects of the intelligibles, although to a lesser degree than al-Bīrūnī. The mathematical experience of the mathematician is a passage to understand some aspects of the world of intelligibles. Mathematical entities could not exist purely by themselves although they do have some natural power.

Newton's concept of time is an example to illustrate the distinction between the sensibles and the intelligibles and his belief that mathematics function as a bridge connecting them.

> Absolute, true and mathematical time, of itself and from its own nature, flows equably without relation to anything

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[52] Ibid., p.546.

external, and by another name is called 'duration'; relative, apparent, and common time is some sensible and external (whether accurate or equable) measure of duration by the means of motion, which is commonly used instead of true time, such as an hour, a day, a month, a year.[53]

The de-deification of nature in Newton's philosophy of mathematics, which is achieved by minimizing any powers associated with natural causes, ends up with its mathematization. We will delve deeper into the status of mathematical knowledge which includes discussion on mathematical truth in accord with Newton's perspective in the next chapter. What we want to emphasize here is that in the case of Newton, the de-deification of nature stemmed from his strong position against idolatory. It is a consequence of his staunch belief that God is the geometer and mechanic who keeps on "forming and reforming" the world. That God is the mechanic and geometer is a fact and not an opinion for Newton whereas the amount of power His creations have is of the status of opinion, an hypothesis and by his account of it can only be included cautiously in his natural philosophy. Thus:

> It is not the Business of Experimental Philosophy to teach the Causes of things further than they can be proven by Experiments. We are not to fill this Philosophy with Opinions which cannot be proved by Phaenomena.[54]

Another point that is relevant and is related to our

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[53] Ibid., p. 6.

[54] See A.R. Hall and M.B. Hall, eds., Sir Isaac Newton: The Unpublished Scientific Papers of Isaac Newton. A Selection from the Portsmouth Collection in the University Library, Cambridge, (Cambridge Univ. Press; London, 1980), p.312.

discussion is Newton's attitude in studying nature. If the amount of power is freely ascribed to natural causes, then it will run counter to an important aspect of his natural philosophy because Newton believes that only God has the greatest power. The study of nature should result in greater knowledge about God and his glorification. "And though every true Step made in this Philosophy brings us not immediately to the Knowledge of the First Cause", says Newton, "yet it brings us nearer to it, and on that account is to be highly valued".[55] This statement about glorifying God as an important end and a desired product in his philosophy of mathematics echoes again in another statement:

> 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.[56]

Thus the de-deification of nature by mathematization and the total acknowledgement of God who is the mechanic cum geometer, the sole creator and the only Lord of the Worlds.[57]

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[55]Opticks, p.370.

[56] Ibid., p.405.

[57]That Newton believes in the plurality of the world, see Brewster, Memoirs,...Vol. II, p. 353. Concerning the glorification of God as the desired product of Newton's natural philosophy, it is interesting to note that in Roger Cotes' introduction to the Principia which recieved Newton's commendation, he writes:

> Therefore we may now more nearly behold the beauties of Nature and entertain ourselves with the delightful contemplation, and, which is the best and most valuable fruit of philosophy, be thence incited the more profoundly to reverence and adore the great Maker and Lord of all. He must be blind who, from the most wise and excellent contrivances of things, cannot see

5.4. Stages of Mathematization

Having discussed Newton's view of God and mathematics, now is the time to examine his mode of inquiry, specifically his pattern of mathematical abstraction. We want to study the process of abstraction imbedded in his method of reducing natural phenomena into mathematical laws.

Phenomena is the most basic concept in his mathematization. In a nutshell, Newton states that "Experimental philosophy proceeds only upon Phenomena and deduces general propositions from them only by Induction".[58] We have explicated Newton's conception of phenomena in section 4.4. We wish only to mention here that by "phenomena" Newton includes "whatever things are perceived, whether they be external things which become known to us through the five senses, or internal which we contemplate in our minds when thinking".[59] Therefore, mathematical objects of the external world and their corresponding mathematical images form parts of phenomena. What remains to be studied are the detailed processes that link phenomena to the mathematical laws, the so

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the infinite wisdom and goodness of their Almighty Creator, and he must be mad and senseless who refuses to acknowledge them. [underline mine] (See Principia, Motte-Cajori, pp. xxxii-xxxiii)

[58]See Isaac Newton's letter dated 31 March 1713 to Roger Cotes. J. Eddleston,ed., Correspondence of Sir Isaac Newton and Professor Cotes, (London, 1969), p.156.

[59]Quoted in I.B. Cohen, Introduction to Newton's Principia, op. cit., p. 30. See also ibid., Issac Newton, The Creative Scientific Mind at Work; Wiles Lecture, (Belfast; Northern Ireland, 1966) p.128. Hereafter referred to as I.B. Cohen, Creative...

called "general *proposition*".

In our point of view, one of Newton's most important passages concerning his mode of mathematization could be found in one of his MSS. He writes:

> As Mathematicians have two Methods of doing things which they call Composition and Resolution and in all difficulties have recourse to their method of resolution before they compound so in explaining the Phaenomena of nature the like methods are to be used and he that expects success must resolve before he compounds, for the explications of Phaenomena are Problems much harder than those in Mathematics. The method of resolution consists in trying experiments and considering all the Phaenomena of nature relating to the subject in hand and drawing conclusions from them and examining the truth of those conclusions from those experiments and so proceeding from experiments to conclusions and from conclusions to experiments until you come to the general properties of things. Then assuming those properties as Principles of Philosophy you may by them explain the causes of those Phaenomena as follow from them which is the method of Composition...
>
> Thus in the Mathematical Principles of Philosophy I first showed from Phaenomena that all bodies endeavour by a certain force proportional to their matter to approach one another, that this force in receding from the body grows less and less in reciprocal proportion to the square of the distance from it and that it is equal to gravity and therefore is one and the same force with gravity. Then using this force as a Principle of Philosophy I derived from it all the motions of the heavenly bodies and flux and reflux of the sea, showing by mathematical demonstrations that this force alone was sufficient to produce all those Phaenomena and deriving from it [a priori] some new motions which Astronomers had not been observed but since appear to be true, as that Saturn and Jupiter draw one another, that the variation of the moon is bigger in winter than in Summer, and that there is an equation of the moons mean motion amounting to almost 5 minutes which depends upon position of her Apogee to the Sun.[60]

On reading the above passage, one is tempted to conclude that experiments are central to Newton's method of Composition and Resolution. While performing experiments is definitely an important

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[60] Ibid., p.98-99.

'external' aspect of his pattern of mathematical inquiry, there is yet another more fundamental aspect than experimentation in so far as mathematical abstraction is concerned. It is none other than observation.

The significance of observation is evident from another passage similar to the above which appears in Query 31 of his Opticks. Newton states:

> As in Mathematicks, so in Natural Philosophy, the Investigation of difficult Things by the method of Analysis, ought ever to precede the Method of Composition. This Analysis consists in making Experiments and Observations, and in drawing general Conclusions from them by Induction, and admitting of no Objections against the Conclusions, but such as are taken from Experiments, or other certain Truths. For Hypotheses are not to be regarded in experimental Philosophy. And although the arguing from Experiments and Observations by Induction be no Demonstration of general Conclusions; yet it is the best way of arguing which the Nature of Things admits of, and may be looked upon as so much the stronger, by how much the induction is more general. But if at anytime afterwards any exception shall occur from Experiments, it may then begin to be pronounced with such Exceptions as occur. By this way of Analysis we may proceed from Compounds to Ingredients, and from Motions to Forces producing them; and in general, from Effects to their Causes, and from particular Causes to more general ones, till the Argument end in the most general. This is the method of Analysis: and the Synthesis 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.[61]

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[61]See Opticks, pp. 404-405. Only half of the quoted passage appeared in Query 23 in the Latin edition (1706). In the other editions, the complete passage appeared in Query 31. It is worthy to note that Roger Cotes, in his introduction to the Principia, has this to say:

> 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 reknowned author most justly embraced in preference to the rest... (See Principia, Motte-Cajori, pp.xx-xxi.).

In light of the above passage, Newton begins by differentiating the Method of Resolution (or Analysis) and the Method of Composition. Examples abound on what counts as a product of Analysis as opposed to Composition for according to Newton, the first two books of his Opticks consists of Analysis with the exception of an example given at the end to illustrate the Method of Composition.[62] Likewise in the Principia, the method of Composition is demonstrated in the third book.[63] What we want to emphasize is that methodologically speaking, the Method of Analysis should be performed first before the Method of Composition. Yet the common methodological aspects underlying them or the "heart" of both Methods so to speak, are observations and experiments. In so far as Newton's mathematization of nature is concerned, it is important to note that in both experiments and observations he believes that the senses play an integral role. "We in no other way know the extension of bodies than by our senses", says Newton.[64]

According to Newton, there are two aspects of observation;[65]

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[62] Ibid., p.405

[63] See footnote 21 of this chapter.

[64] See Principia, Motte-Cajori, pp. 399; Principia, Koyre'-Cohen, pp.553.

[65] It is worthy to note here that Newton was a particularly acute observer, so much so that it could be said that his best scientific instrument was his eyes. His observation on the ordinary bubble which he relates in order to buttress his argument concerning his Experimentum Crucis is a case in point. In his reply to Hooke, he writes:

> ...the Colours of water bubbles and other thin pellucid substances afford several instances of whiteness produced by

the external and the internal. The external aspect is that carried out by the five external senses.[66] Their main purpose is to convey raw data to the sensorium. Speaking of the external senses, Newton writes: "The organs of senses are not for enabling the soul to perceive the species of things in its sensorium, but only for conveying them thither",[67] and elsewhere,

> Is not vision performed chiefly by the vibrations of this medium, ...propagated through...the optic nerves into the place of sensation? And is not hearing performed by the vibrations either of this and some other medium...propagated through...those nerves into the place of sensation? And so of the other senses.[68]

According to Newton, sensation is not the same as reason. It is possible to make judgement from sensation. An example is his discussion on the impenetrabilities of bodies, Newton says: "That all bodies are impenetrable, we gather not from reason, but from sensation. The bodies which we handle we find impenetrable, and thence conclude impenetrability to be a universal property of all bodies whatsoever".[69]

> their mixture...there will appear a great variety of colours all over the top of every bubble, if you view them near at hand; but if you view them at so great a distance that you cannot distinguish the colours one from another, the frost will appear perfectly white. (Phil. Trans., No.88, 1672, p.5102)

[66]Newton also uses the phrase "five powers" to denote the five external senses. For example in commenting on mechanics, he says: "This part of mechanics, as far as it extended to the five powers which relate to manual arts, was cultivated by the ancients,...". [See Principia, Motte-Cajori, p.xvii.]

[67]See Opticks, p.403.

[68] Ibid., p.353.

[69]See Principia, Motte-Cajori, p.399.

The internal aspect of observation concerns the soul, the sensorium and the mind. His discussion about the divisibility of particles leads him to write:

> Moreover, that the divided but contiguous particles of bodies may be separated from one another is a matter of observation; and, in the particles that remain undivided, our minds [not our external senses] are able to distinguish yet lesser parts, as is mathematically demonstrated.[70]

As we have briefly noted in an earlier section, the sensorium is the place into which data passes. It is the place of sensation. "The right side of the sensorium comes from the right side of both eyes....the left side of the sensorium comes in like manner from the left side...",[71] claims Newton.

In his discussion of God, Newton hints that images of the external world which include mathematical images,[72] are transferred into the sensorium by means of the organs of sense, "...of which things the images only carried through the organs of sense into our little sensoriums are there seen and beheld by that which in us perceives and thinks..."[73] As important as the sensorium and the external senses may be, it is not from them that the mathematician perceives. Rather it is the soul that perceives the mathematical meanings of the mathematical images. Newton writes with regards to observing two objects:

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[70] Ibid., p.399.

[71] See Query 15 in Opticks, p.346.

[72] By "mathematical images" I include mathematical relations and figures, be they geometrical or numerical.

[73] See Opticks, p.370.

> In like manner when we look with two eyes distorted so as to see the same object double, if it be asked why those objects appear in this or that situation and distance one from another, the answer should be because through the two eyes are transmitted into the sensorium two motional pictures by whose situation and distance then from one another the soul judges she sees two things so situate and distant.[74]

We posit that Newton also expounds on the perceptive aspect of the soul when he states that: "Every soul that has perception is, though in different times and in different organs of sense and motion, still the same indivisible person".[75] As a point of fact, Newton alludes that it is the soul which hold the place of primacy in the act of perception, mathematical or otherwise; for that matter in the existence of the man. Let us consider the following statement with respect to the preceeding quotation which is given almost as its continuation in the same scholium. "Every man, so far as he is a thing that has perception, is one and the same man during his whole life, in all and each of his organs of sense".[76]

We can still investigate Newton's theory of mathematical perception even further by questioning the way of the arrival of mathematical meaning at the soul. As a matter of fact in his scholium, Newton rejects the concept that we can gain knowledge merely by way of our internal or external senses. Newton puts it succintly when he states:

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[74]See Newton's letter to William Briggs in J. Edleston, op. cit., p. 265.

[75]See Principia, Motte-Cajori, p.545.

[76] Ibid., p.545.

> In bodies we see only their figures and colours, 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 our senses or by any reflex act of our minds;..."[77]

In order to throw some light on, and consequently answer the question posed above, we will study Newton's conception of God as the source of all knowledge which includes mathematics, bearing in mind that Newton was apprehensive about sharing the same camp with supporters of the theory of emanation discussed earlier.[78]

That God who is the creator of everything has all mathematical knowledge is clear to Newton. In Art. 4 of the Twelve Articles, Newton states: "The Father is omniscient, and hath all knowledge originally in his own breast,..."[79] and elsewhere, God "governs all things and knows all things that are or can be done".[80] In other words, mathematical knowledge originates from Him.

Moreover Newton believes that the external world which is the world of multiplicity and the world of mathematical objects is not a result of "unguided" necessity. "Blind metaphysical necessity, which is certainly the same always and everywhere, could produce no variety of things",[81] says Newton. According to Newton, the external world consisting of mathematical objects come into being only through God. God creates mathematical objects from His divine

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[77] Ibid., p.546.

[78] See quotation on p.151 in chapter IV of this dissertation.

[79] See Theological Manuscripts, p.56.

[80] See Principia, Motte-Cajori, p.545.

[81] Ibid., p.546.

Ideas and Will. It is worthy to re-emphasize that Newton states: "All that diversity of natural things which we find suited to different times and places could arise from nothing but the ideas and will of a Being necessarily existing".[82] In light of this statement, from Newton's point of view God is pure existence because only He is necessarily existing.

Following Newton, what sense are we to make of God's existence and the natural philosopher's mathematical perception? Newton gives an enlightening remark with respect to this question. In his discussion of God and motion, he tells us:

> He is omnipresent not virtually but also substantially; for virtue cannot subsist without substance. In him are all things contained and moved, yet neither affects the other; God suffers nothing from the motion of bodies, bodies find no resistance from the omnipresence of God.[83]

Surely the above passage deserves more comment. By the phrase "in him are all things contained and moved", appears the following footnote in his Principia which is of interest to us:

> This was the opinion of the Ancients. So Pythagoras, in Cicer. de Nat. Deor. lib. i. Thales, Anaxagoras, Virgil, George. lib. iv. ver. 220; and Aeneid, lib. vi. ver. 721. Philo Allegor, at the beginning of lib. i. Aratus, in his Phaenom, at the beginning. So also the sacred writers:...The Idolaters supposed the sun, moon, and stars, the souls of men, and other parts of the world to be parts of the Supreme God, and therefore to be worshiped; but erroneously.[84]

Although it is not the purpose of this dissertation to explicate in extensive detail the philosophies adopted by all of the persons

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[82] Ibid.

[83] Ibid., p.545.

[84] Ibid.

mentioned in the passage above (for certainly there are some differences among them), let us consider for example the opinion of Pythagoras who is the first of the ancients mentioned by Newton. Speaking of Pythagoras, d'Olivet has this to say:

> "I have already said that the homogeneity of Nature was, with the unity of God, one of the greatest secrets of the mysteries. Pythagoras founded this homogeneity upon the unity of the spirit by which it is penetrated and from which, according to him, all our souls draw their origin. This dogma which he had received from the Chaldeans and from the priests of Egypt was admitted by all the sages of antiquity...these sages established a harmony, a perfect analogy between heaven and earth, the intelligible and the sentient, the indivisible substance and divisible substance, in such a manner that that which took place in one of the regions of the Universe or of the modification of the primordial ternary was the exact image of that which took place in the other".[85]

Therefore by the phrase "In him are all things contained and moved", we maintain that what is meant by Newton is the knowledge of the pervasive Divine Immanence and Divine Transcendence. It also points to his admission that mathematical perception and consequently the attainment of mathematical knowledge is only possible in so much as it is sanctioned by God; God grants mathematical knowledge particularly by means of His Divine Presence. Also, if we were to take into account his position of God's Essence, His Qualities, and, that God "may give his angels charge over us",[86] as well as the subtility of gravity and the

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[85]See A. Fabre d'Olivet, The Golden Verses of Pythagoras (New York, 1917). p.251. The whole quotation here is taken from S.H. Nasr, An Introduction..., p.4. It is worthy to note that Newton likewise believes in the analogy between the "world natural", which consists of heaven and earth, and the "world politique". See Castillejo, Expanding Force..., op. cit., pp. 32-33.

[86]See Theological Manuscripts, p.51.

world of brute facts, the phrase "In him all things contained and moved" bears a hiearchy of reality with Divine Essence at the outermost layer. The next inner layer will be Divine Qualities, followed consequently by "angelic," "subtle," and the innermost layer, the world of gross matter.[87]

However there is a note of caveat. The role of angels in the case of Newton is not equivalent to that of al-Biruni. Newton's angels only intervenes occasionally, for example, in the case of the well-known anomaly in the motion of Mercury's perihelion. God maintains nature like the mechanic who plays a very creative role only in the first act of invention (creation). Elsewhere Newton refers to the initial creative role of God in his discussion about ether whereby he says that: '...and after condensation wrought into various forms, at first by the immediate hand of the Creator, and ever since by the power of nature,...'[88]

Newton attributes the excitability of the sensation in the course of mathematization to a kind of spirit which is one of God's instruments. The closest he ever comes to identifying the spirit is in the Opticks, particularly in Query 22, whereby he opines that the spirit is the ether.[89] He also describes this "electric and elastic" spirit in his Principia.

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[87]There is a similarity here with the structure of reality propounded by Muslims scholars. See O. Bakar, Tawhid and Science, op.cit, pp.21-23.

[88]See Brewster, op. cit., Vol. I, pp. 390-393

[89]See Opticks, pp. 352-3.

> And now we may add something concerning a certain most subtle spirit which pervades and lies hid in all gross bodies, by the force and action of which spirit the particles of bodies attract one another at near distances and cohere, if contiguous; and electric bodies operate to greater distances, as well repelling as attracting the neighbouring corpuscles; and light is emitted, reflected, refracted, inflected, and heats bodies; and all sensation is excited and the members of animal bodies move at the command of the will, namely, by the vibrations of this spirit mutually propagated along the solid filaments of the nerves, from the outward organs of the sense to the brain and from the brain into the muscles.[90]

Elsewhere, he elaborates on the operation of the spirit; that the spirit by itself is not sufficient to convey the mathematical images from the mathematical objects to the sensorium. There are particular organs in our bodies that function as passages to the spirit:

> And therefore it can no way be conveyed to the sensorium so entirely by the ether itself. Nay, granting me but there are pipes filled with a pure transparent liquor passing from the eye to the sensorium and the vibrating motion of the ether will of necessity run along thither.[91]

Although from Newton's point of view sensations are excited chiefly by mean of the spirit, one should not infer that the spirit possesses mathematical knowledge. Rather, the function of the spirit is just to activate the sensation. In Newton's concept of mathematization, God is still the sole cause that bestows mathematical knowledge to the mathematician and the spirit is not to be ascribed with such power.

Once mathematical images are sent to the brain, the memory of

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[90]See Principia, Motte-Cajori, p.547.

[91]See Brewster, Memoirs..., Vol. I, pp.436.

the perceiver which is the retentive faculty retain the images in the absence of the mathematical objects from any of the external senses. The mathematical images also function as mathematical symbols. The imaginative faculty, which is yet another kind of internal sense, manages the mathematical symbols and formulates them for the soul. This is the level whereby mathematical symbols are stripped from their corresponding physical representations and mathematical interpolation or paraphrasing Newton, the process of mathematical reasoning which at this stage consists of "resolving", is carried out.[92] There are extensive use of geometric figures which are consonant with his belief that God is the perfect geometer. At this level, intermittently the mathematician checks the conclusion of his interpolation by conducting experiments,[93] that is by "proceeding alternately from experiments to conclusions & from conclusions to experiments".

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[92]An example of Newton's mathematical reasoning is given by Roger Cotes in his preface to the second edition of the Principia. Writes Cotes:

> Now it is evident from mathematical reasoning, and rigorously demonstrated, that all bodies that move in any curved line described in a plane and which, by a radius drawn to any point, whether at rest or moved in any manner, describe areas about that point proportional to the times are urged by forces directed toward that point. (See Principia, Motte-Cajori, p. xxii.)

[93]For some examples on the variety of experiments performed in the Principia, see Principia, Motte-Cajori, pp. 22-5 wherein he describes experiments with pendulums to verify the conservation of momentum; ibid., pp.316-26, (to detect 'the resistance of mediums by pendulums oscillating therein'); and ibid., pp. 337-45, ('to find the motion of water running out of cyclindrical vessel through a hole at a bottom'). For other experiments, see ibid., pp. 353-5, 355-66 and 382-4.

We need to emphasize the importance of experiment at the "resolving" stage. We have stated earlier that according to Newton, the world is a work of God. It is "sacred", so to speak. Therefore in his point of view it is not the case that the natural philosopher tests the world against his mathematical interpolation and declares that something is wrong with the world if the intricacies of the world did not fit his mathematical interpolation. Rather the fault or the 'imperfection' lies with the mathematician and not with the world. As a corollary to his position, to blame nature amounts to entertaining the idea that God is not a 'perfect' Creator and consequently blinding oneself to Divine Wisdom and Providence! This aspect points to a 'sacred' characteristic of his concept of mathematization.[94]

The process of resolving continues "until you come to the general properties of things", says Newton. These "general properties" later functions as mathematical axioms. In the "resolving" process, the products of interpolation are retained by the memory. In one of his drafts, Newton in fact mentions both of the internal senses.

> Hypothesis 5. The essential properties of bodies are not yet fully known to us. Explain this by the cause of gravity, and by the metaphysical power of bodies to cause sensation, imagination, and memory, and mutually to be moved by our thoughts.[95]

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[94]Newton's repeated statements on the significance of experiments are used by an army of commentators to support their positivists position. In my opinion, they would not have included Newton in their camps had they payed heed to the transcendantal aspect of his philosophy.

[95]See I.B. Cohen, Creative..., p.91.

Once the "general properties" are established, the method of composition follows by taking the "general properties" as principles or demonstrable truths.[96] The principles are used in explaining other phenomena or in other words, in solving problems which Newton believes are mathematically related to the principles. They are connected in the sense that the solutions to the problems are derivable from the principles. For example are problems entitled "To find the hourly variations of the inclination of the moon's orbit to the plane of the ecliptic"[97] and "To find the force of the moon to move the sea"[98] wherein he uses propositions proven earlier.

So far we have addressed the process of mathematical observation understood within the schema of Newton's philosophy of mathematics. In sum, mathematical images from the phenomena are sent via the senses into the brain when sensation is excited, and thereafter is analysed and synthesized by way of the imaginative faculty and retentive faculty, and judged by the soul who attains mathematical knowledge which ultimately issued forth from God who is the source of all knowledge. In all event, Newton's "phenomena" involves contemplating God and nature as established before.

Since the dominance of God in granting mathematical knowledge is evident in Newton's philosophy of mathematics, his apprehension

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[96]I will deal more on Newton's conception of truth in the next chapter.

[97]See Principia, Motte-Cajori, pp.468-470.

[98] Ibid., pp. 479-484.

about the theory of emanation appears to be that of parts and not in toto.[99] What he is subscribing to is somewhat a modification of the Avicennean cosmology and bears a resemblance to the doctrine propounded by William of Auvergne. Unlike the Avicennean cosmology, God functions as the Active Intelligence instead of the Archangel Gabriel. The will of God is both free and eternal. Yet the effects of God's decisions are not necessarily eternal.[100] Also nature have more 'natural power', resulting in a sharper distinction between the natural and supernatural.

5.5. Conclusion

We maintain that most of the commentaries on Newton's natural philosophy have either missed or overlooked the continuous linkage between his mathematics and the crucial role of God in his philosophy of mathematics. Consequently, they see him as a positivist, pure empiricist or at least as a conscious advocate of

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[99]See footnotes 53, 54 of Chapter IV; cf. F. Manuel's statement in his Religion...., op. cit., p.73.

[100]Interestingly, as has been noted by O. Bakar, "This was exactly the position taken up by the theological school of Kalam in Islam about two centuries earlier in its dispute with the philosophers", See O. Bakar, Tawhīd and Science: Essays on the History and Philosophy of Islamic Science, op. cit., p.148-9. It is worthy of note also that echoing Newton's belief, Clarke states: "'Tis in the frame of the world, as in the frame of man's body: the wisdom of God does not consist, in making the present frame of either of them eternal, but to last so long as he thought fit". See Leibniz-Clarke Correspondence, "Clarke's second reply", pp.22-23.

secularism.[101]

Our knowledge about God increases when we constantly engage in studying and probing nature which is God's work. Nature can be mathematized and in Newton's point of view, God who is the First Cause, The Mathematician and Mechanic, and the source of all knowledge, endows mathematical knowledge on any soul He so chooseth. In fact, Newton contends that there is always the connection between God and the purity of the soul so much so that in his opinion, the overall process of reducing natural phenomena to even more quantitative mathematical laws, the stages of mathematization, is organically related to moral philosophy. They are harmoniously bonded. More than anything else, this intimate relationship points to the unity of knowledge imbedded in his philosophy of mathematics. Speaking of the profound conceptual relationship, Newton writes:

> And if natural Philosophy in all its Parts, by pursuing this Method, shall at length be perfected, the Bounds of Moral Philosophy will also be enlarged. 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. And no doubt, if the worship of false Gods had not blinded the Heathen, their moral Philosophy would have gone farther than to the four Cardinal virtues;...[102]

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[101] Underlying their arguments are their interpretations on Newton's statement that "religion and philosophy are to be preserved distinct..." without giving equal weight to the wealth of evidence concerning Newton's opinion of religion vis a vis Divine Transcendence. See for example, D.T. Whiteside, The Mathematical Principles Underlying Newton's Principia Mathematica, (University of Glassgow, 1970). More importantly, the statement should be understood in a holistic and integrated manner.

[102] See Opticks, pp.405-406.