The Laws of Nature and Purpose in the Universe: An Historical Overview

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Introduction

It would appear to me to be rather pretentious to attempt to describe what we know of the laws of nature and what we think we know about purpose in the evolutionary universe without some overview of how humankind has seen these issues over the centuries. There is the temptation to view the debate about such matters as the laws of nature, intelligent design and purpose, as a phenomenon of our times, a young and exciting field of inter-disciplinary studies born from the marvelous recent advances in the natural sciences and the openness of philosophers and theologians to take seriously the impact of those advances on fundamental matters of philosophy and of religious faith. If yielded to, that temptation could eviscerate the dialogue we seek between the results of science and their philosophical and religious implications. So please allow me to present an historical review of our growth in the view of the laws of nature up to the birth of modern science and on to our day.

Purpose inevitably implies religious connotations. The laws of nature are the fruit of scientific discovery. The great intellectual and spiritual currents of religion and of science run through our civilization from its very beginning. Sometimes they have seemed to be in opposition. More often they have worked together as inseparable elements of a common human quest for understanding. Their mutual relationships have at times been very conspicuous, at other times obscure, but never absent. Some of them, in so far as they have to do with the laws of nature and purpose, are presented here.[i]

The Age of Mythology and the Greek Awakening

All ancient civilizations in Egypt, Mesopotamia, Greece and many other parts of the world have left evidence of an early stage of intellectual development at which the discourse about nature was framed in the ordinary language of interpersonal communication between human beings. Consequently, nature was conceived as a kind of all-embracing society or state, the rulers of which were a number of more or less powerful gods, spirits and demons.[ii] The arbitrary will of the gods of nature was behind everything, serving the human as a reasonable, or at least intelligible, explanation of all phenomena. There was no split between nature and culture.

The old mythological conception of nature gradually began to yield to the new idea that

the phenomena of nature did not appear as a consequence of the free decisions of its gods, but because they had to appear as a consequence of an inner necessity which forced them to do so. This was a stark denial of the wisdom of all previous ages and as such it provoked an intellectual upheaval compared with which all later "scientific revolutions" appear as mere ripples on the surface of that ocean of thought which was first stirred by that band of innovators who have become known an the Presocratic Philosophers.

It was a Greek movement but over the last hundred years the history of science has been able to shed much new light upon the achievements of the earlier great civilizations[iii] and, even if we cannot always trace the channels through which Eastern knowledge percolated into Hellas, there is no doubt whatever that many individual features of the Greek intellectual world from about 600 BCE were not conceived here but in earlier cultures. If this is so there arises the question as to why the Ionian philosophers along the coast of Asia Minor were able to accomplish an intellectual breakthrough on this formidable scale. An answer may be sought in the very different structure of societies. In Egypt the king was divine, and in Babylon he was the highest representative of his people vis-a-vis the heavenly court. In neither country could a process of demythologization set in without disturbing the very political order. In Ionia the situation was different after the expulsion of the kings or tyrants and the establishment of some kind of government by the people. It is worth remembering that Thales is said to have been active both in philosophy and in politics.

Looking back upon this development which ultimately changed the intellectual outlook of a great part of all mankind one cannot help but be struck by the sheer linguistic difficulties of the whole undertaking. There came a time when this unitary type of discourse between humans and their gods began to appear in a less satisfactory light and a new intellectual approach to nature began to emerge. It is difficult to say precisely why this happened; but it is a reasonable assumption that the essential freedom of the gods of nature must have become more and more problematic. For how could it guarantee the many regularities which nature so obviously exhibits? If winter comes because the sun god is on holiday in Ethiopia, how can one be sure that he will again return at the appropriate time of the year? Would the new approach not, however, be a truly preposterous program, inevitably doomed to failure because the existing language was unable to accommodate the ideas which gradually dawned upon the philosophers? We have no evidence that the Ionian thinkers stated this problem in so many words; but we can clearly see how they grabbled with it and tried to solve it in two very different ways: by metaphor and by mathematics.

Throughout the centuries the Greek philosophers pursued numerous experiments in the metaphorical use of ordinary language. The result was a new vocabulary of technical terms the metaphorical origin of which went into oblivion in the course of the long process which

gradually made the Greek world familiar with the idea of a non-mythological account of the ways of nature. The age-long mythological discourse on nature had been framed in the ordinary language of human affairs in which there simply were no words for the abstract ideas which the new discourse tried to work out.

As an example of metaphor let us examine how they tried to explain the regular, seasonal flooding of the Nile River. Previously it was the god, Hapy, who took care of matters. Herodotus tried to come up with another explanation which would make a connection between the inundation, which occurred during the same season each year, and an unfailing annual phenomenon that could be connected to it. As such he proposed the annual motion of the sun. Even if he forgot that this motion ought also to affect the other rivers in the same way, his explanation was clearly more satisfactory from a philosophical point of view than previous theories since it so to speak worked every year without any recourse to the whims of the gods. As we know today it also happened to be correct in so far as the swelling of the Nile is due to the melting each spring of the snow on the mountains around its sources, a phenomenon which Herodotus ignored like everyone else. Everything considered his theory shows that he was able to handle the idea of cause and effect in nature with considerable skill only a century or so after the new discourse on nature had begun to emerge.

However, the new theory of the Nile also reveals the linguistic difficulties accompanying the attempt to abandon the mythological discourse. For when Herodotus tried to say that the sun was the Acause@ of the inundation he had no such word at his disposal. What he actually said was that the sun was the *aitia*[iv] of the swelling of the waters, using a well known Greek word which was in common use as a term denoting the guilt which a criminal brings upon himself by committing his offence. In other words, Herodotus said that the sun was Aguilty@ of the inundation. Taken in the literal sense this was a rather astonishing and perplexing statement. It made the sun a criminal and even an habitual criminal since he committed his Acrime@ year after year. Moreover, his crime was no crime at all, but a universal blessing for all the land of the Egyptians.

What has happened in this little linguistic episode is a good example of a general pattern in which a common word is lifted out of its everyday context and used metaphorically in a different field of thought as a means of expressing an idea that is homeless in ordinary language. Examples of similar procedures are legion. For instance, the fundamental idea of the inherent necessity in nature with which the new discourse would stand or fall was expressed by the word *ananke*. This belonged to ordinary language in a sense which appears in Herodotus= story about a criminal cowherd who was apprehended by the guards and forced to confess his offence Aunder stress of necessity@ (*de agomenos es tas anankas*).[v] In general the word *ananke* was used of all the means, from persuasion to torture, by which a criminal could be forced to

confess because he was unable to resist them. Now it was adopted by the new philosophers who used it to denote that hidden connection in nature which forces the phenomena to appear in an irresistible way.

A very different solution than metaphor was discovered by the Pythagoreans. This discovery of a mathematical alternative to the metaphorical discourse about nature had far-reaching consequences. Since then science has never forgotten that nature contains necessary, internal connections which only mathematics is able to disclose and express. However, this new insight had to fight for its survival. Aristotle had already fought this special conception of the mathematical discourse on nature on several fronts. In the final chapter of the *Metaphysics* he raised his voice against numerological speculations in a rhetorical manner in marked contrast with his usual style, as if he were almost emotionally involved in this question.[vi] This stems from Aristotle=s particular concept of philosophical knowledge in general and natural knowledge in particular. Here the key word is Acause.@ The point is that any account of nature must remain incomplete of it ignores one or more of the four causes: material, formal, efficient and final. If a philosopher does not discover them he has not reached his goal. While the mathematician is not concerned with final causes the natural philosopher is obliged to study all the four types of causation.[vii] When all is said and done Aristotle would have refused to admit not only the mathematician but also the mathematical physicist to the kingdom of final causation with the obvious inference that the purely mathematical discourse on nature contributes nothing to the quest for wisdom and is unable to shed any light upon the ultimate questions of human existence. Aristotle succeeded inasmuch as he was able to identify his God not only with the Prime Mover and Supreme Cause of the world but also with the Supreme Good and Life as such, making Him the source of both the unity of the universe and the moral existence of man. Nevertheless, one has to admit that the God of Aristotle remained a purely rational construction which was unable to appeal to the religious consciousness of the great masses.

But it is impossible to realize what happened in both Hellenistic and later science without admitting the existence of a another great tradition which may be properly named after Archimedes. This tradition is characterized by a consistent use of the language of mathematics and by a general disregard of causal and teleological explanations.[viii] The Archimedean approach was fruitfully adopted by medieval scholars and both Galileo and Kepler used it to lay the foundations of modern mechanics and astronomy. So, even if Archimedes failed to comply with Aristotle's insistence on causal explanations as the hallmark of a scientific description, it is impossible to ignore the fact that over the ages the Archimedean tradition was able to produce an ever increasing body of insights into the connections of the phenomena of nature, insights that were obtained thanks to mathematical discourse and could not have been obtained or expressed in any other way. And it gives food for thought that Archimedes' results in mechanics

are valid even today when Aristotle's causal explanations have largely fallen into oblivion.

Among the later philosophico-religious systems the most important from a historical point of view was the Anatural theology@ of the Stoics. Their view of the world carried the Aristotelian discourse on nature to an inevitable conclusion in the form of a universal determinism from which perhaps only the human mind had a slender chance of escaping through its deliberate acceptance of the inevitable. Never before had the problem of human freedom versus universal causality been so clearly grasped or its ethical implications so seriously envisaged. The result was an impressive structure of thought in which man became more intimately related to nature than in any previous system.

In summary, the Greek cosmos was a rational construction based on the fundamental assumption that the regularities of natural phenomena were grounded upon necessary connections or relationships inherent in nature itself, and that apparent irregularities must in some way be reducible to necessary and regular laws. Consequently, the task of the natural philosopher was to find means of expressing the material necessity in nature by a logical necessity in the discourse on nature.

The Age of Christianity

Into this world torn by conflicting views on the proper discourse on nature and the true relations between God and human beings Christianity emerged from its obscure origin in Palestine. At first sight it would seem that it must stay out of the philosophical battle as a non-combatant who was singularly uninterested in the scientific achievements of the Greeks. There is no treatise on cosmology in the New Testament and extremely few references to particular elements of the Greek account of the universe. All efforts are spent on the proclamation of the belief that the birth, life, death and resurrection of Jesus had radically changed the way in which the relations between God and the world should be envisaged.

From the religion of Israel Christianity also inherited the belief that the one Lord of the world is also its Creator.[ix] Time and again the Old Testament underlines the fact that the world is created. This is almost always understood in the sense that it has come into being independently of man and without human assistance. AWhere were you when I laid the foundations of the earth?@[x] was God's question to Job. However, the Biblical doctrine of creation seems to be marked by a paradox. On the one hand there is a chasm between God and His creatures. Nothing in nature is divine. On the other hand, the created world is said to testify to the divinity of its creator. God must be present within it in such a way than man can recognize it as created. The beginning of the gospel of St. John indicates a solution of this dilemma. AIn the beginning was the *logos*, and the *logos* was with God, and the *logos* was God.

He was in the beginning with God. All things came into being through him, and without him not one thing came into being.@[xi] Here the Pauline proclamation of Jesus as the redeemer of the world is supplemented by a specific Johannine discourse on Jesus as the divine *logos*. When the fourth Gospel opens by saying that: AIn the beginning was the *logos*,@ it looks at first sight like the introduction to a Greek philosophical treatise on the *arche*, or *principium* of the universe.[xii] To use the word in a Christian context was an important step towards assimilating the conception of the world as a rational structure according to the basic tenet of Greek philosophy. It is difficult to reject the idea that by describing Christ as the universal and divine *logos*, and as such the ground of all creation, Christianity was prevented, at least in principle, from rejecting the Greek conception of the universe as a rational structure.

Despite its apparent ignorance of all matters scientific the New Testament presented Christianity in a way that contained a number of seminal ideas out of which the future relationships between the scientific discourse on the laws nature and the religious belief that these laws revealed a divine plan would develop. The belief in One God implied a demythologization of the discourse on nature. That nature was created meant that its inner connections were established independently of the human mind which had to respect them when they were discovered. The transcendence of God would eventually remove the fear of trespassing upon the forbidden ground or the sacred by subjecting nature to scientific investigation. Finally the *logos* Christology made the idea of an all-permeating rationality at home in a religion which hailed Christ as the Lord of the World. It is difficult not to see a connection between this insight and the emergence of experimental methods in science.

But in later centuries there were to be diverse Christian traditions as to the implications involved in affirming a rational structure to the universe. What is characteristic, for instance, of Thomas Aquinas is his insistence that the natural knowledge of God must be acquired in the same way as all other knowledge. This means that Ait does not go beyond that kind of knowledge that is acquired through the senses.@[xiii] Bonaventure represented a much more traditional theology which gave natural reason a more limited scope.[xiv] We have here a clash between two different attitudes. Bonaventure is imbued with the Augustinian notion of the interior light by which God illuminates the soul so that it cannot look at the world except as something which is related to him. This was consciously a polemical stand against Aquinas who upheld the autonomy of human reason within its proper bounds without the special assistance of grace. Another great tradition in Christian thought is that of Duns Scotus. Aristotle had found the ultimate happiness of man in the intellectual knowledge of the Divine. Duns Scotus was well aware of this; but he also maintained that this kind of knowledge is not identical with the Good News of the Gospel about salvation from sin and life in the beatific vision of God, being fully aware that this was a strictly theological position which cannot be founded upon purely philosophical reasons. The believer simply knows something which the pure philosopher

ignores. This becomes manifest when we consider the doctrine of creation. The philosopher is unable to describe creation except in terms of cause and effect with the consequence that the world derives from God by necessity. On the other hand, the theologian knows that the world came into being through a free act of God just as man is saved by a free gift of grace. This meant that the laws of nature are such as they are because of a free decision by God. If God had so willed, they might have been different. The recognition of the laws of nature as contingent upon the Divine will was more than a theological subtlety. It had implications of immediate importance for the scientific approach to nature.

The Birth of Modern Science

The increasing use of mathematical arguments in the 14th century went hand in hand with a new awareness of how thought experiments based on common sense and everyday experience could contribute to the critical re-examination of the discourse on nature. No previous scientist had ever been able to carry this type of mathematical approach to nature to a similar perfection with such a methodological freedom and open-mindedness as did Johannes Kepler. More than anyone else it was Kepler who became the herald of a new era in which mathematical physics would go from strength to strength. With Kepler the Book of Nature[xv] reached the summit of its metaphorical life as the vehicle of the self-understanding of a first rate scientist who was deeply committed to the Christian Faith. But with Galileo the Book of Nature was confronted with the Book of Scripture in a dramatic encounter which has ever since been regarded as one of the most decisive interactions between the world of science and the world of belief. Many polemicists have even taken it as the final proof of the alleged incompatibility of these two worlds and evidence of an essential enmity between the Catholic Church and the scientific attitude. After many years of quiet work at Pisa and Padua Galileo suddenly rode to European fame in 1610 when he published the first results of his epoch making astronomical observations with the telescope he had constructed. All the world was amazed at the mountains on the moon, the innumerable fixed stars, the resolution of the Milky Way into separate stars, and the four satellites revolving around the planet Jupiter.[xvi] The framework of traditional cosmology, based principally on Aristotle and Ptolemy, had no room for such discoveries and would collapse under their weight.

The results of Kepler and Galileo provided a completely new point of departure for the science of mechanics. The philosophers were duly impressed and already in 1637 Descartes proposed a general theory of the universe in terms of purely mechanical interactions between various types of fundamental particles supposed to fill all space and influencing each other by their mutual collisions. On the other hand more mathematically inclined scientists became increasingly aware that Descartes had built his physics on shaky foundations. In Book I of the *Principia*[xvii] Newton showed how all problems of motion could be mathematically stated on the

basis of a few fundamental axioms, Newton's Laws, so that their solutions would depend only on appropriate mathematical techniques. This victory made a strong impact on the minds of the 18th century. Voltaire hailed Newton as the great rationalist in whom human reason had defeated the intellectual darkness of all previous ages, a picture which also satisfied the positivistic philosophers of science in the 19th century.

Newton argued that nature exhibits a number of mechanical phenomena for which no theoretical explanation could be found within a theory that was designed to comprehend all the motions of the bodies in the whole universe. From these premises he had constructed his argument for the existence of a Deity whose direct intervention would explain the gaps in the theoretical discourse. But this manner of reasoning made Newton's natural theology extremely vulnerable. His argument would clearly lose its force at the moment when this discourse itself became sufficiently advanced to close the gaps by its own force. In astronomy this situation arose already towards the end of the 18th century when a number of French mathematical physicists of no common genius utilized Newton's laws of motion to create a highly sophisticated celestial mechanics which seemed to solve those problems which Newton's own account had left unanswered. In the beginning of the 19th century the work of Laplace and his colleagues produced a growing feeling that at long last Newtonian mechanics itself had become able to stop the gaps in which Newton had found room for the Deity. This is the background of the popular anecdote of Laplace replying to Napoleon: ASir, I have no need of that hypothesis,@ when the Emperor asked him why God did not figure in his *Mécanique céleste* (1799 CE and later).[xviii]

The New Physics

At the birth of modern science there was the persistent idea, as there had been for the Pythagoreans, that physicists were discovering some grand transcendental design incarnate in the universe. As we have seen, for instance, the concept in St. John's Gospel of the *logos* becoming incarnate was particularly appropriate and hailed back in some way to Platonic and Pythagorean concepts of the world of eternal ideas and of the transcendental character of mathematics. Indeed, Newton, Descartes, Kepler and others can be cited as viewing physics and mathematics in this way. Kepler for instance, saw geometry as providing God with a model for creation. He went so far as to see the circle as transcendentally perfect, the straight line as the totally created and incarnate and the ellipse as a combination of the two, an incarnation in this world of what would have been the perfect geometry for the motion of the heavenly bodies in an ideal world. The simple equations in which Newton expressed the law of gravity and the laws of motion redirected for future centuries the role of mathematics in physics. No longer was mathematics simply a description of what was observed; it was a probe of the very nature of

what was observed.

As usual in scientific revolutions, what was happening with this mathematization of physics only came to full realization after it had happened. A three-layered conception of the universe, only partially inherited from the Platonic-Pythagorean tradition, came to be accepted implicitly, and only slowly did it come to consciousness. There was the layer of the true mathematics, the mathematical structures of which the world is truly made. Then there was the second layer, the mathematics of we humans, structures which were in a Platonic sense only the shadows of the first layer. Finally there were at the third layer the images in concrete reality of the true mathematical structures which we humans attempted to understand with a our shadow mathematics. However, there is a subtle development, described well by Michael Heller[xix], in which at the second layer mathematics is not only the language or the interpretative tool of physics (the formal object in scholastic terminology) but it becomes also the "stuff" of the ideal world of physics (material object in scholastic terminology). For the present this "stuff" remained under the control of empirical verification i.e., the third layer, the images in concrete reality, remained the test of how true the human mathematical structures were.

The rise of quantum mechanics and of relativity theory at the beginning of the 19th century soon weakened the connection between the second and third layers described above and, in fact, reemphasized the connection between the second and first layers. It seemed that the images in concrete reality made very little, if any, sense as a test of mathematical "stuff" of the ideal world of physics. There are no natural images or representations which correspond to Hilbert spaces, the mathematical "stuff" of quantum theory. And while general relativity has passed all of the experiments yet made to test its empirical predictions there are no adequate images or representations which correspond to motions at relativistic velocities or under very large gravitational forces. In its "purest" form the physics of both the sub-quantum world and the world "beyond-relativity" is strictly mathematical in the tradition of Plato and Pythagoras and apparently has little to do with any sensory component.

There is another significant element in the new physics. The studies of the dynamics of non-linear systems has given birth to the fields of chaos theory and complexity. This represents, in some sense, a return from quantum physics to the world of macroscopic physics and it is, in another limited sense, a vindication of Aristotle's view that the world of the senses is too rich to be limited to or comprehended by mathematics. From what we have said about the new physics, there appear to be two strains in modern science which are in tension with one another. On the one hand, there is the mathematization of physics and the apparently diminished connection to sense experience. On the other hand, there is the recognition that the world of sense experience has an innate unpredictability which prevents it from being subject to ultimate mathematical analysis.

Summary and Conclusions

From this historical overview we can garner the following characteristics which contribute to our understanding of the laws of nature and the search for purpose in the universe. In the age of mythology there was no split between nature and culture. For the Pythagoreans nature contains necessary, internal connections which only mathematics is able to disclose and express. While Aristotle insisted that nature could only be understood by searching out the four causes, Archimedes emphasized that knowledge of nature came through sense experience and experimentation with the use of mathematics. The Stoics carried the emphasis on causality to its limit by proposing a universal determinism, thus challenging human freedom. The human being was intimately related to nature but only to her/his detriment, being caught in a web of universal causality. Christianity at its very birth asserted that the Lord and Savior was also the Creator of the world and, through the *logos* theology of John, that there was a rational structure in creation which derived from the very triune nature of the Creator. Thus, the world of the senses was worth investigation through the experimental method. The question arose, however, as to whether there is a necessary connection between the Creator and the rationality of the universe or whether God freely chose that rational structure. With the birth of modern science and the new physics the delicate balance between the search for necessity and for spontaneity in the evolution of the universe was threatened and no scientist could afford any longer be too facile in arguing for intelligent design from our knowledge of the laws of nature.

Although it is admittedly a very summary statement, I think it fair to say that from Plato to Newton the contest as to what part mathematics has had in coming to a scientific understanding of the universe took place in a religious framework. And today, after a period of what might be called "atheistic rationalism," we again hear the refrain of discovering "the mind of God" coming from scientists. A serious attempt must be made to evaluate that long previous history and to make sense of its echo in our times. As I hope I have indicated above, the methodology of modern science is evolving and that is why I call it a new physics. The suggestion here is that the methodology of philosophy and theology, in the search for understanding of the laws of nature and of purpose in the universe, must also be in flux. As an effort at coming to a rational understanding of revealed truth, theology is subject to all of the vagaries of human thought. And revealed truth, granted that it first occurred at a privileged time and to chosen persons, is continuous and incarnate. What is revealed is deeply imbedded in the way we think and the understanding of it is, therefore, evolving. Furthermore, all rational knowledge of God is analogous and it would, therefore, be appropriate that concepts from the new physics be taken as analogies in the search to understand God. The methods of theology have always been very determined by prevailing philosophies and Christian theology in particular has since the Middle Ages been very much attached to the Aristotelian-Thomistic

tradition, and especially to the concept of final cause. Thus such notions as purpose and design have been dominant. Might theology not apply itself to an attempt to understand God, the creator of a universe where purpose and design are not the only, nor even the dominant factors, but where spontaneity, indeterminacy (even at a macroscopic level) and unpredictability have contributed significantly to the evolution of a universe in which life has come to be?

In light of our discussions and as a thought experiment on the connection between the laws of nature and purpose in the universe, let us ask a leading question, one which certainly has the intimations of ultimacy. Had we been given the initial physical parameters in an expanding universe at some time near the Big Bang (a few Planck times) could we have predicted that life would come to be? Is life the result of so many bifurcations in non-linear thermodynamics that we could not have predicted, even if we knew all the laws of microscopic and macroscopic science, that it would come to be? This is a question somewhat different than that raised by the anthropic principle, whether taken in the weak or strong sense. The questions there have to do with interpreting and/or explaining the apparent fine tuning of all of the physical constants and conditions required for the emergence of life. I am asking whether, given antecedently all of the physical constants and conditions necessary for life from our *a posteriori* knowledge of it, could we have predicted that it would have come to be? Did life happen to be or, given the conditions for it, did it have to be? Was life predetermined by the laws of nature? Was it intended purposefully?

Notes

[i] I am very much indebted to the lifelong research of Olaf Pedersen (deceased in 1997) for this historical survey. I am preparing the posthumous publication of his voluminous work, *The Two Books*, a brief presentation of which is given in *The Book of Nature*, Vatican City, Vatican Observatory Publications, 1992.

[ii] Thorkild Jacobsen, AThe Cosmos as a State,@ in H. Frankfort, H. A. Frankfort, J. A. Wilson, Th. Jacobsen, *Before Philosophy*, London, 1949 (1st ed. Chicago, 1946) 137-199. A large number of relevant texts (in English translation) are found in J. B. Pritchard, *Ancient Near Eastern Texts Relating to the Old Testament*, Second Edition, Princeton, 1955 (Third Edition 1969).

[iii] M. L. West, *Early Greek Philosophy and the Orient*, Oxford, 1971.

[iv] Herodotus, *Historia*, II, 26.

[v] Herodotus, *Historia*, I, 116; cf. the similar use of the word in Homer, *Odyss.*, VI, 136.

[vi] See the posthumous work by T. L. Heath, *Mathematics in Aristotle*, Oxford, 1949, in which almost all mathematical passages in the works of Aristotle have been collected and translated into English.

[vii] Aristotle, *Phys.,* II, 7, 198a.

viii. See A.G. Drachman, AArchimedes and the Science of Physics,@ *Centaurus*, 12 (1967) 1-11.

[ix] See R. J. Clifford, @Creation in the Hebrew Bible,@ in R. Russell, W. Stoeger and G. Coyne (eds.), *Physics, Philosophy, and Theology*, Vatican Observatory, Vatican Observatory Publications, Second Edition, 2000, 151-170. Cf. the various essays in B. A. Anderson (ed.), *Creation in the Old Testament*, Philadelphia, 1984.

[x] *Job* 38, 4.

xi. John, I, 1.

[xii] See W. Kelber, *Die Logoslehre von Heraklit bis Origenes*, Stuttgart, 1958.

[xiii] *Summa contra Gentiles,* III, 47. Cf. I, 3 quoted above.

[xiv] *Itinerarium mentis in Deum.*

[xv.] The metaphor of the Book of Nature goes back to the age of the Fathers but it took quite a long time before it got off the ground. Its prehistory is as old as theology itself since the fundamental idea was already expressed by St.Paul's assertion that the works of God disclose His divinity, invisible being and eternal power [Rom 1, 18 - 20]. How this should be understood was not specified and it became a problem already in the early Church how to solve this issue.

[xvi.] *Sidereus Nuncius,* Venice, 1610, in Galileo Galilei, *Opere,* A. Favaro (ed.), III, 55-96. English translation in Stillman Drake, *Discoveries and Opinions of Galileo,* New York, 1957, 21-58.

xvii. Isaac Newton, *Philosophiae Naturalis Principia Mathematica*; the third and final edition (1726) has been assembled and edited by A. Koyré and I.B. Cohen, Cambridge, MA, Harvard University Press, 1972.

[xviii] It is very difficult to trace the origin of this story which is found mentioned for the first time in Rouse Ball=s *History of Mathematics* from 1888 (4th ed. 1908, 417 f.). Probably it is a clever invention on a par with Galileo=s *Eppur si muove.* It has given place to some highly polemical discussions of Laplace=s own religious attitude; see G. Sarton, ALaplace as a run of the mill Catholic,@ *Isis* 33 (1941), 309-312 and J. Pelseneer, ALaplace as a non-Christian materialist,@ *Isis* 36 (1945), 158-160. Cf. R. Hahn, ALaplace=s religious views,@ *Archives Internationales d'Histoire des Science* 30 (1958), 38-80.

[xix] M. Heller, *The New Physics and a New Theology*, Vatican City, Vatican Observatory Publications, 1996.