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MATHEMATICS, EXPLANATION AND REDUCTIONISM: EXPOSING THE ROOTS OF THE EGYPTIANISM OF EUROPEAN CIVILIZATION

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ABSTRACT: We have reached the peculiar situation where the advance of mainstream science has required us to dismiss as unreal our own existence as free, creative agents, the very condition of there being science at all. Efforts to free science from this dead-end and to give a place to creative becoming in the world have been hampered by unexamined assumptions about what science should be, assumptions which presuppose that if creative becoming is explained, it will be explained away as an illusion. In this paper it is shown that this problem has permeated the whole of European civilization from the Ancient Greeks onwards, leading to a radical disjunction between cosmology which aims at a grasp of the universe through mathematics and history which aims to comprehend human action through stories. By going back to the Ancient Greeks and tracing the evolution of the denial of creative becoming, I trace the layers of assumptions that must in some way be transcended if we are to develop a truly post-Egyptian science consistent with the forms of understanding and explanation that have evolved within history.

KEYWORDS: History of cosmology; History of Mathematics; Process metaphysics

In *Twilight of the Idols*, Nietzsche characterized the idiosyncrasy of philosophers:

> There is ... their hatred of even the idea of becoming, their Egyptianism. They think they are doing a thing *honour* when they dehistoricise it, *sub specie aeterni*—when they make a mummy of it. All that philosophers have handled for millennia has been conceptual mummies; nothing actual has escaped their hands alive. They kill, they stuff, when they worship, these conceptual idolaters—they become a mortal danger to everything when they worship. Death, change, age, as well as procreation and growth, are for them objections—refutations even. What is, does not *become*; what becomes *is* not … Now they all believe, even to the point of despair, in that which is.[1]

Is this a correct characterization of philosophy? And if it is, What is the source of this idiosyncrasy? and Why has it prevailed? And what has been the effect of this idiosyncrasy?

Nietzsche was referring to philosophy over its entire history, from the Ancient Greeks onwards until his own day. He acknowledged that not all philosophers were

[1] Friedrich Nietzsche, *Twilight of the Idols* [1889], tr. R.J. Hollingdale, Penguin Books, Harmondsworth, 1968, p. 35.

guilty, citing Heraclitus as an exception. But were there not other philosophers concerned with change, creation and death? Surely Aristotle and his followers were centrally concerned with such issues. But then perhaps even Aristotle, and even more his followers, were biased against change even when they acknowledged its reality. The highest reality for Aristotelians was the 'unmoved movers', and it was the unchanging relationship between classes or forms on which Aristotle's syllogistic logic was based which was extolled as the highest form of knowledge. More generally, given the opposing positions of Heraclitus and Parmenides, one seeing the world as perpetually changing, the other seeing all change as an illusion, the vast majority of philosophers have aligned themselves with Parmenides, even if they felt compelled to modify this position to account for at least the appearance of change. The atomists took the unchanging atoms as the basic existents. Plato argued that the eternal forms are real and knowable, the sensible world only being taken to be real and knowable to the extent that it participates in the forms. The Neoplatonists embraced this doctrine and took the unchanging One to be the source of all the other forms. This is the philosophy used to interpret and defend Christianity with God identified with the unchanging One and the changing sensible world denigrated as a manifestation of our fallen state, a world of temptations to be overcome. This provided the basic framework of medieval culture.

While Nietzsche questioned this whole tradition of European thought, and Christianity in particular, he was mainly concerned with the culture of modernity. As Nietzsche recognized, in the modern world Egyptianism is at its most influential and most problematic in science.[2] So while prevailing philosophy was clearly a target, in his early notebooks Nietzsche was more concerned with science. Science, like philosophy, has exalted a realm transcending and denying the reality of change to the perceived world. Writing of the illusions associated with claims to truth, Nietzsche argued that language works to construct concepts. The outcome of this labour is that 'the great edifice of concepts displays the rigid regularity of a Roman columbarium[3] and exhales in logic that strength and coolness which is characteristic of mathematics'.[4] Science has taken over this labour, working 'unceasingly on this great columbarium of concepts, the graveyard of perceptions.'[5] But a concept, Nietzsche argued, 'is merely the residue of a metaphor.'[6] The 'truths' gained by such labour, Nietzsche suggested, 'are illusions which we have forgotten are illusions; they are metaphors that have become worn out and have been drained of sensuous force, coins which have lost their embossing and are

[2] See Milič Čapek, 'The Myth of Frozen Passage: The Status of Becoming in the Physical World', *Boston Studies in the Philosophy of Science,* ed. Robert Cohen and Marx Wartofsky, Vol.2, New York, Humanities Press, 1965, pp. 441-463.

[3] A columbarium is a vault with niches for funeral urns containing the ashes of cremated bodies.

[4] Friedrich Nietzsche, *Philosophy and Truth: Selections from Nietzsche's Notebooks of the Early 1870's,* ed. and trans, Daniel Breazeale, New Jersey, Humanities Press, London, 1979, p. 85.

[5] Nietzsche, *Philosophy and Truth*, p.88.

[6] ibid., p.85.

now considered as metal and no longer as coins.'[7] Science, taking the place of Christianity, had consolidated the Egyptianism of European philosophy and culture.

Nietzsche was writing over a century ago. Has the situation changed? There has been a reaction against this Egyptianism. Apart from philosophers influenced by Nietzsche, Charles Sanders Peirce, Henri Bergson, Alfred North Whitehead, hermeneutic phenomenologists and 'post-structuralists' among others have struggled to uphold the reality of temporal becoming. However, while such philosophers have often gained attention from the public, within the mainstream of academia they have always been looked upon as irrationalist deviations from the quest for a rational comprehension of the cosmos. Far more significant has been the analytic tradition of philosophy which has sought to develop and interpret symbolic logic, to reduce mathematics to logic, and to characterize and defend the ultimate goal of science as creating a logically coherent mathematical structure able to deduce everything that has occurred in the past or will occur in the future. This goal has been upheld as an ideal even where it is acknowledged that it is unrealizable in practice. Along with this, the tradition has sought to uphold an 'objectivist' theory of meaning and an 'objectivist' theory of rationality virtually identical to that attacked by Nietzsche in his early notebooks.[8] Nicholas Rescher, a contemporary American philosopher uninfluenced by Nietzsche, observed that philosophers generally are overwhelmingly hostile to the notion of process.[9] Egyptianism still reigns supreme.

Why does this matter? To begin with, despite the successes of efforts to construe the world in such terms (although these successes are far less than is generally appreciated), these very successes have generated an increasing number of irresolvable paradoxes.[10] To begin with, the very nature of mathematics has become increasingly uncertain.[11] In theoretical physics, quantum theory remains problematic, with no universally accepted interpretation. Elementary particle physics is in even greater difficulties. While proponents of string theory proclaim success in uniting quantum theory, the special and general relativity theories and elementary particle theory, many physicists remain skeptical that any significant achievements have been made at all.[12] And it is now recognized that even if string theory were developed successfully, it would still not be the primary theory of the universe.[13] This is at the level of the physical sciences. There

[7] ibid., p.84.

[8] For an account of this and its inadequacies, see Mark Johnson, *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason,* Chicago and London, The University Of Chicago Press, 1987, Intro. and Ch. 1.

[9] Nicholas Rescher, 'The Revolt against Process,' *Journal of Philosophy,* Vol. 59, 1962, 410-17.

[10] For a compendium of these, see A.K. Dewdney, *Beyond Reason: 8 Great Problems That Reveal the Limits of Science,* Hoboken, John Wiley, 2004.

[11] For an account of this see Morris Kline, *Mathematics: The Loss of Certainty,* Oxford, Oxford University Press, 1980.

[12] See for instance C.J.S. Clarke, 'Process as a Primitive Physical Category' in *Time and Process: Interdisciplinary Issues,* ed. J.T. Fraser and Lewis Rowell, International Universities Press, 1993, pp. 53-69.

[13] Gordon Kane, *Supersymmetry: Squarks, Photinos, and the Unveiling of the Ultimate Laws of Nature*, Cambridge, Mass., Perseus, 2000, p. 132.

are far deeper problems, however, problems which were evident at the birth of modern science. If it is the goal to explain the whole of reality in such mathematical terms, there can be no place for life or mind. Efforts might be made to explain life and mind, but the success of such efforts would be to have shown that life is not life and mind not mind, but complex physical structures that have the appearance of life and mind. At best, the mind would be an epiphenomenon. And if this were the case, the claim to have knowledge would have been shown to be an illusion, since the epiphenomena of people claiming to have knowledge, including rival claims by other people, would have been shown to have been merely mathematically predictable effects.

But it is not only theoretical problems that are at issue. Proponents of science so conceived openly deny validity to any claim to truth by the humanities (apart from analytic philosophy); for such science, the narrative forms of literature and history are merely forms of amusement. And indeed, if time is an illusion, then the claims to truth in literature or history must be false, because overwhelmingly, the insights claimed in these domains pertain to a world conceived as in the process of becoming, in which the future is not determined by the past, and human agency is real, not mere appearance. In fact this opposition to the humanities is a continuation of the struggle against the ideas which emerged in the Renaissance. Modern science developed in reaction to and in opposition to Renaissance culture, both the civic humanism that had developed in the Renaissance and the more radical ideas of the 'nature enthusiasts' who had celebrated nature as divine. It was the civic humanists who revived and developed history as a discipline.[14] The synthesis of the ideas of the civic humanists and the 'nature enthusiasts' made up what Margaret Jacob called the 'radical enlightenment' committed to democratic republicanism.[15] The 'moderate enlightenment' associated with Cartesian, Newtonian and Leibnizian science, while also opposed to the power structures inherited from feudalism, was developed in part to neutralize the influence of the radical enlightenment with its commitment to democracy.[16] The hidden project of this moderate enlightenment was to develop a form of knowledge that would not only facilitate control over nature, but also facilitate control over people; that is, to produce a social order in which people would be organized efficiently.[17] The relationship between this Egyptianism of modern science and this hidden project confirms Nietzsche's suggestion that 'To impose upon becoming the character of being - that is the supreme will to power.'[18]

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[14] See Hans Baron, *The Crisis of Early Italian Renaissance: Civic Humanism and Republican Liberty in an Age of Classicism and Tyranny*, Princeton, Princeton University Press, 1966, Ch. 3.

[15] Margaret C. Jacob, *The Radical Enlightenment: Pantheists, Freemasons and Republicans*, 2nd ed. The Temple Publishers, 2003.

[16] See Jonathan I. Israel, *Radical Enlightenment: Philosophy and the Making of Modernity 1650-1750,* Oxford, Oxford University Press, 2002, Part IV.

[17] On this, see Stephen Toulmin, *Cosmopolis: The Hidden Agenda of Modernity,* University of Chicago Press, 1990.

[18] Friedrich Nietzsche, *The Will to Power*, § 617, tr. Walter Kaufman and R.J. Hollingdale, New York, Vintage, 1968, p. 330.

It is the success in the project of controlling nature and people that has given science its legitimacy as a core institution of modernity; but this success has increasingly exposed its dark side. This dark side was recognized early by poets who saw in this drive to control to the world, hostility to life. 'We murder to dissect' wrote William Blake, attacking the new mechanical philosophy and keeping alive the enthusiasm for living nature that had developed in Renaissance culture. Opposition to this culture of domination was developed most fully in German philosophy in the work of Herder, Goethe, Schelling and the Romantics. Nietzsche's work can only be properly understood as a development of this tradition of thought.[19] Reflecting on the implications of science, Nietzsche asked:

> Has not man's determination to belittle himself developed apace precisely since Copernicus? ... Ever since Copernicus man has been rolling down an incline, faster and faster, away from the centre—whither? … All science … is now determined to talk man out of his former respect for himself, as though that respect had been nothing but a bizarre presumption.[20]

But it was only in the twentieth century that the full implications of this attitude manifest itself. The brutal aggression through which Europeans had dominated other people was directed at other Europeans. Then the world was brought to the precipice of annihilation as the weapons of mass destruction, the ultimate triumph of modern science forged in Europe's premier colony, USA, generated an arms race that came very close to a global nuclear war. Concomitantly, the global ecological crisis revealed the project of total control of the world to be unviable. It was then that the nihilistic implications of this world view reached their fullest expression.[21] A distinguished Professor of Political Economy at the University of London wrote in *Business and Society Review:* 'Suppose that, as a result of using up all the world's resources, human life did come to an end. So what?'[22] This would seem to justify Nietzsche's claim that 'The goal of science is the destruction of the world.'[23]

THE EGYPTIANISM OF MODERN SCIENCE

The full extent of the Egyptianism of science is evident in views expressed by Einstein. Einstein remarked that 'It is a characteristic of thought in physics … that it endeavours in principle to make do with "space-like" concepts *alone,* and strives to express with their aid all relations having the form of laws.' He argued that it is natural

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[19] As Andrew Bowie has argued. See *Aesthetics and subjectivity: from Kant to Nietzsche,* 2nd ed. Manchester, Manchester University Press, 2003.

[20] Friedrich Nietzsche, *The Genealogy of Morals*, tr. Francis Golffing, New York, Doubleday, 1956, Third Essay, XXV, p. 291f.

[21] See Arran Gare, *Nihilism Incorporated: European Civilization and Environmental Destruction*, Bungendore, Eco-Logical Press, 1993, Ch. 7. This book has been republished as the first part of *Nihilism Inc.: Environmental Destruction and the Metaphysics of Sustainability*, Sydney, Eco-Logical Press, 1996.

[22] Cited by Robert L. Heilbroner, *An Inquiry into the Human Prospect*, New York, W.W. Norton, 1975, p. 170.

[23] Nietzsche, *Philosophy and Truth*, p. 156n.

'to think of physical reality as a four-dimensional existence, instead of, as hitherto, the *evolution* of a three-dimensional existence.'[24] That is, real temporality, temporality as process of becoming and destruction, should not be countenanced, or it should be treated as a mere illusion. Einstein was espousing what became the orthodox view within science.[25] Hermann Weyl, a major theoretical physicist of the following generation, followed Einstein and simply asserted as fact that 'The objective world simply *is,* it does not *happen.*'[26] Quantum theory did not really change this way of thinking much. As Paul Davies wrote with reference to quantum theory, 'the [post-classical] physicist's image of reality is rooted in a sort of meta-universe of mathematical objects and relationships that are concrete, eternal and totally dependable, while the Universe is nebulous, shifting and unpredictable.'[27] That Einstein and other theoretical physicists in their search for the underlying unity behind appearances have denied reality to temporal becoming is highly significant. It was they who provided theoretical insights that made nuclear weapons a possibility. And yet these physicists were no evil genii. Their work could be regarded as the fulfilment of a long tradition of thought. The conception of a four dimensional world echoed the views of the eighteenth century mathematical physicist, Lagrange, who argued that the time variable of rational mechanics based on Newton's laws of motion could be regarded as the fourth dimension of space. G.J. Whitrow, commenting on this in *The Natural Philosophy of Time,* noted that 'By regarding physical time as a fourth dimension of space, Lagrange all but eliminated time from dynamical theory.'[28] In doing so, Lagrange was making explicit what had already been implicit in Newton. Alexandre Koyré argued that Newton's conception of motion as a state had virtually denied its reality, and along with it, time. In *Newtonian Studies* he pointed out that 'The "motion" of geometrical bodies in geometrical space changes nothing at all; the "places" in such a space are equivalent and even identical. It is a changeless change. … It is a timeless motion … or … a motion in timeless time—a notion as paradoxical as that of changeless change.'[29]

While change was denied to ultimate reality and an ideal was upheld of knowledge in a form which would give no place to time, in practice science has had to accept its limitations in this regard. Particularly at the intermediate level of everyday life the large number of interacting components has made unpredictable change ubiquitous. Science has dealt with this by showing how unpredictability of details can nevertheless generate statistical regularities. For the most part, the use of statistics is seen as a compromise with the ideal of absolute knowledge of a reality in which there is no real becoming,

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[24] Albert Einstein, *Relativity: The Special and the General Theory,* tr. Robert W. Lawson, New York, Crown Trade Paperbacks, 1961, p. 141.

[25] On this see Čapek, 'The Myth of Frozen Passage'.

[26] Hermann Weyl, *Philosophy of Mathematics and Natural Science,* Princeton, Princeton University Press, 1949, p.116. Similar views were expressed by James Jeans and Kurt Gödel.

[27] Paul Davies, 'Law and Order in the Universe,' *New Scientist*, 1634 (Oct. 15th, 1988), pp. 58-60, p. 60.

[28] G. J. Whitrow, *The Natural Philosophy of Time,* 2nd ed., Oxford, Clarendon, 1980, p. 3.

[29] Whitrow, *The Natural Philosophy of Time*, p. 10f.

useful because of the impossibility of detailed knowledge of ultimate reality. However, the introduction of statistics has provided the means, when combined with more traditional ideals of scientific knowledge, of explaining more complex features of the world in which we live. Evolution, it is believed, can be explained as the outcome of a combination of statistical analyzable variations and rates of survival and deterministic physical and chemical laws characterizing how organisms pass on 'information' to their progeny and how this 'information' determines the growth of organisms.[30] Our own existence is then accounted for in this way, or so it is believed by orthodox scientists.

However, as noted, 'explanation' here really means explaining away, showing that what appeared to be entities existing in their own right are really nothing but the effects of their constituents and environments, and ultimately are mere appearances (to what?) of the basic existents or existent of the universe. As G. Spencer Brown noted:

> To *explain*, literally to lay *out* in a *plane* where particulars can be readily seen. Thus to *place* or *plan* in *flat* land, sacrificing other dimensions for the sake of appearance. Thus to *expound* or *put out* at the cost of ignoring the *reality* or *richness* of what is so put out. Thus to take a view away from its *prime reality* or *royalty,* or to gain knowledge and lose the kingdom.[31]

Where does this lead? Émile Meyerson argued that 'scientific explanation actually ends up dissolving the external world into undifferentiated space.'[32] Elaborating on this, he wrote:

> [D]iversity in space is unquestionably an enigma for us, a grounds for astonishment if not identical, at least very similar to that we discover in the case of diversity in time. As a consequence we cannot escape the conclusion that if our reasoning is correct, the goal of explanations and theories is really to replace the infinitely diverse world around us by identity in time and space, which clearly can only be space itself.[33]

POST-EGYPTIAN SCIENCE?

Not all scientists are wedded to this Egyptianism, however, and recently there has been a concerted effort to give a place to real becoming associated with the development of complexity theory, the effort to understand 'organized complexity'. In 1980, *From Being to Becoming: Time and Complexity in the Physical Sciences* was published, a work in which Ilya Prigogine attempted to convey to the reader his 'conviction that we are in a period of scientific revolution—one in which the very position and meaning of the scientific approach are undergoing re-appraisal—a period not unlike the birth of

[30] For a popular exposition of this explanation of life see Richard Dawkins, *The Blind Watchmaker,* New York, Norton, 1987.
[31] G. Spencer Brown, *Laws of Form,* London, George Allen and Unwin, 1969, p. 126n.
[32] Émile Meyerson, *Explanation in the Sciences,* tr. Mary-Alice and David A. Sipfle, Dordrecht, Kluwer Academic Publishers, 1991, p. 1.
[33] Meyerson, *Explanation in the Sciences*, p. 136f.

the scientific approach in ancient Greece or of its renaissance in the time of Galileo.'[34] Clarifying this, Prigogine proclaimed:

> Since the beginning of Western science, we have believed in the "simplicity" of the microscopic—molecules, atoms, elementary particles. Irreversibility and evolution appear, then, as illusions related to the complexity of collective behaviour of intrinsically simple objects. This conception—historically one of the driving forces of Western science—can hardly be maintained today. The elementary particles that we know are complex objects that can be produced and can decay. … [T]here is a second reason why I am convinced that we are in the middle of a scientific revolution. The classical, often called "Galilean" view of science was to regard the world as an "object," to try to describe the physical world as if it were being seen from the outside as an object of analysis to which we do not belong. This attitude has been immensely successful in the past. But we have reached the limit of this Galilean view. To progress further, we must have a better understanding of our position, the point of view from which we start our description of the physical universe.[35]

Prigogine argued that this revolution involves taking time seriously. The book begins with the sentence, 'This book is about time' which he characterized as 'the Forgotten Dimension'. What he meant by claiming that time is the forgotten dimension is that in classical science, time appears as a mere 'geometrical parameter.'[36] In place of this, Prigogine argued, we need a conception of time which involves irreversibility with an asymmetric relation between the past and the future and which gives a place to evolution towards greater complexity. As Prigogine and Stengers noted in *Order out of Chaos,* 'On every scale self-organization, complexity, and time play a new and unexpected role.'[37] We must recognize that we, with out experience of time as becoming, are part of the world we are trying to comprehend. This means that science must now be allied to the humanities, which have always stressed the reality of creative becoming.

In making this argument, Prigogine and Stengers aligned themselves with the philosophies of Bergson and Whitehead, and contextualized historically Prigogine's own work in chemical thermodynamics. Prigogine developed the notion of 'dissipative structures', 'structures' which develop by dissipating entropy to increase the rate at which entropy is produced, as a way to bridge the gap between the physical and the biological sciences: life forms can be conceived as essentially complex dissipative structures feeding on negative entropy (or exergy). Prigogine's work was taken up and had a major influence on the development of complexity theory, and his work was welcomed by members of the tradition of process metaphysics. However, most of those

[34] Ilya Prigogine, *From Being to Becoming: Time and Complexity in the Physical Sciences*, San Francisco, W. H. Freeman, 1980.
[35] Prigogine, *From Being to Becoming*, p. xiii, xv.
[36] ibid., p. xi.
[37] Ilya Prigogine and Isabelle Stengers, *Order out of Chaos: Man's Dialogue with Nature,* Toronto, Bantam Books, 1985.

engaged in complexity theory have ignored the deeper philosophical implications of his position. For many such theorists, complexity theory is treated as an extension of mainstream reductionist science to deal with organized complexity, that is, organization generated by the interaction between large numbers of components, and involves no fundamental break with traditional science.[38] Even if it is accepted that there is some form of emergence and that developments in complexity theory show that it is impossible to completely predict the future, this is only at the level of appearance. Reality itself is still treated as the deterministic behaviour of components. Prigogine himself was ambiguous on this point. In *From Being to Becoming* he argued that the illusion of determinism is generated by the use of mathematical idealizations that go beyond the possibilities of measurement.[39] This argument is not developed, however, and in *Order out of Chaos* Prigogine and Stengers suggested that 'God could, if he wished to, calculate the trajectories in an unstable dynamic world.'[40] This implies that creativity in the universe is mere appearance generated by our own limited cognitive capacities.

This suggests that even those who are struggling to overcome the Egyptianism of science have great difficulty freeing themselves from its basic assumptions.

THE ROOTS OF THE EGYPTIANISM OF SCIENCE

What then are these assumptions? And what is their source? To begin with, the revival of mathematics as the basis for describing and explaining all that exists appears to be a major component of and possible source of this Egyptianism. Does this mean that as long as mathematics is taken as the basis for interpreting the world then we can give no place to creative becoming? And why does mathematics have such an exalted place within science? Was it the founders of modern science who put these assumptions in place?

Nicholas Cusanus, Copernicus, Bruno, Kepler, Galileo, Gassendi, Descartes, Boyle and Newton are usually taken as the major figures in the birth of modern science. Of these, Descartes stands out as 'the true legislator of modern science', as Meyerson put it.[41] Descartes claimed to be starting afresh, building knowledge on new foundations. It was he who claimed to be ushering in a revolution in thought, and thereby who is most responsible for the idea of the seventeenth century scientific revolution. And it was the ideas and problems generated by his philosophy that were the point of departure for almost all subsequent developments in science and philosophy. And in Descartes the motivations were clear. He wanted to create a conception of the world that would

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[38] See Arran Gare, 'Systems Theory and Complexity', *Democracy and Nature,* Vol. 6 No. 3, 2000: pp. 327-339.

[39] Prigogine, *From Being to Becoming*, p. 215.

[40] Prigogine and Stengers, *Order out of Chaos,* p. 271f. It is not clear from the context whether Prigogine and Stengers are upholding this view or merely explicating the common view of science.

[41] Meyerson, *Explanation in the Sciences*, p. 135.

overcome the strife that Renaissance culture, he believed, was unable to deal with.[42] He was concerned to promote a form of knowledge that would enable us to master nature and to create a stable social order—a 'cosmopolis'. It was this that provided the motivation to embrace mathematics as a model of permanence and clarity. In particular, he was concerned to deploy analytical geometry, that is, the algebraic representation of geometry. To such ends Descartes developed a complete metaphysical system which both gave and provided justification for the primary role of mathematics in gaining knowledge of the physical world. Descartes reconceived the nature of the physical world to justify his claim that it could be known through mathematics, to this end virtually identifying matter and space. He also reconceived rationality on the basis of the kind of reason associated with mathematics. Arguments were to be accepted only if they could be grasped as 'clear and distinct ideas'. Descartes believed that through such clear and distinct ideas he could justify belief in the existence of a God who guaranteed the knowledge gained by investigating the world in this way. While his dualism enabled him to give a place to the spontaneous actions of individual minds, it was his analytic geometry, which underlay the development of the calculus, which led to attempts to reduce 'time' to a dimension of space. Descartes' conception of nature, modified to incorporate time as spatial dimension, was very close to the position embraced by Einstein when he developed his general theory of relativity, as Einstein fully appreciated,[43] and underpinned Einstein's conviction that 'God does not play dice'. All this would suggest that we can take Descartes and his commitment to a mathematical understanding of nature as the source of the Egyptianism of modern science.

However, Descartes cannot be taken at face value as the originator of the scientific revolution or the originator of the commitment to mathematics. Each of the founders of modern science took a stand against the prevailing neo-Aristotelian cosmology and each had been concerned to revive interest in mathematics as a means to comprehend nature. They differed profoundly, however, in their philosophies and how they interpreted the role of mathematics. They differed in their characterizations of matter, the physical and the corporeal, what they understood mathematics to be, and how mathematics applied to each of these.[44] Nicholas Cusanus who was responsible in the fifteenth century for reviving Platonism, argued that all knowledge of the finite world is gained by establishing ratios or proportions and that mathematics is the supreme method for examining these ratios, identifying the mathematical with the physical produced through making what is 'implicate' within God (identified with the 'infinite') 'explicate' through 'contraction'. Synthesising Nicholas Cusanus' ideas with aspects of Stoic physics, Bruno identified this God with matter which he took to be the source of

[42] See Toulmin, *Cosmopolis*, esp. Ch. 2.
[43] Einstein, *Relativity: The Special and the General Theory*, p. 176f.
[44] On this see Ivor Leclerc, *The Nature of Physical Existence*, London, George Allen & Unwin, 1972, esp. Ch. 15.

the physical, identifying this with individual corporeal existents.[45] Galileo was more influenced by Terminist reflections on kinematics and the critical tradition of Italian Aristotelianism along with the newly rediscovered work of Archimedes.[46] Mainly through methodological considerations he came to defend atomism, identifying mathematics, the physical conceived as matter, and the corporeal, but then could not account for why atoms should be bounded and indivisible. To avoid this problem, Gassendi revived the ideas of the ancient Atomists and argued for a complete separation between the mathematical and the physical, but then could not show why mathematics is applicable at all to understanding atoms. Descartes identified the physical and matter, which was then also identified with mathematics as the *res extensa*, but distinguished these from the corporeal. While Descartes claimed to be building his knowledge from the ground up to allow only what could be known with certainty, in fact he was developing his new philosophy in an effort to overcome the problems of his predecessors, and as John Herman Randall has shown, his philosophy was a revival of the ideas of St Augustine.

It could be argued that while the picture of Descartes making a new beginning was wrong, he was still the figure who finally provided the integrated philosophy that could serve as the starting point for modern science. However, while Descartes' philosophy was enormously influential and seemed to have been vindicated by Einstein's physics, his ideas were hardly the last word on the place of mathematics in nature. In the eighteenth century, Newtonian physics prevailed against Cartesian physics. Apart from having advanced beyond Descartes by developing the calculus, Newton had identified the physical with the corporeal, but argued that corporeal atoms were extended by an independent existent, space, which was at the same time seen by him as the sensorium of the Deity and the means through which He acted in the world, helping to change the positions of corporeal beings though 'time', which was also conceived to be an independent existent.[47] The introduction of time as a dimension along with the calculus enabled Newton to represent not only motion but also acceleration mathematically. Opposing Descartes' philosophy, Newton interpreted his work partly through the Aristotelian Thomist tradition (the tradition inspired by St Thomas Aquinas) as investigating the basic principles or *archai* which formed the rational structure of the world of ordinary experience, and partly through the Terminist (or Nominalist) Aristotelianism of the Ockamites (followers of William of Ockham) to develop a deductive postulate system that could serve to represent and predict natural events.[48] Leibniz then challenged Newtonian physics, offering a quite different interpretation of physical existence and its relationship to mathematics.

[45] Leclerc, *The Nature of Physical Existence*, p. 131ff.
[46] See John Herman Randall Jr., 'Padua Method and Greek Mathematics' and 'Galileo and the New Science' in *The Career of Philosophy*, Vol.1, New York, Columbia University Press, Bk Two, Ch.'s 11 and 13.
[47] Newton to some extent disguised his real views. See Leclerc, *The Nature of Physical Existence*, Ch. 18. See also Ernan McMullin, *Newton on Matter and Activity*, Notre Dame, University of Notre Dame Press, 1978.
[48] See Randall, *The Career of Modern Philosophy*, p. 365f. and Bk 1, Chap. 2.

If Descartes is dethroned and recognized as only one of a number of major philosophers associated with the so-called scientific revolution, and if the school of thought he generated, Cartesianism, was only one of a number of competing schools of thought in the advance of what came retrospectively to be characterized as modern science, does this matter? Can we not still argue that it was the commitment to understanding the world through mathematics that is the source of its Egyptianism? Once we abandon the identification of modern science with Descartes' philosophy, however, the relationship between mathematics, knowledge and Egyptianism becomes far less clear. Egyptianism cannot be merely identified with the elevation of mathematics as a form of knowledge of the world. This is illustrated by Bruno who was influenced by both Neoplatonism and Stoic physics. While defending and radicalizing the Copernican revolution (arguing that all stars are suns, each with their own inhabited planets) Bruno criticized what he took to be Copernicus' excessive pre-occupation with mathematics.[49] He appeared to be concerned that the creativity of nature be appreciated, in opposition to traditional Neoplatonism, identifying the One with matter and arguing that matter should not be seen as mere potential to be formed but should be seen as pregnant with forms.[50] But this did not mean that Bruno was opposed to Egyptianism. He also argued that 'The universe is, therefore, one, infinite and immobile. … It has no local movement since there is nothing outside of it to which it can be moved, given that it is the whole.'[51] Leibniz, on the other hand, did place more reliance on mathematics as a means to understand nature, and criticized Newton for being insufficiently committed to showing how the whole of nature could be understood deterministically, without invoking the continual activity of God. But at the same time, Leibniz was concerned to give a place to creative becoming, even while upholding determinism, and helped inaugurate the tradition of thought which eventually led to more radical questioning of science's Egyptianism.

So while there appears to be a close relationship between mathematics and Egyptianism which had a major influence on the subsequent development of science, neither the birth of modern science nor the embracing of mathematics as a means to comprehend the cosmos can be identified with Egyptianism. To understand the impulse to Egyptianism it is not enough to go back to Descartes and the scientific revolution of the seventeenth century. It is necessary to dig deeper to expose its roots and reveal more precisely how these roots developed into modern science. One possible source of Egyptianism is Christianity. Christianity has been characterized by exaltation of that which is eternal and correspondingly, the denigration of the temporal realm. St. Augustine, who as we noted exerted a major influence on Descartes, had argued that the education of humanity though history consists in humanity leaning to abjure the

[49] See Hilary Gatti, *Giordano Bruno and Renaissance Science*, Ithaca, Cornel University Press, p. 72.
[50] Giordano Bruno, *Cause, Principle and Unity*, Fifth Dialogue, tr. Richard J. Blackwell, Cambridge, Cambridge University Press, 1998, p. 61.
[51] Bruno, *Cause, Principle and Unity*, p. 87.

temporal and to live for what is eternal.[52] But where did this celebration of the eternal come from? It did not come from the Judaic conception of God. The Judaic God of the Old Testament was a jealous, irascible, vindictive, all powerful person acting as a temporal agent, not a timeless source of an illusory temporal world. It was only when Judaic thought was interpreted through Greek philosophy that God came to be identified with the eternal. So while intellectual developments in medieval Christianity might have been a major source of influence on modern science, it is to Ancient Greek thought that we must look for the source of Egyptianism and its relation to mathematics and to understand the background to the philosophical disputes which gave rise to modern science.

THE ORIGINS OF EGYPTIANISM IN GREEK PHILOSOPHY: FROM ANAXIMANDER TO PARMENIDES VIA PYTHAGORAS

It was Pythagoras and the Pythagoreans who most famously promoted mathematics as the way to knowledge in the ancient world and whose ideas were supposedly revived with modern science. Was Pythagoras the source of Egyptianism? According to Iamblichus, Pythagoras had followed the advice of his teacher, and gone to Egypt, where he studied astronomy, geometry and the mysteries of the Gods.[53] He gave a new meaning to *theoria,* which had earlier meant 'curiosity', reinterpreting this as 'the passionless contemplation of unchanging truth'.[54] It was Pythagoras who first used the term '*philosophia*' and endowed it with a strong religious and ethical sense associated with *theoria.* Pythagoras also took up and developed the notion of '*kosmos*', which he conceived to be the universe as ordered by mathematical proportions (*harmonia*). This view was based on his belief that the basic principle or *arche* of all things is number (*arithmos),* as had been revealed to be the case in tuned strings. Ethics was understood as restoring cosmic harmony in the soul (*katharsis*). Pythagoras strongly influenced Parmenides who went on to argue 'that if something exists, it cannot come to be or perish, change or move, nor be subject to any imperfection.'[55] Subsequent philosophy can be understood as a development of the ideas of these thinkers. As an anonymous biographer of Pythagoras wrote: 'Plato was the pupil of Archytas, and thus the ninth in succession from Pythagoras; the tenth was Aristotle. … Plato is said to have learned his speculative and physical doctrines from the Italian Pythagoreans, his ethics from Socrates, and his logic from Zeno, Parmenides and the Eleatics. But all these teachings descended from Pythagoras.'[56] Kenneth Sylvan Guthrie, in the forward to *The*

[52] Saint Augustine *The City of God*, tr. Marcus Dodds, New York, Random House, 1950, Bk 10, Ch. 14
[53] Iamblichus, 'The Life of Pythagoras' in *The Pythagorean Sourcebook and Library,* tr. Kenneth Sylvan Guthrie, Grand Rapids, Phanes Press, 1987, p. 61.
[54] F. M. Cornford, *From Religion to Philosophy',* Princeton, Princeton University Press, p. 200.
[55] G. S. Kirk, J. E. Raven and M. Schofield, *The Aristocratic Philosophers,* 2nd ed. Cambridge, Cambridge University Press, 1983, p. 241.
[56] Anonymous, 'The Life of Pythagoras Preserved by Photinus' in Guthrie, *The Pythagorean Sourcebook,* p. 136, 137.

Pythagorean Sourcebook claimed that 'Neoplatonism is to a very large degree Neopythagorean: it shares the typical interests in theosophy, cosmology, arithmology, speculative music, and exotic religion. In fact, just as Platonists regard Aristotle as a rather limited successor to their master, so Pythagoreans may well regard the Divine Plato.'[57] Given the subsequent influence of Neoplatonism on Christianity, it would seem that here we have finally found the ultimate source of the Egyptianism of philosophy that has permeated European civilization.

Unfortunately, ascertaining and comprehending Pythagoras' views and how Parmenides was influenced by Pythagorean thought, and the subsequent influence of these ideas is far more difficult to ascertain than this sketch would suggest.[58] Pythagoras wrote nothing, and enjoined his followers not to write anything of their beliefs. Later, most of Pythagoras' followers were murdered, and Pythagoras died soon after. Those later Pythagoreans who did write down their views were to some extent heretics and therefore hardly reliable guides to Pythagorean doctrines, and were likely to have been influenced by later philosophers; most importantly, Parmenides. So to interpret and judge Pythagorean philosophy and its contribution to Egyptianism it is necessary to see these in the context of Greek thought more generally. In particular, it is necessary to understand Pythagorean ideas in relation to the ideas of Anaximander, the first philosopher to make a comprehensive and detailed attempt to explain all aspects of the universe.

It was Anaximander who originated the idea of the cosmos, and it was probably he who first deployed the term *kosmos* to characterize this.[59] It appears that Anaximander was also the first thinker to propose what became the standard form of explanation for the cosmos, first, postulating an undifferentiated unity, secondly, arguing that from this unity two opposite powers are separated out to form the world order and thirdly, showing how these two opposites unite again to generate life. Anaximander postulated the *apeiron* or 'unlimited' as the all-enfolding and all-controlling, divine and immortal and indestructible source of the world. An absolute reference point beyond the changing world in which we live had been postulated and divinized—without any reference to mathematics. From this emerged the polar opposites, on the one hand, hot, dry, bright and rare, on the other, cold, damp, dark and dense. It was the interaction between these that generated the diversity of the cosmos, the celestial bodies, meteorological phenomena, the sea and dry land, animal life and humans. In characterizing celestial bodies, Anaximander was the first mathematical physicist outside Babylon and given the dimensions he postulated, evidently believed that the

[57] Guthrie, The Pythagorean Sourcebook, p. 13.
[58] On this, see F. M. Cornford, 'Mysticism and Science in the Pythagorean Tradition' and Charles H. Kahn, 'Pythagorean Philosophy before Plato' in *The Pre-Socratics: A Collection of Critical Essays*, ed. Alexander P. D. Mourelatos, Princeton, Princeton University Press, 1993.
[59] See Charles H. Kahn, *Anaximander and the Origins of Greek Cosmology*, (1960) Indianapolis, Hackett, 1994, Appendix I.

universe was governed by simple mathematical ratios.[60] On this basis he argued that 'The earth is aloft, not dominated by anything; it remains in place because of the similar distance from all points [of the celestial circumference].'[61] This, as noted by Kahn, involved a new form of mathematical reasoning. It is, as he put it, 'a general expression for the principle of symmetry or indifference. It is indeed the same notion which was glorified in modern time by Leibniz as his Principle of Sufficient Reason, according to which everything which is true or real implies a reason why it is so and not otherwise.'[62] But outside the celestial realm, and despite reference to the immortal *apeiron,* the *kosmos* was conceived by Anaximander as dynamic and historical. Here, mathematical reasoning had at most a very subordinate position. Life had evolved and was continuing to evolve. The first living beings had emerged in moisture and migrated to drier parts, and humans had evolved from fish.

Pythagoras and the Pythagoreans appear to have accepted the basic structure of Anaximander's cosmology, but radically extended the place accorded to mathematics. While the Pythagoreans built on the mathematics developed by the Egyptians and Babylonians and by Thales and Anaximander, according to Proclus, it was they who developed it as a systematic body of knowledge 'seeking its first principles in ultimate ideas, and investigating its theorems abstractly and in a purely intellectual way.'[63] While the basic principle and root of all things was taken to be number, the basic principle and root (*arche*) of number is the Monad or Unity. 'One' was not taken to be a number, but as the principle underlying number conceived as diversity, which in turn is the condition for achieving relations between diversity. That is, the triadic form of explanation of the cosmos was taken over from Anaximander, but was conceived in mathematical terms. As Kenneth Sylvan Guthrie put it, 'If One represents the principle of Unity from which all things arise, then Two, the Dyad, represents Duality, the beginning of multiplicity, the beginning of strife, yet also the possibility of *logos,* the relation of one thing to another.'[64] In the movement from one to two to three to four we have a return to unity of the *tetractys* of the Decad (an equilateral triangle of ten dots), which was taken to be perfect and to embrace the whole of nature. For instance One represents the point, Two represent the line, Three represents the surface, and Four the tetrahedron, the first three dimensional form, the Tetraktys representing this emerging multiplicity from unity as the unity of the Decad. So, as Theon of Smyrna put it, 'the Decad determines every number, including the nature of everything, of the even and the odd, of the mobile and immobile, of good and evil.'[65] The Decad was identified with *kosmos* (conceived as 'world-order'), essentially a mathematic harmony. There was no distinction between physical bodies and ideal mathematical

[60] Kahn, *Anaximander and the Origins of Greek Cosmology*, p. 96f.
[61] Quoted ibid., p. 76.
[62] ibid., p. 77.
[63] Cited by Marshall Clagett, *Greek Science in Antiquity,* 2nd ed. [1963], Princeton Junction, The Scholar's Bookshelf, 1988, p. 36.
[64] Guthrie, *The Pythagorean Sourcebook*, p. 21.
[65] ibid., p. 171.

constructions, or between rigid geometrical form and the vital processes of living things; numbers were thought to be separated by breathing in spirit and void out of the unlimited.[66] With this doctrine the Pythagoreans were led to examine the relationships of numbers and geometrical forms as a means to investigate the entire cosmos, extending Anaximander's notion that everything that is true or real requires a 'sufficient reason' to explain why it is so and not otherwise. However, not everything was explained by the Pythagoreans in this way. Much of Pythagorean doctrine appears almost arbitrary, as when Pythagoras said that the human soul was a tetragon with right angles.[67] It is against the background of Pythagorean insights and arbitrariness that we can understand the ideas of Parmenides and Zeno.

Parmenides, taking the principle of sufficient reason to its extreme and focusing on what is intelligible concluded that there is simply the One or unity of Being; he argued that there was no development of diversity from the One and so no harmonizing of the diverse. Such would imply coming into being and ceasing to be. Since this assumes that we can know a prior state of not being, which is by definition not, and therefore unknowable, this is unintelligible, Parmenides argued. The only secure way to truth is that which concerns what 'is', and this cannot come to be or perish, change or move, nor be subject to imperfection. So, from postulating more abstract entities and charting new notions of intelligibility in comprehending these abstract entities and their relations pioneered by Anaximander and developed by Pythagoras, Parmenides focused on this abstract realm of thought and what is intelligible and concluded that the world that we normally take to be reality is merely the opinion of men. This did not stop him going on to elaborate a whole cosmology, portraying the cosmos as developing out of the opposition between light and night, but at the same time he denigrated such accounts as nothing but inventions of the human mind. Parmenides defended his claims by showing the logical coherence of his ideas and that the alternatives to them led to contradictions. This was the origin of logic (as 'dialectic'), which was further developed by Parmenides' student, Zeno, who used it to show the incoherence of believing in plurality or motion. Parmenides' arguments were based on two assumptions: that logically true things and properties of real things coincide, and that any proposition is either true or false; there can be no third case.[68] Both of these assumptions came to be accepted and have pervaded thought ever since (although each assumption has been questioned).

HERACLITUS VERSUS THE PYTHAGOREANS AND PARMENIDES

While this account schematically describes the development of Egyptianism, it is

[66] Aristotle, *Physics,* 213 b22.
[67] Guthrie, *The Pythagorean Sourcebook*, p. 179.
[68] For an analysis of Parmenides' and Zeno's arguments, see George Kampis, *Self-Modifying Systems in Biology and Cognitive Science: A New Framework A New Framework for Dynamics, Information and Complexity*, Oxford, Pergamon Press, 1991, p. 84ff.

the response to Pythagoras and Parmenides which most clearly reveals the commitment to the assumptions which gave rise to it.

To begin with, there was some opposition to this trend of thought. The most significant of this came from Heraclitus and is followers. Heraclitus, as Charles Kahn has noted,[69] was more concerned with the human condition than with the physical world that had preoccupied his predecessors (although insofar as he was concerned with the physical world he was closer to Anaximander than to later philosophers). Developing a philosophy adequate to this, he attacked Pythagoras and developed a philosophy focusing on change, life and death, almost totally contrary to the philosophy of Parmenides. Even Heraclitus contributed to Egyptianism, however. He argued that men should try to comprehend the underlying coherence of things. This, he argued, is expressed in the *logos*, the element of arrangement common to all. As Kirk et. al. wrote of this, 'The effect of arrangement according to a common plan or measure is that all things, although apparently plural and totally discrete, are really united in a coherent complex of which men themselves are a part, and the comprehension of which is therefore logically necessary for the adequate enactment of our own lives.'[70] This appears to be consonant with the Pythagoreans. Heraclitus' *logos*, however, was characterized not so much as a harmony but as a unity of opposites of various kinds. Opposites inhere in or are simultaneously produced by a single subject, or are connected through being different stages in a single invariable process. Each pair of opposites forms both a unity and a plurality and different parts are found to be interconnected. This unity is beneath the surface, and depends upon a balanced reaction between opposites, as in the bow and the lyre. That is, the opposites are active forces. Balance in the cosmos is maintained only though unending 'strife' between opposites. As Heraclitus put it, '[i]t is necessary to know that war is common and right is strife and that all things happen by strife and necessity.'[71] Through the balance of opposing forces, there can be temporary stability, but underlying such apparent stability is change. So, Heraclitus proclaimed: 'Upon those that step into the same rivers, different and different waters flow … They scatter and … gather … come together and flow away … approach and depart.'[72] The world is then seen as an ever-living fire: 'This world-order… did none of gods or men make, but it always was and is and shall be: an everliving fire, kindling in measures and going out in measures. … All things are an equal exchange for fire and all fire for all things, as goods are for gold and gold for goods.'[73]

Heraclitus' efforts to uphold the primary reality of becoming, conflict and process were rejected by most subsequent philosophers, while despite the apparent absurdity of the conclusions defended by Parmenides and Zeno, subsequent philosophers accepted

[69] See Charles H. Kahn, *The Art and Thought of Heraclitus*, Cambridge, Cambridge University Press, 1979.
[70] Kirk et. al. *The Presocratic Philosophers*, p. 187f.
[71] ibid., p. 190.
[72] ibid., p. 195.
[73] ibid., p. 198.

that there was something fundamentally right in their arguments. Even when they opposed their conclusions, they accepted that what is known must be unchanging. Embracing the central argument of Parmenides while modifying his position to account for the appearance of change, the atomists, Leucippus and Democritus, postulated a plurality of unchanging plenums or atoms of different shapes and sizes within a void, that is, what is and what is not, taking the void, 'what is not', to exist, so making intelligible the movement of atoms in relation to each other.[74] Shape, arrangement and position, identified with 'rhythm, touching and turning' were taken to be the 'differences' (i.e. what could be different) which are the 'causes' of other things. Later Pythagoreans modified Pythagorean ideas to accord at least to some extent with Parmenides' philosophy. Archytas, a contemporary of Plato, extolled logic, writing of it that compared to the other sciences 'it is by far the most successful and succeeds in demonstrating its objectives even better than geometry. Where geometric demonstration fails, logic succeeds…'[75] He went on to claim that it is impossible for opinions if they are true to contradict each other, implicitly rejecting Heraclitus' claim that contradictory assertions are true. Another Pythagorean, Ocellus Lucanus argued in Parmenidian fashion that the universe cannot have begun, nor can it end, 'For if some one should claim that it was once generated, he would not be able to find anything into which it can be corrupted and dissolved, since that from which it was generated would be the first part of the universe; and again that into which it would be dissolved would be the last part of it.'[76] Parmenides argument that the One is undifferentiated was rejected, but his arguments still led to a more static conception of the diversity that was acknowledged. In opposition to Anaximander's evolutionary view of the cosmos, Ocellus argued that 'Man's generation did not originate from the earth, other animals, or plants… As primarily the world existed always, its parts must coexist with it…'[77]

PLATO

It is in Plato's work, however, that we can most clearly see the working out of the opposition between Parmenidian and Heraclitean thought. Plato was influenced by and responded to all these thinkers; to the Heraclitean Cratylus, the Pythagoreans, Parmenides, Socrates who himself was influenced by both the Pythagoreans and Parmenides, and the atomists; the study of his work therefore provides the best vantage point to understand the underlying assumptions of Greek culture. To begin with, Plato developed Socratic logic or dialectics, which in turn was a development of the logic of Parmenides and Zeno. Following Socrates, Plato used this logic to search for true definitions, extending the examination of these and their relationships beyond

[74] Aristotle, *Metaphysics,* 985b4. See Kirk et. al. *The Presocratic Philosophers*, p. 414.
[75] 'The Fragments of Archytas' in Guthrie, *The Pythagorean Sourcebook*, p. 193.
[76] Ocellus Lucanus, 'On the Nature of the Universe' in Guthrie, *The Pythagorean Sourcebook*, p. 203.
[77] Ocellus Lucanus, 'On the Nature of the Universe', p. 208.

mathematical definitions to ethical and political definitions. Plato took very seriously Parmenides' argument that that which is not, cannot be known because it has no object, and therefore there can be no coming to be or change. His response to this, presented in *The Sophist,* was to argue that when we claim that something is not, we do not mean that it is not anything, but that it is one Kind and not another. As he concluded his argument, 'When we speak of "that which is not", I don't think we mean something contrary to what exists, but only something that is different.'[78] But Plato still accepted that these 'things' must be unchanging. Criticising mathematicians who 'constantly talk of "operations"' like "squaring," "applying," "adding," and so on. As if the object were to *do* something,' Plato argued that 'the true purpose of the whole subject is knowledge—knowledge, moreover, of what eternally exists, not of anything that comes to be this or that at some time and ceases to be.'[79] Taking such mathematical objects as prototypical Plato took objects of knowledge to be incorporeal and intelligible 'forms', dismissing those who took material bodies to be reality as vulgar.[80]

These forms subsequently became the basis of his cosmology. In the prelude to *Timaeus* he wrote:

> What is that which is always real and has no becoming, and what is that which is always becoming and is never real? That which is apprehensible by thought with a rational account is the thing that is always unchangeably real; whereas that which is the object of belief together with irrational sensation is the thing that becomes and passes away, but never has real being.[81]

This did not mean that the realm of belief and becoming were to be dismissed entirely. Becoming was granted a place in relation to agency, in this case, of the eternal Demiurge who had fashioned the universe using the forms as a model. While an account of what is abiding will itself be abiding, Plato argued, where agency is concerned it is only possible to give a probable account (or 'likely story'), less improbable than any other and so believable rather than knowable. As he put it, 'as being is to becoming, so truth is to belief.'[82] However, since the Demiurge was conceived to be good, it could be assumed that he would attempt to make the universe as like himself as possible. For this reason, the universe to a considerable extent is knowable through reason. Plato argued that the Demiurge had formed the receptacle into five different kinds of polyhedrons, making air, fire, earth and water, the elements from which the Demiurge brought the universe into being, 'coming into concord by means of proportion.'[83] The fifth element was used by the Demiurge to arrange the constellations of the whole heaven. On this basis Plato foreshadowed the mathematical

[78] Plato, 'The Sophist', 257b. in *The Collected Dialogues of Plato,* ed. Edith Hamilton and Huntington Cairns, Princeton, Princeton University Press, 1982, p. 1003.
[79] Plato, *The Republic,* 527a-b.
[80] Plato, *The Sophist,* 246a-e.
[81] Plato, *Timaeus,* 27d-28a. tr. John Warrington, London, Dent, 1965.
[82] ibid., 29c
[83] ibid., 32c.

treatment of time. He argued that while it was impossible to fully endow a generated thing with eternity, the Demiurge 'planned to make as it were a moving likeness of eternity; and, at the same time that he set in order the Heaven, he made, of eternity that abides in unity, an ever-flowing likeness moving according to number—that to which we have given the name Time.'[84]

In elaborating this philosophy Plato was particularly concerned to defend the reality of these forms against the followers of Heraclitus. His argument against the Heracliteans was presented most forcefully in the dialogue *Cratylus.* Here, Plato argued that if reality were taken to be process, then there could be no knowledge:

> Nor can we reasonably say, Cratylus, that there is knowledge at all, if everything is in a state of transition and there is nothing abiding. For knowledge too cannot continue to be knowledge unless continuing to exist. But if the very nature of knowledge changes, at the time when the change occurs there will be no knowledge, and, according to this view, there will be no one to know and nothing to know.[85]

What is amazing is that this appears to have been taken to be a good argument. Jaakko Hintikka has offered an explanation for why this should have been so. He noticed that the Greeks, including Plato and Aristotle, assume that sentences expressing human knowledge are *temporally indefinite;* they depend on some feature or features of the occasion on which they are uttered.[86] Truth was not understood by them in relation to a context independent proposition but to thoughts of people who uttered sentences. This in turn was a manifestation of a deeper assumption, that knowledge is some kind of perception or direct acquaintance with the objects of knowledge. As W.G. Runciman concluded after a study of Plato's *Theaetetus,* 'The general impression left by the *Theaetetus* is that Plato continued to think of knowledge as a sort of mental seeing or touching.'[87] The consequence of this is that the Greeks simply assumed that we can have genuine knowledge, that is, knowledge which continues to be knowledge, only of what is eternal, or at least, changeless; that is, with that which is 'omni-temporal'.

We can now see the assumptions underlying Greek thought. To begin with, there was the assumption which developed with Greek philosophy that a proper explanation of anything involves supplying a sufficient reason why anything should happen, an assumption was closely associated with the use of mathematics. There were deeper assumptions at work, however; to begin with, the assumption that we can only have true knowledge of what is omni-temporal or eternal. This in turn was based on the assumption that knowledge was 'mental seeing or touching'. This is the assumption which accounts for the ascendancy in Greek thought of Egyptianism, for the movement

[84] ibid., 37d.
[85] Plato, *Cratylus*, 440a *The Collected Dialogues of Plato*.
[86] Jaakko Hintikka, *Knowledge and the Known: Historical Perspectives in Epistemology*, Dordrecht, Reidel, 1974, p. 51.
[87] W. G. Runciman, *Plato's Later Epistemology,* Cambridge, Cambridge University Press, 1962, p. 52, cited by Hintikka *Knowledge and the Known*, p. 59.

from the omni-temporal *apeiron* of Anaximander to the mathematical entities and relationships of the Pythagoreans to the unchanging Being of Parmenides, to the atoms of Leucippus, then to the forms of Plato. It accounts for the emergence of the Principle of Sufficient Reason. And it accounts at least in part for why even Heraclitus, who was most concerned to acknowledge the reality of change, postulated the *logos* as the object to which all people should turn to discover the truth. And it accounts for why Heraclitus' argument that all things flow and everything is changing, did not prevail. Most importantly it accounts for the celebrated status accorded first to mathematics and then to logic.

FROM PLATO TO THE STOICS

If as Whitehead claimed, 'the European philosophical tradition … consists of a series of footnotes to Plato',[88] and if modern science involved a revival of Platonistic thinking in opposition to scholastic Aristotelian thought, then we should now be able to say that we have finally got to the roots of Egyptianism. The issue is still more complex, however. While Platonistic thought might have provided the foundations for the development of modern science, Plato's own philosophy only provided a starting point for the developments which led to this. What we find subsequently is a struggle to simultaneously uphold Egyptianism while still giving a place to the appearance of becoming in the world. The tensions generated by these efforts resulted in a variety of positions which contributed to laying the foundations for modern science.

This tension is clearly evident in Plato's philosophy. To begin with, to some extent echoing Parmenides, Plato extolled mathematical knowledge dealing with an eternal realm of intelligible forms about which we learn through instruction, of which we can be certain, and which can give a true account of itself, and distinguished this from another realm of existence about which we can have true beliefs which can give no account of itself and which can be shaken by persuasion.[89] Since the mathematical forms apparent in the sensible world are mere copies of the intelligible forms, the only kind of knowledge attainable in this case is 'true belief', which for Plato was the 'most probable account'. That is, all that we can hope for is to gain true beliefs about the sensible world, beliefs less improbable than any other. While mathematics was being organized into a coherent body of knowledge founded on basic principles (completed in geometry with the work of Euclid), Plato rejected this approach to cosmogony, claiming that it was not only too difficult to use such a method of exposition to explain the generation of the cosmos, but exclaimed: 'Nor indeed could I ever convince myself that I should do right in shouldering so great a task.'[90] Aiming only at a probable account enabled Plato to include in his explanations reasons for acting by the Demiurge and the

[88] Alfred North Whitehead, *Process and Reality*, Corrected Edition, ed. David Ray Griffin and Donald W. Sherburne, New York and London, The Free Press, 1978.
[89] Plato, *Timaeus*, 51c-e.
[90] ibid., 48d.

lesser gods, the forming of the otherwise featureless Receptacle on the model of the forms, largely chaotic mechanical interactions, as when the elements interact with each other and, with the exception of earth, are transformed into each other, or the elements form compounds, and the cooperation of rational design and causal necessity associated with organisms. But Plato had presented an idea of the highest form of knowledge, presenting his 'probable account' as a deficient form of knowledge. He had set philosophy on a path to augment his 'probable account' to bring it closer to the highest form of knowledge.

The first domain in which knowledge of the sensible world was developed to accord with the ideal achieved by mathematical knowledge was astronomy, and to some extent, to physics generally. Plato's student and associate, Eudoxus, took up Plato's challenge of showing by 'what uniform and ordered motions can the apparent movements of the planets by accounted for?'[91] Eudoxus devised a system of concentric spheres, all having their centre in the centre of the earth, revolving uniformly, but with a number of such circular motions working on each planet. The whole system was a purely geometrical hypothesis. Another student of Plato, Heraclides, suggested that the phenomena could be saved more simply if it were supposed that the Earth revolved on its axis while the heavens remained fixed, and that Mercury and Venus revolve around the Sun. Half a century later, Aristarchus suggested that the Earth revolves around the Sun, suggesting also that the stars were of immense distance from the Sun in order to account for the absence of parallax. Here we have the application of a hypothetico-deductive approach to 'save the appearances'. Aristarchus also attempted to calculate the size of and distances to the Sun and the Moon using observations and geometrical calculations equivalent to later trigonometric calculations. While poor observational data resulted in poor results, similar methods enabled Eratosthenes, a friend of Archimedes, to accurately calculate the circumference of the earth. Such observations go beyond the hypothetic-deductive approach to 'save appearances' in that the observations and observational equipment themselves presuppose a mathematical order in that which is being investigated. Plato's contemporary Archytas is said of have written 'the first systematic treatise on mechanics based on mathematical principles.'[92]

Such ideas were developed much further in Hellenistic science. To begin with, the mathematical approach to mechanics were superseded by Aristotle's more qualitative approach, an approach which lacked formal mathematical demonstrations. But along with further developments in mathematics, the mathematical approach was revived by Euclid and Archimedes. One of the principle developments in mathematics was the systematic application of a method of analysis and synthesis. Analysis commences with the assumption of what is to be proved and then proceeds backwards by successive inferences to theorems of axioms or postulates generally accepted or previously proved,

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[91] Clagett, *Greek Science in Antiquity,* p. 109. This work provides a lucid account of the development of Greek science.

[92] ibid., p. 93.

while synthesis is the reversal of this procedure, proceeding to the proof of the new theorem.[93] This same procedure was then applied to mechanics of levers and hydrostatics, using idealized geometrical magnitudes. The importance of these developments was to have shown that a similar approach could be taken to the world around us as that taken in astronomy. This achievement, however, was at the cost of abandoning the dynamic aspects of Aristotle's work.

It might appear that Aristotle's work and those he influenced countered at least to some extent the advance of this Egyptianism and to some extent moved philosophy back to the more dynamic cosmology of Anaximander. To begin with, Aristotle altered the status of mathematics. For Aristotle, mathematics was nothing more than perceptible things seen in abstraction from their perceptible qualities. Not only did he deny that mathematical entities exist as such, he also argued that the domains in which mathematics was of significance were far more limited than Plato had thought; it was not universal method.[94] Aristotle saw the universe as a hierarchy of forms with different regions characterized by different qualities. Only in astronomy, optics, mechanics and harmony is it appropriate to use mathematics. Elsewhere, a more qualitative, more empirical approach is required with different principles of explanation. As he put it: 'Perceptible things require perceptible principles, eternal things eternal principles, perishable things perishable principles; and, in general, every subject-matter principles which are homogeneous with itself.'[95] The transfer of one method of science to another leads to 'category-mistakes'. Aristotle argued that in the mundane world he accorded a central place to the process of actualizing forms and to generation and corruption.[96]

However, in other ways Aristotle took mathematics to be a more significant aspect of reality than had Plato. As G.E.L. Owen noted, when Aristotle joined the Academy it was distinguished from other schools by its interests in mathematics and dialectics. For Plato, mathematics prepared people for the study of dialectics. Aristotle reversed the priorities.[97] For Aristotle, mathematics is a science of the physical world, not of a Platonic world of transcendent objects. It abstracts from the physical world those aspects of the world relevant to physics. This is then the model of all sciences: it does not merely record but explains, and in explaining, it must generalize. With mathematics conceived in this way, Aristotle could treat mathematical knowledge of the physical world as the highest kind of knowledge, not as an inferior kind to pure mathematics as Plato had argued. Aristotle also argued, contrary to Plato, that

[93] While this method was most clearly spelt out by Pappus of Alexandria who lived at the end of the third and the beginning of the fourth century AD, it is evident in Archimedes' Letter to Eratosthenes', *The History of Mathematics: A Reader, ed. John Fauvel and Jeremy Gray,* London, Macmillan Press, 1987, pp. 167-172. On Pappus and Greek mathematics generally, see Clagett, *Greek Science in Antiquity,* p. 72ff.

[94] Aristotle, *Posterior Analytics,* 75a38 – b6.

[95] Cited by S. Sambursky, *The Physical World of Late Antiquity,* [1962] Princeton, Princeton University Press, 1987, p. 34.

[96] For an interpretation of Aristotle stressing his dynamic view of nature see John Herman Randall Jr., *Aristotle,* New York, Columbia University Press, 1960.

[97] G. E. L. Owen, Aristotle, 'Method, Physics and Cosmology' in *Logic, Science and Dialectic,* ed. Martha Nussbaum, Ithaca, Cornell University Press, 1986, pp. 151-164, p. 153.

knowledge of the world could be presented as mathematics was being presented. He argued that all sciences, whether mathematical or not, should be developed into a system in which theorems are validly derived from basic principles, (although he was seldom able to achieve this goal). Dialectic was reconceived from Plato's conception of it as a free-ranging analysis, critique and development of definitions to an examination of respectable opinions in order to arrive at the first principles of each of the sciences.[98]

This reconceptualization of the nature of knowledge of the world was associated with the development of syllogistic logic. In *The Sophist* Plato had argued that 'dialectic [is] the science whose function is to divide according to Kinds, not believing that the same form is a different one or vice versa'. He went on to suggest that

> …he who can do that intuitively perceives (a) one Form extended everywhere throughout many, where each one lies apart, and (b) many Forms differing from one another, included within one Form; and again (c) one Form connected in a unity through many wholes, and (d) many Forms entirely marked off apart. Thus he knows how to distinguish, Kind by Kind, in what ways the several Kinds are or are not able to combine.[99]

Aristotle developed this suggestion rigorously by characterizing knowledge in terms of class membership. To describe nature exhaustively required comparison and definition. An exhaustive definition required the identification of the closest genus and the specific difference. The aim then was to characterize the whole of nature in terms of an unequivocal hierarchical order of definitions.

On this basis Aristotle developed new forms of logic, an inductive logic concerned with valid inferences from observations of individuals or classes of individuals, and deductive or syllogistic logic concerned with identifying what kinds of valid deductive inferences can be made from assertions affirming or denying something of something to conclusions which are different from the premises.[100] In general, Aristotle took such assertions to be 'categorical sentences', that is, assertions that can be expressed as predicates of subjects or class membership, expressible in forms such as '*a* belongs to every *b*'. This was a logic of terms. This logic not only provided Aristotle with a means to organize knowledge within particular sciences, but also to organize knowledge of the relationship between sciences. The ultimate classes or predicates are the categories. He defined the science grappling with the most fundamental question, 'What is "primary being (*ousia*)"'? as first philosophy (i.e. metaphysics), because knowledge of this underlies and is presupposed by all other sciences.[101] Primary beings are those beings to which all predicates must ultimately be predicated. Aristotle recognized three kinds of primary beings: sensible primary beings (a stone or tree, for example), non-sensible primary beings subject to change (the celestial bodies), and the highest kind, primary beings

[98] See Aristotle, *Topics,* 101b4.
[99] Plato, *The Sophist,* 253d.
[100] Aristotle, *Prior Analytics*, 24.
[101] See Aristotle, *Metaphysics,* 1003b15-23.

which are eternal and unchanging, the 'unmoved movers'.[102] He identified these unmoved movers with the fifty-five spheres which he claimed were required to move the planets (including the sun and the moon).[103] These were taken to be composed of a fifth element, aether. The celestial realm was held by Aristotle to be eternal.

So despite the fact that Aristotle gave a place to diverse kinds of science, some of which involved generation and corruption, all these were organized in an omni-temporal structure of classes which provided the basis for developing and organizing knowledge, which determined which inferences are valid and which provided the omni-temporal objects required for genuine knowledge. And the ultimate objects of knowledge are the unmoved movers, the spheres moving the planets. Aristotle differed from Plato in how he contributed to Egyptianism. Plato's Egyptianism based on transcendent, omni-temporal forms had been abandoned for a more inclusive Egyptianism which gave a greater place to mathematical knowledge of the sensible world than Plato had allowed.

There does appear to be one group of philosophers in the Ancient World who were resolutely opposed to Egyptianism, the Stoics. These were the most influential philosophers for half a millennium from the 2nd century BC to the 3rd century AD, although almost all the most original ideas were developed by its founders. These philosophers appear to have been influenced by Aristotle, but developed his ideas to accord more with those of Heraclitus.[104] Embracing the suggestion made by Plato, that what is real is what can be affected or which can effect a change in something else,[105] the Stoics took force to be the primary feature of physical existence. Essentially, they put forward an early version of field theory in which the whole determines the parts.[106] The universe was seen to begin from a state in which all is fire.[107] This generates the elements (air, fire, earth and water) from which the world we are familiar with is created. This will end in fire and the whole cycle will start again. In this scheme of things, the active elements fire and air (or the hot and the cold) form breath or *pneuma,* the sustaining cause of all existing bodies. There are various kinds of *pneuma*, and the kinds associated with plants and animals guide the growth and development of animate bodies. *Pneuma* acts, and is therefore conceived to be body, playing its role by blending with matter. So what we appear to have is a world of dynamic process. Accordingly, mathematics was seen as derivative from force and given a subordinate place in comprehending this force.[108] 'Mathematics is superficiary, as it were, and builds on

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[102] ibid., 1069a30.
[103] ibid., 1074a11.
[104] That Stoicism derives from Aristotle's philosophy has been argued by David E. Hahm, *The Origins of Stoic Cosmology,* Ohio State University Press, 1977.
[105] Plato, *The Sophist,* 247d-e.
[106] See S. Sambursky, *Physics of the Stoics,* London, Routledge, 1959, p. 33ff. On Sambursky's interpretation, see F.H. Sandbach, *The Stoics,* London, Chatto & Winds, 1975, p. 71.
[107] See A. A. Long & D. N. Sedley, *The Hellenistic Philosophers*, Vol.1, Translation of the Principal Sources, with Philosophical Commentary, Cambridge, Cambridge University Press, 1987, p. 274ff.
[108] Sambursky, *Physics of the Stoics*, p. 87.

someone else's land', wrote Seneca.[109] Formal logic was also modified by the Stoic to accord with their conception of the universe as dynamic process. In place of Aristotle's syllogistic logic they developed a logic of propositions. This enabled the Stoics to accommodate verbs of all kinds, whereas the Aristotelian syllogism only admitted the copula that joins a predicate to its subject.[110]

The Stoics, however, were not only still dominated by Egyptianism; they contributed to its development. Having accepted the mutability of the elements, they concluded that there must be some ultimate principles underlying them: God and matter, the first being active, the second passive, without qualities, although extended and resistant to pressure. As in Heraclitus, God is characterized as *logos.* This has two meanings in Stoic philosophy; the first, that of an eternal rational plan or principle which guides the evolution of the universe; the second, combined with matter to form a *pneuma* that passes through all things and fashions them in accordance with this plan.[111] So despite the commitment to dynamic process, the ultimate principles are timeless. Furthermore, in their determination to uphold a 'materialist' cosmology in which only that which acts on others or can be acted upon is acknowledged to be real, the Stoics collapsed the diversity of sciences of Aristotle into one science. Dynamic process, ultimately controlled by God as plan and God as *pneuma,* was conceived to be deterministic. The Stoics rejected Aristotle's argument that statements about future events can be allowed to be either true or false, and argued that before they happen, such statements must be true or false even if we cannot know what is true until after the event. Their acceptance of determinism based on their conception of God and His role in the cosmos together with arguments based on logic led them to equate the causal necessity of dynamic processes with logical necessity. The cosmos was then seen to repeat of circle of development and conflagration so that everything that happens in each cycle will be repeated eternally.

MODERN SCIENCE AS HEIR TO GREEK EGYPTIANISM

Subsequent to the foundation of the main schools of thought philosophy was characterized by rival traditions both competing and appropriating ideas from each other. Neoplatonism was a synthesis of Plato's diverse ideas with elements of Stoicism and Aristotelianism. A new dimension was added by the integration of these philosophies with Hebraic thought in Christianity. The subsequent synthesis celebrated the eternal as the true reality but at the same time promoted increasing interest in the temporal realm, sharpening the opposition between the Egyptian tendencies of philosophy and the problematic status of change and becoming. The most original thinker in the effort to synthesise Greek thought and Platonism was St Augustine.

[109] Seneca, Letters 88.25-8 in *The Hellenistic Philosophers*, p. 160.
[110] On Stoic logic, see F.H. Sandbach, *The Stoics,* London, Chatto & Winds, 1975, Ch. 5.
[111] On this, see Sandbach, *The Stoics,* p. 72f.

Augustine identified the Christian God with the realm of ideas of the Platonic tradition and developed his theory of knowledge accordingly. As Randall wrote,

> God is the Truth which is the origin of all truth. Since mathematics and the relations of figures and numbers form the clearest illustration of truth, God is the realm of logical and mathematical subsistence. … Thus, the highest conception of Greek science, the idea of a Logos, a rational structure or substance, is identified with the God of Christianity.[112]

But at the same time St Augustine was concerned with the temporal order and developed highly original ideas on temporality which have recently been revived by Paul Ricoeur in his effort to characterize narrative.[113] The most original natural philosopher of Late Antiquity, John Philoponus, strove to adjust physical theory to accord with Biblical account of creation.[114] It was this that led him to criticize Aristotle's defence of an eternal world with a sharp division between the celestial and sublunary worlds.[115] John argued that all sensible things, including those in the celestial realm, are mutable, although some things change only very slowly. While this led him to be skeptical about the efforts to understand nature, he developed the notion of 'impetus' to account for the continued motion of the planets since creation. Such arguments, and the notion of 'impetus', were revived by the Terminists at Oxford and Paris in the fourteenth century and through them had an important influence on the development of modern science.[116]

As noted, the rise of modern science was associated first and foremost with the rise in status of mathematics. In general, as Alexandre Koyré among others have argued, the revival of interest in mathematics was associated with a revival of Platonism and Neoplatonism.[117] Platonism was clearly important in the overthrow geocentricism in astronomy. Copernicus, Bruno and Kepler were all strongly influenced by the revival of Platonism and Neoplatonism.[118] However, not all proponents of mathematics were Platonists, and the Platonism of the early modern period differed from the Platonism of the Ancient World. Kepler in particular, originally a Neoplatonist, later emphasized the need to subordinate mathematical thinking to observation. At the same time, the Neoplatonism of the seventeenth century upheld Egyptianism far more rigorously. Why? Because Platonism did not simply replace the Aristotelianism of Scholastic

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112 Randall, *The Career of Philosophy*, p. 27.

113 Paul Ricoeur, *Time and Narrative,* Vol.1, tr. Kathleen McLaughlin and David Pellauer, Chicago and London, 1984, pp. 5-30.

114 See S. Sambursky, *The Physical World of Late Antiquity,* Princeton, Princeton University Press, 1987, p. 154 ff. Philoponus wrote in the first half of the sixth century A. D.

115 See Johannes Philoponus, 'The unity of heaven and earth' in *Physical Thought from the Presocratics to the Quantum Physicists,* ed. Shmuel Sambursky, New York, Pica Press, 1975.

116 On the contributions of the Terminists, see Edward Grant, *Physical Science in the Middle Ages,* Cambridge, Cambridge University Press, 1977. While Pierre Duhem argued that the Terminists were the true original thinkers whose ideas were merely revived by Galileo, Grant argues that there was far less influence than Duhem claimed.

117 See 'Galileo and Plato' in *Metaphysics and Measurement,* Cambridge, Harvard University Press, 1968.

118 Thomas S. Kuhn, *The Copernican Revolution,* Cambridge, Harvard University Press, 1957, p. 128ff., 199.

Philosophy; it incorporated Aristotelian Egyptianism into it as this had been developed both by the Thomists and the Terminists, along with central doctrines of the Atomists and the Stoics.

The place accorded to mathematics in the new orientation to the world was famously expressed by Galileo when he wrote:

> Philosophy is written in that great book which ever lies before our eyes—I mean the universe—but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. This book is written in the mathematical language, and the symbols are triangles, circles, and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders through a dark labyrinth.[119]

However, this was as much rhetoric as the statement of a coherent philosophical position, and opposing the claims of Koyré that Galileo was a Platonist, John Herman Randall has argued that Galileo was more influenced by Aristotelian thought than Platonism. Galileo's point of departure was the Italian tradition of thought based in Padua concerned to develop a more adequate method to investigate nature. This work involved trying to comprehend and then generalize Aristotle's approach to biology. In his biological investigations, Aristotle began with effects, sought the cause and then explained the effects by that cause. The Italians characterized this as the 'resolutive/compositive' method. According to a leading figure of this school, Zabarella, science proceeds through four stages: first, we observe the single effect, secondly we resolve the complex fact into its component parts and conditions, thirdly we examine this hypothetical cause by mental examination to clarify it and find its essential elements, and finally we demonstrate the effect from that cause.[120] This method was seen to provide the means for establishing the first principles of any science. While Zabarella did not relate this method of investigation to mathematics, and distinguished it from the mathematical method of Archimedes, his successors integrated these two. In general, these Italian proponents of mathematics were Aristotelians rather than Platonists, seeing mathematical forms as discoverable in nature through abstraction. And being artists and engineers, their main motive for extolling mathematics was its practical utility. Leonardo da Vinci, for instance, who played a major role in combining the resolutive/compositive method with mathematics, argued that 'No investigation can claim to be a true science if it does not proceed by mathematical demonstration.'[121] This new model of science was inherited and then developed by Galileo, who at the same time, drawing on the conceptual work of the Terminists (notably, Nicole Oresme and Jean Buridan) and the mathematical work and approach to explanation of Archimedes, was able to go beyond the static thinking of

[119] *Opere Complete di Galileo Galilei*, Firenze, 1842, ff., Vol. IV, p.171, translated by E. A. Burtt, *The Metaphysical Foundations of Modern Science*, revised ed., New York, Doubleday, 1954, p. 75.

[120] On this, see Randall, *The Career of Philosophy*, p. 295. Randall argues against Koyré that Platonism as such had only a slight influence on Galileo.

[121] Quoted by Randall, *The Career of Philosophy*, p. 305.

Archimedes by introducing the notion of 'state of motion' and then characterizing motion mathematically. However, for all his achievements, Galileo did not elaborate an integrated cosmology and philosophy on this basis.

The development of such an integrated cosmology and philosophy involved drawing upon and integrating other traditions of thought. In particular, it involved a synthesis of the project of the Terminists to create an unequivocal language to describe reality and the revival of the Stoic quest to conceive the universe as homogeneous. The Scholastics had taken over from Aristotle the quest for an unequivocal description of nature. The Terminists of the fourteenth century, who had denied reality to universals, were obsessed with precision in language and objected to any equivocation whatsoever, and in their quest to eliminate equivocation and clarify terms made a number of important conceptual advances in kinematics and astronomy, although they made no significant contributions to mathematics. At the same time, however, they followed Aristotle and earlier Scholastic philosophers in holding that the universe has different domains governed by different kinds of 'causes' or principles. They repudiated the idea of dialectic as an overarching science and defended a diversity of approaches to nature. By contrast, the Renaissance philosophers of nature such as Telesio and Bruno, returning to the philosophy of the Stoics, rejected this pluralism, asserting the fundamental homogeneity of the universe. They replaced Aristotelian forms with forces as the basic principle of action and argued that everything in the universe must be explained in terms of basic forces. But at the same time Bruno, following Nicholas Cusanus, argued that there is an inevitable imprecision in our language. The universe, he argued, can never be totally characterized through language; our terms are mere approximations, and diverse symbolic forms are required to reveal diverse facets of this homogeneous universe.[122] Although sympathetic to some extent to the use of mathematics, Bruno criticized excessive preoccupation with mathematical reasoning.

The natural philosophers we associate with the scientific revolution continued to believe that the universe was homogeneous, but at the same time revived the Scholastic quest for a totally unambiguous language. As Amos Funkenstein succinctly put it:

> The [Scholastics] considered their foremost task to be the purification of all ambiguities from language—all the more so since the Nominalist revolution. Renaissance philosophies of nature, on the other hand, abandoned the obsession with language but advanced the ideal of the homogeneity of nature in all its parts, a nature constructed of one matter and of one set of forces. Only in the seventeenth century were both ideals fused into one ideal: a science that has an unequivocal language with which it speaks and uniform objects of which it speaks.[123]

And, unlike both the Terminists and the Stoic revivalists, these philosophers embraced

[122] On Bruno's defence of other forms of language see *On the Composition of Images, Signs and Ideas,* tr. C. Doris, New York, Willis, Locker and Owens, 1991.

[123] Amost Funkenstein, *Theology and the Scientific Imagination From the Middle Ages to the Seventeenth Century*, Princeton, Princeton University Press, 1986, p. 41.

and advanced the use of mathematics. In the context of this unified ideal, the role of mathematics in comprehending the world was made central, and the entire cosmos conceived as a homogeneous order describable in unequivocal language such that it could be investigated and understood completely through mathematics.

DESCARTES' SYSTEM AND CARTESIAN THOUGHT

The first person to develop a coherent total system of philosophy embracing this unified ideal of linguistic precision and ontological homogeneity while upholding mathematics as a means to achieve it was Descartes.[124] Descartes believed that Galileo had found the right method to examine physical matters by mathematics, but that he did not have a philosophy to solve traditional problems or provide a metaphysical framework to set in place a new picture of the world, to guarantee its validity and to spell out its implications. To achieve this Descartes drew heavily on the work of St Augustine.[125] Randall succinctly summarized the central ideas of the Augustinians:

> For this great tradition, the proper object of science is a Logos, a rational structure or system of ideas, an intelligible realm the content of which is best illustrated by the truths of mathematics. The right method of science is the direct apprehension or intuition of these intelligible ideas and their relations or structure by *Nous* or Intellect. Experience is fragmentary and unimportant; at best it affords a dim image or illustration of the ideas which intellect perceives in their purity.[126]

Descartes developed this position to support his natural philosophy by reconceiving the physical world so that it could be understood through the intellect, writing that 'We shall attribute to matter a nature in which there is nothing at all that anyone can not know as perfectly as possible'[127]—i.e. mathematically. The physical world was no longer an imperfect imitation of the ideal world of forms; it was comprehensible with the same certainty as this ideal world. Accordingly, matter was characterized as extended with all points in nature fully occupied. Particles of extension were taken to exist as corpuscles, differing in size, figure and velocity with the added geometrical property of impenetrability. Matter and motion were taken to be conserved. Descartes resolved to account for all the Aristotelian qualities in terms of matter and motion alone, following the Atomists in eliminating teleology as a valid form of explanation in the physical world.

While rejecting Aristotelian physics, Descartes followed Aristotle and the Aristotelians in presenting his whole system as founded on first principles from which

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[124] For a thorough study of Descartes' relation to his predecessors, see Stephen Gaukroger, *Descartes: An Intellectual Biography*, Oxford, Clarendon Press, 1995. See esp. p. 209.

[125] The extent to which he did so is not entirely clear. Gaukroger (p. 207) ascribes less influence to St Augustine than did Randall.

[126] Randall, *The Career of Philosophy*, p. 365.

[127] From *Traité du monde*, cited by Randall, *The Career of Philosophy*, p. 375.

everything else could be derived. However, for Descartes, there is only one science of nature; there is no qualitative diversity in nature and no need for different sciences based on different principles to deal with different domains of nature. The first principles are based on self-evident axioms. As Descartes put it:

> Intuitive knowledge is an illumination of the soul, whereby it beholds in the light of God those things which it pleases him to reveal to us by a direct impression of divine clearness on our understanding, which in this is not considered as an agent, but only as receiving the rays of divinity.[128]

To some extent Descartes disguised his starting point in his *Meditations on First Philosophy* by doubting everything possible and then offering revised Thomist proofs for the existence of God to ground knowledge of the physical world, but as Randall pointed out, 'Descartes proofs of the existence of God are really proofs of the fixed mathematical order of nature, which cannot be proved, as any proof has to assume it.'[129] At the same time Descartes accorded with the tradition of Christian thought in granting an even more fundamental place to the intellect and will than to the physical world. God and mind were capable of autonomous action transcending the principles which operated in the physical world. This enabled him to explain the present state of the world as a result of the will of God, and allowed for the existence of conscious beings not part of the mechanical order of matter in motion to comprehend such matter in motion and be the seat of secondary qualities.

Descartes' attempted to offer explanations for a vast diversity of phenomena, with surprisingly little success. Almost all his mechanical explanations turned out to be wrong. Corpuscles of matter as he had conceived them, even with the non-geometrical property of impenetrability and a conserved quantity of motion, did not to have enough properties to explain anything much. And the explanations offered, despite being caste in a form capable of mathematical treatment, were characterized by an almost complete absence of mathematical treatment. This did not worry Descartes who believed that the enormous complication of movements and interactions precluded mathematical treatment. As Randall characterized his view, 'Only God the perfect geometer could know the details of the pure space or extension out of which he created the world.'[130]

Subsequent generations of natural philosophers and scientists took up the problems raised by Descartes and succeeded in developing more powerful mathematics and, with some modifications, were able to advance Descartes' approach or some modification of it not only in physics, but also in chemistry, biology, economics and to some extent even psychology. Usually, this was at the expense of Descartes' extreme position on what could be admitted as a physical explanation. Most importantly, Newtonians admitted action at a distance (dismissed by Cartesians as occult qualities). But in other ways, the Newtonians augmented the Egyptianism of Descartes' system of thought. To

[128] *Lettres au Marquis de Newcastle*, March or April, 1648, in Randall, *The Career of Philosophy*, p. 388.
[129] Randall, *The Career of Philosophy*, p. 389.
[130] ibid., p. 377.

begin with, treating time as a dimension of space paved the way for the elimination of temporal development from physics, and further developments obviated the need to postulate God and mind to underpin the reality of the physical. What Descartes bequeathed to his successors was an ideal of knowledge of the natural world which was almost entirely Egyptian, synthesizing the Egyptianism of all previous traditions of thought and then developing this to new levels, and it was this ideal that influenced subsequent science even more than his philosophy of nature. With some modifications, often associated with advances in mathematics, this ideal was upheld and reached its apogee in the work of Einstein. While the rise of modern science was associated with the denigration of Aristotelian predicate logic because of its association with the notion of substantial forms, the development of symbolic logic made it possible for epistemologists to attempt to account for both mathematics and post-Aristotelian science through this logic. The ideal of science of Einstein and his followers, to effectively eliminate time altogether and to construe the totality of existence in mathematical terms, an ideal supported by most logical empiricists deploying advances in symbolic logic,[131] came close to replicating the uncompromising Egyptianism of Parmenides and Zeno.

THE FUTURE OF EGYPTIANISM

We have already noted the quest to deny any reality to creative becoming and to uphold the ideal of certain knowledge of an in principle perfectly knowable world has generated a number of insoluble problems. Addressing these problems or accommodating them has been one of the central concerns of mainstream philosophy and science. However, as we have already noted, there is a more fundamental problem associated with the efforts to extend this conception of knowledge and the world to ourselves, a problem which has been central to philosophical thought ever since Descartes. Descartes left the relationship between mind and body unintelligible, generating a whole range of other problems, including the problem of the relationship between free-will and determinism and between the knower and the known. The advance of scientism, the notion that the advance of science will eventually explain everything including consciousness as an effect of the structure and interaction between mathematically describable physical components is ultimately incoherent. If we as knowers are reduced to mere effects of the interactions between our components (or intense curvatures in space-time) then knowledge itself must be an illusion, and the claim to such knowledge is then self-contradictory. The incoherence of this position led to a whole range of 'idealist' philosophies taking either the individual 'mind' (Berkeley, Kant and Husserl) or the social 'mind' (Fichte and Hegel) as the ultimate reference

[131] Including Willard van Orman Quine in *Word & Object*, Cambridge, M.I.T. Press, 1960, p. 172 & 253ff., but most vigorously by Adolf Grünbaum, *Philosophical Problems of Space and Time*, 2nd ed. Dordrecht, Holland, D. Reidel Publishing Co., 1973.

point for developing a systematic philosophy and used this to reduce the significance of the claims to knowledge of the physical sciences. This has led to quite different forms of Egyptianism which I do not intend to consider here. But such philosophies are then faced with the problem of having to presuppose mind and thereby are in no position to explain its having come into being (although it could be argued that this is precisely what Hegel tried to do, developing a new kind of logic to do it).

This problem of accounting for the emergence of mind brings to light the most basic problem of the whole tradition of Egyptianist thought—the basic assumptions about what is knowledge and what can count as an explanation presuppose that there is no real becoming. Somehow, all appearance of becoming if it is to be explained in the canonical way must be shown not to be real becoming but merely the appearance of this. This is not only the core problem in accounting for the emergence of consciousness, the most difficult problem of all, but in accounting for the emergence of any kind of diversity in the universe. This problem was recognized and succinctly stated by Charles Sanders Peirce:

> Is there such a thing in nature as increase in variety? Were things simpler, was variety less in the original nebula from which the solar system is supposed to have grown than it is now when the land and the sea swarms with animals and plant forms with their intricate anatomies and still more wonderful economies? It would seem as if there were an increase in variety, would it not? And yet mechanical law, which the scientific infallibilist tells us is the only agency of nature, mechanical law can never produce diversification. That is a mathematical truth—a proposition of analytic mechanics; and anybody can see without any algebraical apparatus that mechanical law out of like antecedents can only produce like consequents. It is the very idea of law.[132]

Is Peirce's complaint relevant to contemporary science? Science has been dramatically transformed over the last century. The focus of physics has changed from the quest to discover the laws of nature to finding the underlying invariants within nature, interpreted mathematically as 'symmetries'. Such symmetries were always a concern of modern physics, but they were focused upon and their nature and the relationships between them systematically investigated only recently. Symmetries were thought by Heisenberg, one of the first scientists to promote them as being 'truly fundamental in nature', as 'the archetypes of all matter and the ground of material existence … the scientific descendents of Plato's ideal forms.'[133] The ultimate end is now seen as the search for supersymmetry. However, despite appearances, the goal is still essentially the same; the search for supersymmetry is still characterized as 'unveiling the ultimate laws of nature'.[134]

[132] Charles Sanders Peirce, 'Synechism, Fallibilism, and Evolution' [1897] in *Philosophical Writings of Peirce*, ed. Justus Buchler, New York, Dover Publications, 1955, p. 357.
[133] F. David Peat, *Synchronicity*, Toronto, Bantam Books, 1987, p. 94.
[134] See for instance Kane, *Supersymmetry: Squarks, Photinos, and the Unveiling of the Ultimate Laws of Nature*. The relationship between conservation laws and symmetry was analysed and clarified by Eugene P. Wigner in 'Symmetry and Other Physical Problems', *Symmetries and Reflections*, Cambridge, M.I.T. Press, 1970.

While mainstream science is still dominated by the quest to grasp the whole of reality through mathematics, it is now acknowledge that this is not equivalent to being able to predict the future. It has been appreciated that to explain the diversity in the world the simple deterministic models of the past will have to be abandoned. This became evident with quantum physics, and a central role was accordingly granted to quantum fluctuations in the origins of the universe. Physicists have also given a place to 'symmetry breaking' to account for the obvious lack of symmetry in the observed diversity within the world, notably the diversity of forces and elementary particles. But the notion of 'symmetry breaking' is based on representing such diversity as a manifestation of deeper symmetries.[135] At the intermediate level, one of the most active areas of science is the quest to understand organized complexity, including self-organization and emergence. This, it is believed, will allow us to understand the emergence of life.[136] Does this involve a break with the past? Nonlinear dynamical systems, the preferred way of representing such complexity mathematically, are capable of representing the world as unpredictable and generative of macroscopic patterns; but this is at the level of appearance. The dynamics are deterministic and rule out anything but the appearance of creative emergence. As Per Bak, one of the leading members of the Santa Fe Institute, pointed out with reference to the application of complexity theory to examine 'complex adaptive systems': '[W]hat is adaptability of a complex system? Since "purpose" and "rationality," and thus "learning" and "adaptability" do not really exist in deterministic dynamical systems, the question should really be: which are the features of complex systems that an outside observer might interpret as adaptability?'[137] Could a combination of quantum fluctuations, symmetry-breaking and complexity account for the variety of the world? Even at the level of physics the challenge of even beginning to carry out this program is overwhelming. Consider the complaint of a popular expositor of elementary particle physics, Christine Sutton, to just a few of the limitations of this science:

> Why … is electric charge quantized, with the proton's charge the same size (but opposite sign) as the electron's? This comes down to asking why the quarks have charges of 2/3 and 1/3, and leptons have charges 0 and 1 in units of e, the charge of an electron. Electroweak theory does not say what these charges should be; they have in effect to be inserted 'by hand'. Moreover the masses of all the quarks and leptons are quite arbitrary, as are the strengths of the interactions...[138]

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[135] See P.C.W. Davies and J. Brown, 'Introduction' in *Superstrings: A Theory of Everything?* Cambridge, C.U.P., 1988, pp. 1-69, p. 55.

[136] For a succinct statement of this project and ideas associated with it, see Gregoire Nicolas, 'Physics of far-from-equilibrium systems and self-organisation' in *The New Physics* ed. Paul Davies, Cambridge, C.U.P., 1989, pp. 316-347.

[137] Per Bak, 'Self-Organized Criticality: A Holistic View of Nature', *Complexity: Metaphors, Models, and Reality*, ed. George A. Cowan, David Pines and David Meltzer, Proceedings Volume XIX, Santa Fe Institute Studies in the Sciences of Complexity, Reading, Mass., Addison-Wesley, 1994, pp.477-96, p. 492.

[138] Christine Sutton, *The Particle Connection*, New York, Simon and Schuster, 1984, p. 163.

That there are people who believe that the vast diversity of forms, processes, constants and ratios in the universe, including the emergence of sentience and the higher levels of consciousness, can be attributed to nothing but quantum fluctuations, a succession of symmetry-breakings and patterns produced by interacting components at the edge of chaos suggests hubris rather than intelligent commitment to a research program.[139]

CONCLUSION

So what is the problem? The privileged place given to mathematics within science is an issue, but this raised the question Why does mathematics have this privileged status? Meyerson argued, first through an historical study of the development of science, and then through philosophical arguments, that Egyptianism is built into the ideals of explanation that are presupposed within science. It follows from seeking to deduce the phenomena from its antecedents of which it must be the logical consequence, along with the postulate of the rationality of nature.[140] It is this model of explanation that justifies granting so much importance to mathematical models. So is the problem deeply held assumptions about what is to count as a satisfactory explanation, as Meyerson suggested? This study, while to a considerable extent confirming Meyerson's claim, has been concerned to show where this ideal came from and how it evolved to reveal even deeper assumptions underlying it. What we have seen is that the most basic assumption is that knowledge is a kind of perception of what is omni-temporal.

The avoidance of the conclusions reached by Parmenides and Zeno from Plato onwards (with the exception of the Atomists), that there is simply one, unchanging, immutable being, involved allowing diverse other, usually quite crude forms of knowledge and explanation associated with the agency of deities, to complement the ideal form of knowledge. With Christianity an extra explanatory principle was introduced by allowing an all-powerful willing God to create and differentiate the cosmos in the first place. The extreme form of Egyptianism was also avoided in different schools of philosophy by embracing and developing specific aspects of it while expressly repudiating others – such as the assumption of a homogenous universe or the ideal of describing the whole of reality with a univocal language. All the different developments of Egyptianism were brought together in the seventeenth century by Descartes, and even then Descartes had recourse to God and a mind conceived to be of a different order from the physical world. Without this God and disallowing Cartesian dualism, we were forced back to Parmenides' position or something very close to it, and evolution as creative emergence, and our own existence as conscious beings, became

[139] For an exploration of the issues associated with this quest see Roger Penrose, Abner Shimony, Nancy Cartwright and Stephen Hawking, *The Large, the Small and the Human Mind,* ed. Malcolm Longair, Cambridge, C.U.P, 1997.

[140] This was argued historically by Émile Meyerson in *Identity and Reality,* [1912] tr. Kate Loewenberg, New York, Macmillan, 1930, and philosophically in *Explanation in the Sciences.*

unintelligible.

But the initial assumption about what is knowable, and various other developments that followed the acceptance of this basic assumption, can be, and have been questioned. Most profoundly, alternatives have been developed in history and the 'humanistic' human sciences (beginning with Vico, Herder and Hegel and developing through the tradition of hermeneutics—to which Husserl contributed despite himself). These alternatives have been further developed in philosophical anthropology, and in post-mechanistic philosophical and theoretical biology. In the realm of the physical sciences, Egyptianism was more deep-rooted, partly because of the successes deriving from this Egyptianism; but some philosophers have questioned the fundamental assumptions of Egyptianism in relation to the whole of nature. Reviving non-Egyptianist tendencies in Aristotle, Nicholas Cusanus and Bruno, natural philosophers such as Leibniz, Boscovich, Herder (developing Kant's pre-critical philosophy), Goethe and Schelling and then Bergson, Peirce, Whitehead and more recently Deleuze (and those influenced by such philosophers) have gradually worked towards new post-Egyptian ways of understanding the cosmos as essentially creative becoming, upholding a conception of the cosmos closer to that of Anaximander and Heraclitus than to later Greek philosophers. Even among these philosophers, though, it was only after the immense and unsuccessful struggle by Schelling to reconcile the notion of freedom with determinism, required to uphold Schelling's Parmenidian conviction that it is possible to have an intellectual intuition of the Absolute as the unconditioned totality and unity of the cosmos, that the radical step of jettisoning determinism was taken. This required a radical rethinking of the role of mathematics in comprehending the cosmos, of the role of non-mathematical concepts and forms of explanation, the limits of univocal concepts, the role of analogy, metaphor, metonym and narrative in language, thinking and comprehending, and of the complex relationship and interdependence between abstract thought, imagination and 'pre-predicative' experience such as 'feelings' and other forms of 'tacit knowledge'. Scientists who have attempted to follow these post-Schellingian philosophers, such as Prigogine, have sometimes not fully appreciated how radical were these philosophers, and how radical is the revision in science required to do justice to their insights.[141]

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[141] This has been argued by Kampis in *Self-Modifying Systems in Biology and Cognitive Science*, p. 461ff. For a further discussion of this issue, see *Physics and the Ultimate Significance of Time: Bohm, Prigogine and Process Philosophy*, ed. David R. Griffin, New York, S.U.N.Y. Press, p. 186. See also Gare, 'Systems Theory and Complexity', pp. 327-339.