

# **Science and Creation**

*an abridgement of the book by Stanley Jaki*

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*dedicated to my brother Richard on his fiftieth birthday*

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**S.L.Jaki, *Science and Creation, from eternal cycles to an oscillating universe*, Scottish Academic Press, Edinburgh, 1974: 367pp, 14 chapters**

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## **Foreword**

Great cultures where scientific enterprise came to a standstill, invariably failed to properly formulate physical laws. These cultures had theologies with no belief in a personal, rational, absolutely transcendent Lawgiver, or Creator. Their cosmologies reflected a pantheistic and animistic view of nature, and a cyclical view of time that caught them in a treadmill of perennial, inexorable returns.

The scientific quest found fertile soil only when faith in a personal, rational Creator had truly permeated a whole culture, beginning with the centuries of the High Middle Ages. It was that faith that was able to provide sufficient confidence in the rationality of the universe, trust in progress, and appreciation of the quantitative method, all indispensable ingredients of the scientific quest.

Jaki<sup>1</sup> asks why it is that in all recorded history, modern science with all its technical success and mastery has arisen only in Europe? He considers six other civilisations, describes the levels of proto-science they achieved, and then investigates the impact of their cosmologies on the way they thought. He concludes that, in all of these other civilisations, science was stillborn because time was thought of as infinite in extent and cyclic in effect. The gods were irrational and (probably) malevolent, and a man was a fool if he thought he had any eternal significance. Only in Europe, under the strong philosophical influence of Christianity, was time thought of as finite in extent and progressive in effect. God is both the Lawgiver loving justice, and also the Redeemer loving his children and unfolding his salvation through time. The primary requirement for a scientific attitude to take hold is for there to be underlying presumptions that God is rational and that people matter.

This essay attempts a summary of Stanley Jaki's book, mostly in Jaki's own words. This is a long, comprehensively documented, and subtle book. I hope my rendering of it makes it more accessible, but clearly something will be lost. I have simply left out most equivocations. Readers who want a more complete view will have to go back to the text, and the references therein, but I hope to give a flavour of Jaki's depth of scholarship.

I believe this book is important because the idea that took root in the last century that faith and science are somehow inimical to each other still has many adherents today, despite the overwhelming verdict of historians and philosophers of science that precisely the opposite is the truth. This book comprehensively documents an important part of the evidence for this, as a "... major attempt ... to come to grips with the problem of the stillbirths and birth of science." Although the book is not "novel" but a "synthesis" of well established ideas in modern science history, both the broad conclusions and many of the details of the documentation will "... strike as stark novelty a reader accustomed to the clichés of the historiography of science". It is time we became better informed.

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<sup>1</sup> In this abridgement of Stanley Jaki's book I uses Jaki's words extensively without further citation, in the interest of clarity. There are 14 chapters all heavily footnoted, with an index of names. There are references to several hundred different books and articles. The chapter headings in this work follow Jaki, but I have omitted some of his chapters.

## **Hindu culture: “The Treadmill of Yugas”**

Hindu culture had many brilliant insights, discoveries and inventions. One in particular has strongly influenced first Muslim and then European thought: the decimal notation of number. This was clearly known at least by the middle part of the first millennium, being referred to in the *Puranas*<sup>1</sup>, those great Hindu classics of popular mythology and ethics.

However, the idea of cosmological cycles, which involve exceedingly long times, are prominent in the *Puranas*, and many other ancient Hindu literary classics. The oldest and most sacred writings of Hinduism are the *Vedas*<sup>2</sup>, whose phrasing took well over a thousand years culminating not later than the seventh century BC with the composition of the *Upanishads*<sup>3</sup>, the concluding parts of each Veda.

The *Vedas* describe the “creation” of the world as a process subsequent to the rhythmic breathing of “that one Thing”, Vishnu, the Supreme Being, the undifferentiated eternal all which gives rise to all creatures, including the gods, including the Brahmas. The *Upanishads* expressly face the problem of coming into being out of nothing, with an unequivocally pantheistic resolution: “How, from Non-Being could Being be produced? On the contrary, my dear, in the beginning of this world was just Being, one only, without a second.” The *Puranas* drive home the message of eternal returns. Vishnu himself says:

I have known the dreadful dissolution of the universe. I have seen all perish, again and again, at the end of every cycle. At that terrible time, every single atom dissolves into the primal pure water of eternity, whence all originally arose. . . . Ah, who will count the universes that have passed away, or the creations that have risen afresh, again and again, from the formless abyss of the vast waters. Who will number the passing ages of the world, as they follow each other endlessly? And who will search through the wide infinities of space to count the universes side by side, each containing its Brahma, its Vishnu, and its Shiva? . . . Brahma follows Brahma; one sinks, the next arises; the endless series cannot be told. There is no end to the number of those Brahmas . . .

And one life of Brahma is  $31104.10^{10}$  years! Each cosmological cycle of four “yugas”, a mahayuga, which is one-thousandth part of a day of Brahma, is 4.32 million years. At the end of each day of Brahma “a dissolution of the universe occurs, when all the three worlds, earth, and the regions of space, are consumed with fire . . . When the three worlds are but one mighty ocean,

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<sup>1</sup> *The Vishnu Purana: A System of Hindu Mythology and Tradition*, trans. H.H.Wilson (John Murray, London, 1840). See Book VI chap. iii, p630 for a direct reference to “the rule of decimal notation”. However, the decimal system needed a Stevin and a Vieta in the sixteenth century to acquire the conceptual precision demanded by systematic scientific work. Vieta insisted on the value of *decimal* fractions, Stevin was an important populariser of these, also introducing useful notations. But it was Napier in 1617 who introduced the decimal point separatrix.

<sup>2</sup> *The Hymns of the Rig-Veda*, trans. R.T.H.Griffith (Varanasi-1, India: The Chwokhamba Sanskrit Series Office, 1963). These are the most important of the Veda. See also *The Hymns of the Atharva-Veda*, trans. R.T.H.Griffith (2nd ed.; Benares, India: E.J.Lazarus, 1917)

<sup>3</sup> *Thirteen Principal Upanishads*, trans. R.E.Hume, 2nd rev.ed. OUP, London, 1934

Brahma, . . . satiate with the demolition of the universe, sleeps upon his serpent-bed . . . for a night of equal duration with his day; at the close of which he creates anew. Of such days and nights is a year of Brahma composed; and a hundred such years constitutes his whole life. In unending cycles the good and evil alternate. Hence the wise are attached to neither, neither the evil nor the good. The wise are not attached to anything at all.”

This Hindu attitude to reality is symbolised today by the wheel of Asoka on the national flag, as Myrdal has pointed out in a monumental and outspoken study<sup>1</sup>. The four arms and two legs of the Lord of the Dance follow one another in a frenzied rotation, with the same inevitability as do the spokes of a spinning wheel. The infatuation with a cyclo-animistic and pantheistic concept of the world puts a strait jacket on thought and will alike. Escape from the ominous and debilitating treadmill of the wheel of reality was well-nigh impossible either emotionally or conceptually.

Indian historians of science have a twofold problem: On the one hand, there is a chauvinistic tendency which makes Indian historians of science prone to believe that their sciences in high antiquity surpassed even those of today. But there was no serious experimentation and no acceptance of the experimental method after the eighth century AD (and it has not yet been demonstrated that there was any before), and this has been blamed on the backwardness and the scant measure of honesty that are often in evidence in various Indian efforts and in everyday life: “Instead of following the path of truth, progress, and science, we succumbed to moral and mental slavery.”<sup>2</sup>

On the other hand is a tremendous uncertainty on the dating of manuscripts and artefacts. The world-consciousness of the Hindu man has an a-historical structure, which is a natural product of the ubiquitous doctrine of perennial returns that debased any phase of history to one of countless repetitions of the same cyclic pattern. This slighting of history prevented the development of a proper sensitivity for the historical dimension of individual and social existence. Ancient Hindu authors and scholars did not treat the appearance of a book written by a single author as an event determinate in time.

The indifference of Hindu scribes to producing reliable copies was deplored by al-Biruni, the famous Persian (Muslim) man of science, in unusually strong terms: “the highest results of the author’s mental development are lost by their [the scribes’] negligence, and his book becomes already in the first or second copy so full of faults that the text appears as something entirely new, which neither a scholar nor one familiar with the subject, whether Hindu or Muslim, could any longer understand.”<sup>3</sup> He accused them of having no love for truth, for being unable to overcome the many absurd notions about the physical world that infested their religious literature, pointing to their infatuation with very large numbers and very long epochs of great variety. One can clearly see here that the ancient Hindu doctrine of eternal cycles seriously inhibited the adoption

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<sup>1</sup> Gunnar Myrdal, *Asian Drama: An Inquiry into the Poverty of Nations*, The Twentieth Century Fund, New York, 1968, Vol.I, pp93-112

<sup>2</sup> N.R.Dhar, *Progress of Science and the Experimental Method*, in “Proceedings of the Symposium on the History of Sciences in India” (Calcutta, August 4-5, 1961) *Bull.Nat.Inst.Sci.India* **21** (1963) 31-35

<sup>3</sup> *Alberuni’s India: An Account of the Religion, Philosophy, Literature, Geography, Chronology, Astronomy, Customs, Laws and Astrology of India about A.D.1030* Trans. E.C.Sachau, Kegan Paul, Trenech, Trübner & Co., London, 1910

of sober scientific thinking. “They cannot raise themselves,” wrote al-Biruni, “to the methods of strictly scientific deduction.”

That Brahma itself was often depicted as reclining on a bed of convoluting snakes served as a powerful reminder that in the universe everything was prey to blind, capricious convolutions or cycles. The laws of those cycles permitted no rational explanation, as it was a patently absurd task to make a critical analysis of the breathing of Brahma, which allegedly regulated the universe. If man was a tiny part of a huge cosmic animal, there remained little if any psychological possibility that he could ever achieve a conceptual stance which would put him outside the whole for a critical look at it. Overpowered by the illusion that he was a senseless product of an all-pervading biological rhythm, man had no choice but to capitulate to the perennial rise and fall of the cosmic waters of existence, whose murky depths exuded no sense of purpose.

## **Chinese culture: The Lull of Yin & Yang**

“China has no science, because according to her own standard of value she does not need any. . . China has not discovered the scientific method, because Chinese thought started from mind, and from one’s own mind.”<sup>1</sup> The study of physics remained atrophied in ancient and mediaeval China. But even in other branches of science where the Chinese made some stunning anticipations of modern scientific insights, the promising starts failed to be followed up. A good illustration of this is the reflection of Chu Hsi in the twelfth century on the significance of fossil oyster shells found on high mountains. He argued correctly that only a great vertical displacement of the sea bed could account for such findings. He expressed hopes that careful consideration of such phenomena would lead to “far reaching conclusions”. These failed to be drawn by Chinese men of science. Their curiosity about nature never turned into a sustained resolve to exploit fully the meaning of valuable observations and inventions.

Despondency about man’s ability to decipher the exact patterns of nature made itself felt time and again before China’s long isolation from the Western World came dramatically to an end around 1600. Wang Yang-Ming, the most notable Chinese thinker of the early sixteenth century, spoke in a tone of resignation about the futility of trying to find out anything at all about nature, and about the headaches that went along with such efforts. A friend of his, he noted, tried to discover the principles embodied in the structure of bamboos. For three days running he tried, but only to become completely exhausted mentally. Then it was the turn of Wang Yang-Ming who devoted seven days to the task, but to no avail. He too became ill from being unduly burdened with thoughts. The conclusion reached by the two friends is worth quoting: “Thus we both sighed and concluded that we could not be either sages or men of virtue, lacking the great strength required for carrying on the investigation of things. . . . I knew there was really no one who could investigate the things under heaven. The task of investigating things can only be carried out in and with reference to one’s body and mind.”<sup>2</sup>

The two main systems of Chinese thought were Confucianism and Taoism, both very ancient.<sup>3</sup> Both were committed to the Yin and Yang. The Yang, which

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<sup>1</sup> Yu-Lan Fung *Why China has no Science - An Interpretation of the History and Consequences of Chinese Philosophy* Int.J.Ethics **32** (1922) 238, 260

<sup>2</sup> *The Philosophy of Wang Ying-Ming* trans. F.G.Henke (Open Court, Chicago, 1916)

<sup>3</sup> For Confucius (551 - 479 B.C.) and his followers, man’s social existence “custom” served as the principal source of information about nature as well. Such an approach to nature could hardly inspire a search for quantitatively exact laws. “Custom is that whereby Heaven and Earth unite, whereby the sun and moon are brilliant . . . Is not custom the greatest of all principles?” (Hsun Tzu, a leading Confucian of the 3rd century B.C.) Tung Chung-Shu succeeded in making Confucianism the official state doctrine in 136 B.C. Just as the Confucians tried to understand society by overemphasising the intuitive aspects of reasoning, the Taoists considered intuition the chief avenue to the understanding of nature. But the two were very different: The early Taoists lived as hermits whose withdrawal from society stood for the rejection of the Confucian method of finding the pattern of cosmic order through reflection on social life. The two schools were already competing by at least 250 B.C. The principal proponent of Taoism was Lao Tzu.

originally meant bright sunlight, was subsequently identified with the principle of maleness and also with the qualities of hardness and weightlessness. The Yin, which originally referred to dark clouds, became the word for the feminine, soft, and heavy. Later connotations of the Yang extended to everything hot, dry, and pure, whereas the Yin became tied to everything cold, turbid, and moist. Again, fire was spoken of as Yang, and so was everything ready to extend or move upwards. Yin, in turn, was said to be the essence of water and of downward and contracting movements. Yang produced everything round and moving, while Yin represented squareness and stillness.

In every Chinese school of thought there is present “the idea that the principle of a good universal agreement is identical with the principle of universal intelligibility”.<sup>1</sup> That is to say, what we would call a natural law, which has good (ideally “universal”) agreement with reality, is substituted in Chinese thought by a plausible explanation, for instance in terms of Yin and Yang, which is easily grasped (“intelligible”) and apparently goes to the root of the matter (“universal”).

Unfortunately, such intelligibility is anything but universal. It implies a marked insensitivity to clear-cut propositions and to strict, quantitative correlations concerning nature. Intelligibility of this type corresponds to a sad weakness of mind. Ultimately, logic and search for truth make sense only if they exclude compromise with illusions, vagaries and empty words. The confident expectation of obtaining exact results seems indeed to be an indispensable condition of a sustained investigation of the workings of the external world.

It is this systematic research that failed to get its wings in ancient and mediaeval China. Such research means far more than the compilation of encyclopaedias in the traditional Chinese style. These the Chinese possessed in oppressively large numbers about every topic under the sun. But most of these encyclopaedic statements about nature have not much tangible to offer. They mostly paraphrase vague and unverifiable concepts bordering often on the mystical. “The abstract, general form which these concepts have taken on allows a twofold process of analysis and synthesis that has the semblance of being logical. This always futile though smug process is carried on endlessly. Those who are most familiar with the Chinese mentality . . . almost despair of ever seeing it [the mentality] emancipate itself and stop going round in circles.”<sup>2</sup>

The Chinese mind was trapped in a conceptual merry-go-round. The great French sinologist, M. Granet, has pointed out: “the conviction that the All and everything composing it, have a cyclic nature” drastically stymied the Chinese awareness of causal connections between events. A telling evidence of this is the fact that the Chinese saw nothing inordinate in attributing the political failure of a certain prince to the sacrificing of humans at his *own* burial.<sup>3</sup> How can the effect precede the cause? But as both political impotence and cruelty evidenced the absence of the same virtue, in the Chinese mind one could replace the other as explanation regardless of their sequence. What the Chinese preferred to register were not, in Granet’s words, “causes and effects, but manifestations,

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<sup>1</sup> M. Granet *La pensée chinoise* La Renaissance du Livre, Paris, 1934.

<sup>2</sup> L. Levy-Bruhl *Les fonctions mentales dans les sociétés inférieures* Félix Alcan, Paris, 1910. Levy-Bruhl was a keen interpreter of the frame of mind of ancient civilisations.

<sup>3</sup> J. Needham *op cit.* But for him it was not a mockery of logic, but a “timeless pattern” of thought. Needham remained blind to the psychological impact which the organismo-cyclic world view is bound to exercise on the enquiring mind.



whose order mattered little. . . . Equally expressive, they appeared interchangeable. . . . Instead of considering the course of things as a succession of phenomena, susceptible to measurement, and to subsequent coordination, the Chinese see in the sensible [apparent to the senses] reality only a mass of concrete signs. The task of making a repertory of them imposes itself not on the physicist but on the chronicler: History holds the place of Physics.”<sup>1</sup>

Francis Bacon believed that the factors that did more than anything else to usher in the age of science were printing, gunpowder and magnets.<sup>2</sup> But magnets were known to the Chinese from the Han period (220B.C. - 220A.D), and printing and gunpowder from the Thang (618-906): they nevertheless remained hopelessly removed from the stage of sustained, systematic, scientific research. They had rockets for centuries, but failed to investigate their trajectories, or to probe into the regularities of free fall. Unlike in the West, bookprinting did not lead in China to a major intellectual ferment. Although magnets were installed in Chinese ships, which formed the best navy in the world during the fourteenth and fifteenth centuries, their captains never had the urge to circumnavigate the globe.<sup>3</sup>

This blindness is well illustrated in the account of Father Mateo Ricci, who settled on the Chinese mainland in 1583. By 1595, after his initial admiration of the Chinese success in predicting two eclipses of the moon without apparently any knowledge of Ptolomeic astronomy, he writes: “In truth, if China was the entire world, I could undoubtedly call myself the principal mathematician and philosopher of nature, because it is ridiculously and astonishingly little what they know; they are all preoccupied with moral philosophy, and with elegance of discourse, or to say more properly, of style.”<sup>4</sup> Two years later he writes:

About the learned among the Chinese, let me say this: [they] have no [physical] science at all; one may say that only mathematics is cultivated, and the little they know of it is without foundation; they stole it from the Saracens.<sup>5</sup> Only the King’s mathematicians teach it to their sons. They just manage to predict eclipses, and even in that they make many mistakes. All are addicted to the art of divinations, which is most unreliable and also completely false. Physics and metaphysics, including logic, is unknown among them . . . Their literature consists wholly in beautiful and stylish compositions all of which correspond to our humanities and rhetoric.

The numerous references in Ricci’s letters to the addiction of the Chinese to astrology (“divinations”) indicate his awareness of the deepest reason for the backwardness of Chinese science. Ricci understood the all-consuming preoccupation of the Chinese to have their calendar meticulously coordinated with the revolution of celestial bodies. But they did not know how to calculate the yearly ephemerides either accurately or economically. Wanting to expose the Chinese

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<sup>1</sup> M.Granet *ibid.*

<sup>2</sup> F.Bacon *The New Organon and Related Writings* (1620) (F.H.Anderson (ed), Liberal Arts Press, New York, 1960)

<sup>3</sup> see J.Needham *et al: Science and Civilisation in China* Cambridge University Press, 1954 - . A monumental study unsurpassed for its wealth of material. Needham is the leading Western historian of Chinese science. However, the interpretative sections are heavily biased by Needham’s avowed Marxism.

<sup>4</sup> *Opere storiche del P.Matteo Ricci S.J.* P.Tacchi Venturi (ed), F.Giorgetti, Macerata, 1911-13. See also H.Bernard *Matteo Ricci’s Scientific Contribution to China* transl.E.C.Werner, H.Vetch, Peking, 1935

<sup>5</sup> Muslim astronomers had been in China for some centuries. This is rather unfair to Chinese mathematics.

to the paragon of clear, stringent, demonstrative procedure in science with which they were wholly unfamiliar, Ricci supervised the translation of Euclid into Chinese (printed in 1608). He said that it “was much more admired than understood. It, however, served well the purpose to humble the Chinese pride; it forced their best scholars to admit that they had seen a book which, though printed in their own language, they could not understand even after studying it with great attention; such indeed was a fact that may not have happened to them before.”

While the harmony displayed in the heavens is the supreme embodiment of the “normalcy” of the universe, this is not, for the Chinese, the outcome of a superior ordinance. The Tao, or the all-embracing order, produces everything, feeds everything, but does not lord over anything. Its ordinances are wordless edicts. The sustained emphasis on the “silence” of the universe, on its being “voiceless”, is more than entertaining poetry. According to the *Chuang Tzu* there was no absolute origin - no Creation. The Tao itself is not an ultimate entity because it is the supreme non-being as well. “Since it is non-being, how can it be prior? Thus, what can it be that is prior to things? And yet things are continually being produced. This shows that things are spontaneously what they are. There is nothing that causes them to be such.” In a universe without the voice of God there remains no persistent and compelling reason for man to search within nature for distinct voices of law and truth.

Even Needham had to admit that it is the a-theological orientation of traditional Chinese thought that should ultimately be singled out as the decisive factor which blocked the emergence of a confident attitude towards systematic scientific investigations in contrast to Western Europe, where all the early cultivators of science drew courage for their pioneering efforts from their belief in a personal rational Creator. “There is no robber greater than the Yin and Yang, from whom nothing can escape at all between heaven and earth. But it is not the Yin and Yang that play the robber; - it is the mind that causes them to do so.”<sup>1</sup> The victim of the robbery was the most ancient of all living cultures, the Chinese. Lulled by the deceitful hum of the Yin and Yang, it remained deprived of a special maker of modern culture, exact physical science.

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<sup>1</sup> *Chuang Tzu* the second most important book of Taoism, put together around 300B.C. (in *The Texts of Taoism* trans. J.Legge, Julian Press, New York (1959) Book XXIII, par.8, p524)

## **Central American Cultures: The Wheels of Defeat**

Why did Cortés and his tiny band of mercenaries triumph over the expanding and powerful Aztec empire at Tenochtitlán, the ancient Mexico City<sup>1</sup>, in 1519? And hardened though they were, the Spaniards could not help being appalled on learning about the gruesome details of human sacrifices as practised by the Aztecs.

Mexican cosmological thought does not make a radical distinction between space and time; it refuses, in particular, to conceive of space as a neutral and homogeneous medium, independent of the process of duration.<sup>2</sup> It fluctuates across heterogeneous and individual categories, whose particular characteristics succeed one another in a fixed rhythm and a cyclic pattern. For it there are no space and times, but only space-times, in which are submerged the phenomena of nature and human actions, all stamped with the qualities particular to each location and each moment. [In the absence of a generalised notion of space and time, the basic conceptual foundation also was missing for a consideration of a succession of events as a rationally explorable chain in which each link is causally acted and is acted upon. The world picture of Aztec cosmology resembles . . . a screen on which a tireless mechanism flashes various colours in an unalterable succession. But the process in question] is not conceived as the result of a 'becoming' more or less rooted in duration, but rather as a sequence of total and sudden changes: today it is the East that dominates, tomorrow it will be the turn of the North; today we still live under propitious omens, but it will be without any transition that we shall come under the ominous cloud of evil days. The law of the universe is an alternation of distinct, neatly separated qualities, which dominate, disappear and reappear without end.<sup>3</sup>

Man in that outlook was of necessity reduced to the status of flotsam and jetsam, and his interests appeared to be best served if he plunged headlong into the cyclic, rhythmic, and basically violent transformations of nature that surrounded him. This is why Aztec life took the form of carefully observed, rhythmically returning, gruesome rituals. The supreme aim of Aztec life was a participation in the rhythm of that violent action whereby their own gods lived. They in turn were representatives of the cataclysmic, cyclic forces of nature. The savagery of many of these rituals expressed their desire to experience in full

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<sup>1</sup> Described in all its grandeur and magnificence by Bernal Díaz del Castillo, one of Cortés' comrades in arms, who ranked the Great Temple patio above all the splendour of Renaissance Rome and Venice: *Historia verdadera de la conquista de nueva España* Ediciones Mexicanas S.A., Mexico, 1950, p164. But for all its gleaming pyramids, temples, plazas, palaces, causeways, bridges, walls and material abundance, it was an elaborate labyrinth with no promising horizons or ideological encouragement for the cultural aspirations of the human mind.

<sup>2</sup> The fact that Einstein's General Theory of Relativity, with its experimental corroboration, supports this attitude does not detract from the force of the problem: how many people today understand the sophisticated tensor formulation of the General Theory? Or even the simple algebra of the Special Theory? As a first approximation to the ways things are it is not helpful, as the rest of this section will make clear.

<sup>3</sup> J.Soustelle *La pensée cosmologique des Anciens Mexicains: Représentation du monde et de l'espace* (Hermann, Paris, 1940) p85

the cruelty of nature. Such a desire was prompted by the paradoxical hope to find escape from cruelty by becoming submerging into it.

Beneath the readiness of the Aztecs to cultivate cruelty lay an image of nature that could inspire no confidence either emotional or intellectual. This is well illustrated by the famous statue of Coatlicue<sup>1</sup>, known as “the Lady of the Serpent Skirt”, which represented in the Aztec belief the mother of gods, or rather nature itself. The head of the figure consists of two serpents, its necklace is made of human hands and hearts, its hands and feet end in claws, its skirt is a broad array of writhing snakes. Life and history became, therefore, trapped for the Aztecs in a vicious circle. The securing of life needs more human sacrifices, these in turn demanded the renewal of warfare. In such a framework proto-scientific achievements, such as papermaking<sup>2</sup>, wooden and clay stamps for the impressing of glyphs, and the storing of records in the royal archives<sup>3</sup> could not produce an intellectually promising perspective.

The background of frightening cosmic cycles with its debilitating fatalism undermined not only the chances of the Aztecs for meaningful cultural advances, but also destroyed their political future. Permeated as they were with ideas deriving from the inexorability of cosmic cycles, they readily came under the sway of ominous predictions about the imminent end of the actual world period.<sup>4</sup> The year 1519 was the first year of the 52 year cycle in the Aztec calendar<sup>5</sup>, and was expected to be the year of the legendary Quetzalcóatl’s return<sup>6</sup>, an expectation that was enhanced by the first appearance in 1502 of bearded white beings with huge ships in the Gulf of Mexico and related omens; and there was a growing sense of hopelessness among them as 1519 approached. Already demoralised, Moctezuma’s powerful army proved no match, despite its great numerical superiority, for a small band of adventurers, armed as they were not only with some strange weapons but also with an outlook on nature, life and history which could not have been more different from the Aztecs’.

Likewise, the Inca Empire with all its political organisation, excellent roads, bridges and postal service, and extravagant amounts of gold and silver, when faced with Pizarro and a handful of his fellow conquistadors, remembered the old legend that told of Viracocha’s descent on earth, about his walking among people teaching them how to live, and about his disappearing on the sea off the coast of Ecuador. Could it be that the Viracochas, the people whom the Incas

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<sup>1</sup> For a description and illustration see the very readable G.C.Vaillant *Aztecs of Mexico: Origin, Rise and Fall of the Aztec Nation* (Doubleday, Garden City NY, 1953) p163

<sup>2</sup> V.W.von Hagen *The Aztec and Maya Papermakers* (Augustin, New York, 1943)

<sup>3</sup> V.W.von Hagen *The Aztec, Man and Tribe* (rev.ed.: New American Library, New York, 1961) p192

<sup>4</sup> See Laurette Séjourné *Burning Water: Thought and Religion in Ancient Mexico* (Vanguard Press, New York, 1961) p39. She gives valuable interpretation of Aztec cosmological myths.

<sup>5</sup> Derived from the Maya calendar (see below). The Aztecs had a sacred “year” of 260 days and a 360 day calendar, to which 5 “useless” days were added which were used for elaborate ceremonial. The simultaneous start, every 104 years of the 260 day sacred year, the 365 day solar year and of the 52 year period was of enormous significance to them. See G.C.Vaillant *op cit*

<sup>6</sup> Quetzalcóatl was the ancient Toltec ruler of Tula, a temple city about 60 miles north of Tenochtitlán. He became a sort of cultural hero and mythical godlike figure after his death. He opposed human sacrifices, making him a sworn enemy of the Aztecs. According to a highly respected tradition, when he was defeated in a civil war he disappeared over the sea vowing to return in a year corresponding to the year of his birth, to re-establish his rule.

once routed and whose god they expropriated, were on their way back to avenge themselves?

The Maya did not equal the Inca in the art of roadbuilding, nor are their pyramids as massive as those of the Aztecs. But they represent in pre-Columbian America not only the longest continuous historical phenomenon<sup>1</sup> but also a political and social organisation markedly different from the strongly centralised authoritarian rule that characterised the Aztec and Inca Empires. The loosely knit system of Maya cities spreading across the Yucatan peninsula easily evokes the association of city states in classical Greece. The climate left the Maya with ample leisure time for the satisfaction of their cultural aspirations (as it also did for the Greeks) since their main staple, maize, reached the harvesting stage in only about two months.

The Maya had the two highest intellectual achievements in pre-Columbian America: writing<sup>2</sup> and number. They achieved the enormous feat of devising a positional type of counting which, in an indirect sense, included even the use of zero. This was contemporaneous with the development of positional arithmetic in India in the first centuries A.D. However, this was not accompanied by the development of arithmetical operations beyond those of addition and subtraction. There are no traces of multiplication, division or of even the simplest fractions in the computational tables of the Codex Dresdensis, one of the three surviving Maya documents<sup>3</sup>.

The same baffling disparity characterises the accomplishments of the Maya in the field of astronomy. For example, Mayan data on Venus make almost inevitable the conclusion that the Maya achieved a remarkably exact determination of its synodic revolution: 583.920 days compared with the modern value of 583.935 days. They also recorded the phases of the moon with great care. Experts on Maya history and culture who were not themselves astronomers readily hypothesised about a Maya Hipparchus (the great Greek astronomer who determined the precession of the equinoxes).<sup>4</sup> Most general accounts of Maya culture abound in superlatives about the astronomical attainments of the Maya<sup>5</sup>, but a more complex picture emerges from special studies<sup>6</sup>. But the principal objection against reading scientific astronomy into Maya timekeeping comes from the single-minded devotion of the Maya to their sacred calendar, the tzolkin, consisting of 260 days “based on an arbitrary and orderly succession of days and months

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<sup>1</sup> The pre-Maya era undoubtedly goes back to the third millennium B.C. The Maya probably had recorded dates as early as 353 B.C. The Old Empire lasted from A.D.317 - 987, with its highest state of flourishing in the so-called Great Period starting 731.

<sup>2</sup> See J.E.S.Thompson *Maya Hieroglyphic Writing: An Introduction* (new ed.: Norman: Univ.Oklahoma Press, 1960) As the chief objective of Maya writing was the fixing of events in various time series, or cycles, this book is invaluable for anyone trying to see the extent to which the Maya world view was caught up in speculations about small and large cycles of time.

<sup>3</sup> J.E.S.Thompson, “Maya Arithmetic” in *Contributions to American Anthropology and History* **8(36)** (Carnegie Inst.Washington, Washington D.C., 1942) 37-62. The utter primitiveness of Maya arithmetic can be seen in all extensive accounts such as: C.P.Bowditch *The Numeration, Calendar Systems and Astronomical Knowledge of the Mayas* (Cambridge University Press, 1910)

<sup>4</sup> See for example S.G.Morley *The Ancient Maya* (Stanford Univ.Press, 1946)

<sup>5</sup> See for instance H.J.Spinden “Ancient Mayan Astronomy” *Scientific American* **138** (Jan.1928) 9-12

<sup>6</sup> J.E.Teeple “Maya Astronomy” *Contributions to American Archeology* **1(2)** (Carnegie Inst.Washington, Washington D.C., 1931) 29-116.

in regular order, going on forever without regard to any natural phenomenon”<sup>1</sup>. Maya astronomers were rather astrologers, with no primary interest in systematic observations and in quantitative (that is, scientific) correlation of the periods of the moon, sun and planets. Their aim was “to find a figure which contained an even number of multiples of the 260-day period, in order that after a suitable interval the same phenomenon would be repeated on the same day of the tzolkin”.<sup>2</sup>

The failure of the Maya to break out from the blinding confines of cycles and make a convincing step towards a truly scientific interpretation of nature brings into focus the extent to which engrossment with cyclic concepts undermines the chance of man’s incipient gropings toward science. These cyclic concepts held complete sway over the Maya outlook on time and nature, as well as human history. Their wheel-like calendars, known as katun-wheels, are a telling illustration of this. Their cosmology tells the same story. According to Maya belief, the world had already been destroyed three times, and the present world would be terminated by a flood coming out of the mouth of a gigantic serpent girdling the whole world. This fusion of cyclic and organismic concepts in Maya thought is worth noting. Among its various manifestations is the invariable representation of the moon by the Maya as a woman. In the same organismic vein they attributed the eclipses, a major cyclic phenomenon of the heavens, to the periodically aroused appetites of ants to eat away part of some celestial bodies. The succession of four world catastrophes is in Maya thought like the four principal spikes of a wheel and their unceasing rotation reflects the life-rhythm of that huge animal, the world. Its symbol was, in a crass animistic fashion, either a serpent, a ubiquitous figure in Maya art, or an alligator on which, according to Maya belief, the world was resting.

The Maya expected catastrophes as part of the defeatist psychological climate created by the combined impact of cyclic and organismic ideas. Time and again their best built cities were abandoned in a rush, in a way that wars, famine, epidemics or other natural disasters cannot entirely explain. In March 1698, Ursua and his 108 men faced some 7000 Itza<sup>3</sup> soldiers on the shores of the inaccessible Lake Peten Itza. The Spanish only fired their guns for the Itza to take flight, leaving behind their families, homes and everything they had built for centuries. They were doomed to lose. It was the last and tragically mocking obedience of the Maya civilisation to the tyranny of cycles.

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<sup>1</sup> Teeple *ibid.* p36

<sup>2</sup> M.W.Makemson “The Enigma of Maya Astronomy” *Dyn* **1(4-5)** (1944) 52

<sup>3</sup> The Itza were the last independent Maya tribe. The Spanish controlled much of the Yucatan by 1546.

# ***Ancient Egyptian Culture: The Shadow of Pyramids***

The Egyptians have a reputation for scientific genius. Did they not build the pyramids, those great Wonders of the World? Like the early students of Maya science, Egyptologists of the nineteenth century gave exaggerated accounts of the scientific achievements of ancient Egypt. More recently these have been evaluated more realistically. The record shows, in close resemblance to the achievements of the Maya, several impressive but disconnected insights against a vast background of practical skill but grossly erroneous beliefs.

To secure the proper distribution of grain and other basic commodities of life, ancient Egypt had to rely on a laborious system of stock-taking and bookkeeping. The practical task facing them was gigantic in view of their rudimentary methods of calculating, and this “burden of bookkeeping kept Egyptian arithmetic in a bondage from which it had never freed itself”<sup>1</sup>. Plato remarked that they were a “nation of shopkeepers”<sup>2</sup>. Numbers in Egyptian records almost invariably refer to quantities of given items, such as 5 stones, 8 loaves and the like. They did not have the addition or subtraction signs. The use of zero was only implicit and the idea of place was entirely absent, although they had a decimal system of counting with special glyphs for all powers of 10 up to 1 million. This preference given to concrete terms over abstract ones is a main characteristic even of the Rhind Papyrus, the most advanced form of all extant Egyptian mathematical documents<sup>3</sup>. This promises to be “The entrance into knowledge of all existing things and all obscure secrets”, but leaves the modern reader with a keen sense of disappointment. To perform, for example, the most elementary types of division the Egyptian scribe had to fall back on the equivalent of the lengthy method of proportional division, or preferably on practical tables dealing with concrete situations. It seems that they felt that once the practical problem had been solved there was no need for theoretical formulation and refinement. A good example

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<sup>1</sup> J.Vercoutter in his chapter on mathematics & astronomy in R.Taton (ed.), *History of Science*, Vol. I, *Ancient and Medieval Science*, transl. A.J.Pomerans (New York: Basic Books, 1957)

<sup>2</sup> See *Laws* 747c. Of course, by Plato’s time money was widely used in Egypt, and he refers both to the Egyptians’ love of money (*Republic* 436c) and to their expertise in geometry (*Laws* 819c-d).

<sup>3</sup> *The Rhind Mathematical Papyrus*, Introduction, transcription, translation and commentary: T.Eric Peet (Liverpool: University of Liverpool Press, 1923). Peet says: “The outstanding feature of Egyptian mathematics is its intensely practical character”, a point he repeats later in “Mathematics in Ancient Egypt” *Bulletin of the John Rylands Library*, **15** (1931) 409-441. Carl Boyer in *A History of Mathematics* (John Wiley, 1968) says: “This papyrus is about 1 foot high by 18 feet long, was bought by one Henry Rhind in 1858 and is now in the British Museum. It is also known as the Ahmes papyrus after the scribe who copied it in about 1650BC. Ahmes tells us that the material comes from a Middle Kingdom prototype of between 2000BC and 1800BC, and it is possible that some of this knowledge may have been handed down from Imhotep, the almost legendary architect and physician to the Pharaoh Zoser, who supervised the building of his pyramid about 3000BC. In any case, Egyptian mathematics seems to have stagnated for some 2000 years after a rather auspicious beginning.”

is their use of fractions. With the exception of  $2/3$ , all the fractions recorded in the various papyri and stone monuments are unit fractions ( $1/2$ ,  $1/4$  etc). Odd as it may be, ancient Egyptians never used the fraction  $1/3$  which they obtained by explicitly halving  $2/3$ . Quantities like  $3/4$ ,  $4/5$ ,  $5/7$  and so forth had no appeal to them, although these would have greatly facilitated their work.

Herodotus is often cited as claiming that the Greeks learned their geometry from the Egyptians<sup>1</sup>, but Egyptian geometry - land surveying – always stayed on the level of procedures by trial and error. For example, the Egyptian way of calculating the area of a circle by squaring eight ninths of the diameter is worthy of admiration as it implies a value 3.1605 for  $\pi$ , a rather good approximation<sup>2</sup>, better than 1%. Yet the accomplishment cannot be considered science, but only a piece of protoscience in which statements and procedures are not generalised and supported by proofs.

This lack of generalisation is palpably evident in the wholly unsystematic character of Egyptian astronomy, which has an “otherworldly” or “non-scientific”<sup>3</sup> character, standing not so much in the service of the living as of the dead. Their astronomical texts have one overriding concern: the fixing of the hour and season of religious festivals. There were three calendars, two lunar and one civil, the latter of 365 days<sup>4</sup>. But the crowning ceremony of the Pharaohs contained an oath barring any attempt at calendar reform<sup>5</sup>: time was conceived of as overwhelmingly ritualistic and cyclic, a symbol of the ultimate changelessness of the cosmos.

The equivalence of 309 lunations to 25 astronomical years was therefore of great importance to them<sup>6</sup>. For the ancient Egyptian man eternity, and his chief

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<sup>1</sup> *Herodotus* with an English translation by A.D.Godley (London: Heinemann, 1926) vol.I, p.399. In the context (Book II, sec. 109) Herodotus speaks of the complaints of those Egyptians whose taxes remained unchanged though the size of their plots diminished through the changes of the Nile’s riverbed following each inundation. Because of their complaints: “the king would send men to look into it and measure the space by which the land was diminished, so that thereafter it should pay the appointed tax in proportion to the loss. From this, to my thinking, the Greeks learned the art of measuring land [geometry]; the sun-clock and the sundial, and the twelve divisions of the day came to Hellas not from Egypt but from Babylonia.”

<sup>2</sup>  $\pi = 3.14159265$  (9 sig.figs). This is not so good as  $355/113=3.14159292$  though, a value discovered by Tsu Ch’ung-chih (430-501AD) who also knew that  $\pi$  lay between 3.1415926 and 3.1415927, although we no longer have his reasoning (see C.B.Boyer *A History of Mathematics*, 2<sup>nd</sup> ed. Revised by U.C.Merzbach, John Wiley, 1968, 1989, 1991). Carl Boyer notes that: “We should bear in mind that accuracy in the value of  $\pi$  is more a matter of computational stamina than theoretical insight.” However, this accuracy is not equalled anywhere until the fifteenth century.

<sup>3</sup> See O.Neugebauer and R.A.Parker, *Egyptian Astronomical Texts*, Vol.I. *The Decans* (Providence, R.I.:Brown University Press, 1960), and Vol.II *The Rameside Star Clocks* (1964)

<sup>4</sup> Which therefore gained a full month in 120 years. The astronomical calendars involved the heliacal rising of Sirius (Sopedet in Egyptian, Sothis in Greek) (i.e. the time when Sirius became visible above the horizon shortly before dawn: this closely coincided with the yearly rising of the Nile). There is still debate on whether the Egyptians were aware of the Sothic cycle of 1460 years, as the Greeks and Romans were later, and even whether their calendars were systematically based on the Sothic cycle, which would presuppose regular observations of Sirius over several centuries for which there is no evidence.

<sup>5</sup> R.A.Parker, *The Calendars of Ancient Egypt* (The Oriental Institute of the University of Chicago, Studies in Oriental Civilisation, No 26: Chicago, University of Chicago Press, 1950)

<sup>6</sup> This is illustrated in the Carlsberg Papyrus No.5, where we find 16 ordinary years of 12 (lunar) months, and 9 long years of 13 months.



duty in life, consisted in assimilating himself to major cyclic motions in nature through symbolic means. Such motions could be the daily round of the sun or the motions of circumpolar stars. Souls that had supposedly reached the realm of those stars were called *ahku* or transfigured spirits. The wish to be absorbed into the great rhythm of the universe is the great theme that united the countless details of the journey of the souls of the dead as fancied by ancient Egyptian religion.

The Pyramid Texts mostly date from the latter half of the Old Kingdom. Their cosmogony is faithfully replicated in Middle Kingdom accounts<sup>1</sup>. Here is an example of a monologue of Atum, the creator of the world:

I am he who came into being as Khepri [the Becoming One]. When I came into being the beings came into being, all the beings came into being after I became. I, being in weariness, was bound to them [the things to be created, heaven, earth and the animals] in the Watery Abyss. I planned in my own heart, and many forms of beings came into being as forms of children, as forms of their children. I conceived by my hand, I united myself with my hand, I poured out of my own mouth, I ejected Shu, I spat out Tefnut. It was my father the Watery Abyss who brought them up, and my eye followed them while they became far from me. After having become one god, there were now three gods in me.<sup>2</sup>

The ultimate entity in Egyptian cosmogony is the Watery Abyss, the primeval ocean. The Nile itself was believed to be the physical manifestation of this. The Nile's yearly inundations served as supreme evidence of the inevitable restoration to life through mystical immersion into the Watery Abyss. Ritual texts abound in such references. Immersion into this primeval water was the condition both for the mighty sun as well as for the puny individual to regain the strength of life. The primeval water was the destination and the unfailing source of life's rebirth in the long and elaborate journey which the dead had to undertake. An embalming prayer has:

Thou drinkest from them, thou art satiated from them. Thy body fills itself with fresh water, thy coffin is filled with the flood, thy throat overflows.  
Thou art the Watery Abyss, the oldest, the Father of the Gods.

The prayer fittingly enough starts with a reference to Osiris, the classic Egyptian symbol of the cyclic death and renewal of nature and of everything, divine and human, generated by nature. While the fancy of ancient Egyptians was not exercised about world catastrophes and rejuvenations, the cyclic throbbing of cosmic life was implied in their pantheistic conception of nature. Their gods were rooted in the strength of the primeval mound which in turn was imagined to be the result of the ever active, innate life of the primeval chaos. This life manifested itself in an upward stirring, which was the symbol of life, light, land, and consciousness. The personalisation of the vague, ultimate being is the deity, Atum, or the 'Complete One'. He is at the same time also the source of light, or sun-god, and the origin of the world mound rising out of the primitive waters, and the producer of all forms of life appearing on the slopes of what later became formalized as the world pyramid.

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<sup>1</sup> Old Kingdom: Dynasties III-VI, c. 2660BC – 2180BC; Middle Kingdom: Dynasties XI-XIII, c. 2080BC – 1640BC

<sup>2</sup> From the English translation of the cosmogonical section of the "Book of Overthrowing Apopsis", in Alexandre Piankoff, *The Shrines of Tut-Ankh-Amon* (New York, Pantheon Books, 1955)

The animistic world view of the Egyptians is well indicated in the way creation proceeds, first by the masturbation and expectoration of Atum and then by various couplings of the resulting gods. But note that the idea of Atum is pantheist, he is not prior but consequent to matter: "I came into being out of the primeval matter, taking manifold forms from the beginning"<sup>1</sup>.

Egyptian medical art is a classic case of the bondage in which a fledgling branch of knowledge could be held by a heavily animistic world view. The physicians of ancient Egypt have to their credit the first rudiments of a medical terminology, the first use of bandages, the pioneering of anatomical investigations, and the first listings of some truly useful, naturally available drugs. These feats exercised a crucial influence, both on Greco-Roman and Arabic medicine. However, ubiquitous in their medical papyri are incantations and magic formulae: only in the case of wounds inflicted externally were rational procedures applied as well as magical rites<sup>2</sup>. There is something deeply tragic in a promisingly eloquent passage: "The beginning of the science of the physician; to know the heart's movement and to know the heart."<sup>3</sup> Such an auspicious beginning, but underlying it is the belief that the cause of sickness was an animistic force or spirit.

The promising initiatives and subsequent stagnation that characterized Egyptian medicine form also the pattern of the history of technical skills in the Nile valley. Mechanical techniques saw "little radical progress from the Third Dynasty until nearly Ptolomaic times"<sup>4</sup>. This is despite the enormous skill and ingenuity of Egyptian craftsmen in getting the best out of their tools. The simple but effective way of producing paper from the papyrus plant was an enormous advance on animal skin "paper". They were the first to produce plywood with as many as six layers of different woods. They made effective all-wood joints in ships' hulls. The decorative crafts, inlaying, veneering and overlaying, are displayed at an astonishingly high level in the tombs of the Pharaohs of the XVIII Dynasty (16<sup>th</sup> century BC). And then there were the Pyramids. For all the primitiveness of his instruments and methods the Egyptian stone cutter and mason worked marvels in fitting huge blocks of stone together. The average separation of the casing blocks at the foot of the Great Pyramid is only ½mm. Unfortunately, no longer can be seen those marble plates of extraordinary smoothness that turned

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<sup>1</sup> Found in a late 4<sup>th</sup> century papyrus text (the beginning of the Hellenistic period), translated in Sir E.A.Wallis Budge, *From Fetish to God in Ancient Egypt* (London: Oxford University Press, 1934) pp432-436. The world view of the late periods replicates faithfully that of the early periods. Only picturesque, grotesque, and often morbid details were added through the long centuries of Egyptian history to the classic original narratives of the world's "creation". The basic ideas were carefully retained.

<sup>2</sup> So the most enlightening section of "the first scientific medical treatise" (as claimed by James H.Breasted, *The Edwin Smith Surgical Papyrus*, Chicago: University of Chicago Press, 1930) are restricted to the treatment of fractures and wounds. The oldest of these papyri date from the early part of the second millenium, and are themselves copies of extracts from much earlier texts.

<sup>3</sup> From the longest and most famous medical text, the Ebers Papyrus. Quoted by Warren R.Dawson, "Medicine" in *The Legacy of Egypt*, edited by S.R.K.Glanville, Oxford: Clarendon Press, 1942). The immediately following section refers not only to the physician but also to the exorcist, and in a typical animistic vein describes the pulsebeat as the heart's speech to the vessels.

<sup>4</sup> That is, from about 2650BC to 330BC. R.Englebach, in a perceptive study of "Mechanical and Technical Processes: Materials", in *The Legacy of Egypt*, edited by S.R.K.Glanville, Oxford: Clarendon Press, 1942.

the sides of the pyramids into almost perfect mirrors, a spectacle of which ancient authors spoke with awe.

But the pyramids were more than superbly constructed facilities to secure the king's safe ascent to the divine realm. Nor were they ultimately only a reflection of the social and political system of ancient Egyptian life. In their deepest meaning the pyramids were symbols of a conception about the world that nipped in the bud all scientific endeavour. Such was the shadow they cast on Egyptian religiosity and world view. They are monumental reminders of the primeval mound, which in turn is intimately tied to an animistic world view inimical to a concept of time that affirms the unique meaning of each moment.

Much of the intellectual history of the Egyptians had been a long stagnation in the morasses of an animistic and cyclic world view, which in turn rested on their conception of the Watery Abyss as the ultimate entity. From its dark pantheistic depths and from its utterly unpredictable stirrings there could not emerge an unambiguous and effective pointer suggesting the presence of clear, rational laws in the universe. The actual world was not seen to display what the source, the murky chaos, was itself lacking. "Indian man forgot everything, but Egyptian man forgot nothing"<sup>1</sup>, but in this respect the Hindu and the Egyptian were the same: both failed to reach the level either of scientific or of historical thinking. Though they recorded data with extraordinary diligence, the Egyptians had as little appreciation of history as did the Hindus who hardly recorded anything. Science and historiography are but different types of a causal and rationally confident probing into the space-time matrix in which external events, physical or human, run their courses. To achieve science one has to recognise that these courses are *not* returning on themselves in a blind circularity.

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<sup>1</sup> O.Spengler, *The Decline of the West*, transl. C.F.Atkinson (New York: Alfred A.Knopf, 1957), Vol.I p12

## ***Ancient Babylonian Culture: The Omen of Ziggurats***

Where the Egyptians had mastered the arithmetic of fractions using reciprocal numbers, the Mesopotamians used a quite different method approximately equivalent to our decimal notation, except that they used a sexagesimal system<sup>1</sup>. With this notational understanding they were able to execute remarkably accurate calculations, the best until the Renaissance. Thus, they knew how to extract square roots<sup>2</sup>, they had the real roots of quadratic equations, they knew the (real) roots of most cubic equations. They made tables of what were effectively tangents and logarithms. But all the available texts come from only two relatively short periods in Babylonian history: the age of the Hammurabi dynasty from the nineteenth to the seventeenth centuries BC, and the Selucid era of the last three centuries BC.<sup>3</sup>

It is no exaggeration to say that in more than one way the calculators of Hammurabi's age were more than three thousand years ahead of general mathematical development. It should seem puzzling that a period of short flourishing had been followed by thirteen centuries of neglect, and that a second period of flourishing had achieved only the recovery of the attainments of the first<sup>4</sup>. The fate of mathematics in ancient Mesopotamia is more than a problem of progress and stagnation: it is rather another instance of the inability of scientific thinking to reach a stage where its progress becomes self sustaining.<sup>5</sup>

Of course, ancient Mesopotamia was not blessed with the favorable and dependable climactic conditions of the Nile valley<sup>6</sup>. On the contrary, weather conditions have always been very erratic in the Tigris and Euphrates valley with frequently disastrous consequences. Unexpected torrential rains, followed by savage floods, could destroy in a matter of hours all buildings and irrigation works over large areas and reduce life to a mere subsistence level. So the ziggurats of Mesopotamia were in constant need of repair, and the theology of the

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<sup>1</sup> That is, base 60 instead of base 10. Base 60 is useful computationally since 60 has no less than 10 factors (2, 3, 4, 5, 6, 10, 12, 15, 20, 30), and it is therefore quite easy to choose units which it is not necessary to subdivide (such as hours, minutes, seconds).

<sup>2</sup> Using "Newton's algorithm" (!). The figure given for  $\sqrt{2}$  is correct to about 6 parts per million for example. But they did not have a good value for  $\pi$ , 3 being a typical Mesopotamian value (correct to about 5%, for example see 2Chronicles 4:2), although evidence for a value of  $25/8$  was found in 1936 at Susa.

<sup>3</sup> The Hammurabi period coincided with the political ascendancy of Babylon: hence the name Babylonian. However, the Babylonians took over the Sumerian culture almost in its entirety, following the capture of the Sumerian city-states by the Semitic prince Sargon (2371BC-2316BC).

<sup>4</sup> The one major addition during the second period seems to be the explicit use of zero

<sup>5</sup> The best general summary of Babylonian science is the chapter, "Mesopotamia" by R.Labat and others in R.Taton (ed.) *History of Science*, Vol.I, *Ancient and Medieval Science*, translated by A.J.Pemerans (New York: Basic Books Inc., 1963)

<sup>6</sup> "Egypt is a gift of the River": Herodotus, transl. A.D.Godley (London: William Heinemann, 1926) Book II, §5

Mesopotamians assumed that every part of nature had a will of its own, often capricious and standing in continual conflict with one another.

The ziggurats were a symbol of cultural unity in ancient Mesopotamia. Their prototypes were constructed early in the Sumerian period (28<sup>th</sup> – 25<sup>th</sup> centuries BC) and intensive repair work was still being done on them early during the Persian occupation (538BC – 323BC) that put an end to Mesopotamian independence. Ziggurats were built and kept in repair throughout the Tigris and Euphrates valley regardless of which group of city states dominated much of the land. This cultural unity is all the more remarkable as it came about through an amalgamation of Sumerian and Semitic elements. Historically speaking, the centre of political power showed a gradual shift in the upriver direction from Ur to Babylon to Assur. Although power often changed hands between these last two, the culture, the world view, the religious outlook, the political organisation, the industrial crafts, the intellectual and scientific heritage retained much the same character.

So what did the ziggurats signify?<sup>1</sup> These monuments, together with the surrounding temple complexes and cities, signify wide ranging expertise, in the handling of bitumen<sup>2</sup>, in ceramics and metallurgy, and in writing.<sup>3</sup> They usually had a three-tiered construction with a small temple covered in glittering blue glazed tiles at the top and a larger temple on the ground floor. The presence and relative simultaneous position of two temples indicate that they formed a symbolic staircase for the periodic descent of deity from his heavenly abode<sup>4</sup>. In this respect they are quite different from the pyramids which were royal tombs. But we have seen that the pyramids were, at a deeper level, symbolic replicas of the primeval cosmic mound from which everything derives. There are strong indications that the ziggurats at this level also represented the primeval mound with connotations similar to those of the pyramids. The upper and lower temples of the ziggurats can be interpreted as the places where the periodic death and rise of the local deity took place. Furthermore, the upper temple also probably served as the place where the consummation of the annual “sacred marriage” occurred.

The Mesopotamian creation myth, the *Enuma Elish*,<sup>5</sup> was solemnly recited in its entirety at each year’s Akitu festival. According to this poem, only the divine

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<sup>1</sup> An informative discussion of the culture and history of ancient Mesopotamia can be found in H.W.F.Saggs, *The Greatness that was Babylon: A Sketch of the Ancient Civilisation of the Tigris-Euphrates Valley* (London: Sidgwick & Jackson, 1962) and Georges Roux, *Ancient Iraq* (London: Allen & Unwin, 1964).

<sup>2</sup> There was a very well developed chemical technique using pestles, mortars, crucibles, drip-bottles, mills, strainers, and apparatus for filtering distilling and extraction. They used various acids including sulphuric acid and perhaps *aqua regia*, salts including washing soda, common salt, borax, saltpetre and copper sulphate. They were familiar with mercury, sulphur, arsenic and their compounds. They could tan leather and dye wool in shades of yellow, blue, black, red and purple. See M.Levey, *Chemistry and chemical technology in ancient Mesopotamia* (London: Elsevier Publishing, 1959)

<sup>3</sup> The cuneiform writing of ancient Mesopotamia should convey forcefully the intellectual acumen of their users. From the viewpoint of technical execution the clay tablets on which the cuneiform writing was recorded were often masterpieces of manual skill, and this holds even more so of the cylindrical seals by which standard series of symbols were imprinted into the wet clay.

<sup>4</sup> See A.Parrot, *Ziggurats et Tours de Babel* (Paris: Albin Michel, 1949) p37

<sup>5</sup> Of the many discussions and translations of this poem the one by Alexander Heidel, *The Babylonian Genesis: The Story of Creation* (Chicago: University of Chicago Press, 1942)

parents Apsu and Tiamet, and their son Mummu, existed in the beginning. They represented the sweet water, the salt water and the mist hovering over both. The origin was therefore a chaotic mixture of waters and vapours with no definite entity standing out in the amorphous vastness. As the poem pointedly notes, nothing could yet be seen, not even “pasture land or reed marsh”.<sup>1</sup> Tiamet, the part-symbol of the original chaos, gives birth to a brood of lesser boisterous deities who turn against their own mother:

They disturbed Tiamet and assaulted their keeper;  
Yea, they disturbed the inner parts of Tiamet,  
Moving, running about in the divine abode

Apsu suggests the elimination of all the unruly gods so that he and Tiamet may sleep soundly. But Tiamet’s motherly instincts revolt. The gods fearful for their lives engage the good services of Ea, the great-grandson of Apsu and Tiamet, who draws a magic circle round Apsu, puts him to sleep by incantations, tears off his crown, and slays him. Apsu’s body becomes the foundation, the primeval mound, upon which Ea then builds his abode. There Ea’s wife, Damkina, gives birth to Marduk, a fearsome figure with four eyes, four ears and clothed with the rays of ten gods. “He caused waves and disturbed Tiamet” who now begins to resent the loss of her husband, and starts another war against those responsible for his death. So the deities gathering around Ea finally decide to cast their fortunes with the powerful Marduk, but he only accepts the leadership if he is worshipped as “king over the totality of the universe” by the gods. Marduk vanquishes Tiamet and all her supporters:

The lord trod upon the hinder part of Tiamet,  
And with his unsparing club he split her skull.  
He cut the arteries of her blood  
And caused the north wind to carry it to far places . . .  
The lord rested, examining her dead body,  
To divide the abortion and to create ingenious things therewith.  
He split her open like a mussel into two parts;  
Half of her he set in place, and formed the sky therewith as a roof.

Obviously, a cosmos, and particularly a sky, with such origins could not function as a paradigm of impersonal order but only as the personification of wilfulness. All this was in line with the picture of the world as a huge animal with apparently no beginning and end, subject to the various periodic changes evident in the life of the animal kingdom. Changes in human life, in society, and in the immediate physical surroundings of man were naturally pictured as the effects of the periodic clashes of large scale forces and phenomena in nature. Most of these, the wind, the rain, the clouds, the daylight and the night were readily connected with the heavens. The observation of the heavens seemed, therefore, to be the logical clue for learning something about the course of events on earth. Those events were believed to have a recurring pattern because the phenomena of the sky also recurred. The period of solar year and the periods of the moon were obviously the two principal ones of the heavenly cycles, and the correlation of these two formed the principal burden of the Babylonian observers of the sky.

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stands out for its clarity and documentation. The Poem consists of several parts, each on a separate clay tablet.

<sup>1</sup> The Neoplatonist Damascius (or Nicholas of Damascus, fl.510AD) noted disdainfully of this: “the Babylonians seem to pass over in silence the one principle of the universe, and they assume two, Tauthe [Tiamet] and Apason [Apsu], making Apason the husband of Tauthe and calling her the mother of the gods”, quoted in Heidel, *The Babylonian Genesis* (1942)

It was not however a scientific burden for them in the modern sense of the word. The ultimate motivation of their preoccupation with the phenomena of the heavens came from that animistic, cyclic conception of the world in the same way as the observation of eclipses and the investigation of the entrails of animals<sup>1</sup> were as many methods for them to divine ways and means for assimilating themselves with the cosmic life repeating itself for eternity.

A principal repetitive feature of the cosmos, the succession of solar years, dominated completely the Babylonian interpretation of the world.<sup>2</sup> The year formed for them the principal paradigm of the animistic roots and cyclic patterns of existence. It also set the measure of order which the universe could have in their estimate. That measure was meagre indeed. A telling proof of this can be found in the various details of the great New Year festival, the importance of which in the entire texture of Babylonian life cannot be exaggerated.<sup>3</sup> Sumerian in its origins, many of its parts were faithfully acted out in the Akitu festival in Babylon. The culminating point of the ritual consisted in the sacred marriage of the king and the high priestess of the ziggurat. The purpose of the rite was to secure for the king and his people the unimpeded flow of the forces of fertility for another round of the year-cycle. All this was spelled out most explicitly in the "fixing of destiny" which the high priestess read to the king following the completion of their sexual union.

The main concern rested with a general desire to re-experience once in every year the transition from chaos, represented by the yearly floods, to a more orderly and secure phase of life. But the ascendancy of order over chaos was not thought to be final. The rites of the Akitu festival are permeated with the fear that order, cosmic and social, may fall prey at any time to chaos. The faithful performance of the Akitu rites could secure the orderly course of cosmic and historical events for only a year. Beyond the one-year limit there lay a fearsome uncertainty with no truly hopeful perspectives.

In Babylon the succession of years did not mean the accumulation of building blocks with continuous constructive potential. They rather meant the transition from one world period into another separated by the discontinuity of chaotic

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<sup>1</sup> The ancient Babylonians were addicted to haruspicy, see M.Jastrow, *The Religion of Babylonia and Assyria* (Boston: Ginn and Co., 1898)

<sup>2</sup> I consign to a footnote a discussion of Babylonian astronomy since it occurred in almost complete isolation, and in its absence the history of astronomy would practically have remained the same. One looks in vain for a mention of it in Greek literature or scientific writing, except for some recordings of eclipses which proved valuable for Ptolemy. Hipparchus was also helped by Babylonian data in the discovery of the precession of the equinoxes: see O.Neugebauer, "The alleged Babylonian discovery of the precession of the equinoxes", *Journal of the American Oriental Society*, **70** (1950) 1-8. Some information did also pass to India. Babylonian astronomers were preoccupied by the succession of specific phenomena, such as the heliacal risings and settings, zodiacal stations, oppositions and the like. Only "special phenomena" were of interest for the purposes of divination: in ancient Mesopotamia astrology did not merely coexist with astronomy, it wholly dominated it. The skilful calculators of Babylonian lunar theory were primarily astrologers, magi and soothsayers. G.Sarton, a scholar known for emphasising the scientific achievements of ancient cultures, felt impelled to note that the planetary and lunar ephemerides of the Babylonians "were partly empirical and largely *a priori*; they suggest a complicated form of divination rather than a new branch of science" ("Chaldean astronomy of the last three centuries BC", *Journal of the American Oriental Society*, **75**, 1955, 170). See also *Astronomical Cuneiform Texts. Babylonian Ephemerides of the Seleucid Period for the Motion of the Sun, the Moon and the Planets* (London: Lund Humphries, 1955).

<sup>3</sup> E.D.van Buren "The sacred marriage in early times in Mesopotamia", *Orientalia*, 13 (1944):1-72

conditions. Babylonian culture seemed to be trapped in the treadmill of basically ominous yearly cycles. Perhaps this is the reason why in Babylon, prior to the Selucid era, there had never developed a continuous chronology starting from some outstanding event, such as the counting of years in Greece from the first Olympiad.

The Babylonians were fundamentally pessimistic<sup>1</sup>, leading to cultural discouragement and deep-seated intellectual inertia. The difficult climate is not a sufficient explanation of this although its cultural influence cannot be emphasised enough. For many centuries the adversities of weather were successfully faced with relatively primitive techniques, and the fertility of the Tigris and Euphrates valley was well secured in spite of the many wars whose desructive role should not be exaggerated. Babylon and Assur enjoyed repeated periods of peace long enough to permit the emergence of a truly scientific endeavour in one or other direction at least. Again, the Mesopotamians displayed more than enough intellectual acumen, inndustrial skills, curiosity and patience in observations, that is, qualities indispensable for the creation of science. They did not come even moderately close to it. The promising creativity of Hammurabi's age was not followed up in later times either in literature, or in arts, or in legislation, let alone in matters of scientific learning.

The basic reason for this failure is neither geophysical, nor socio-economical, but has rather to do with the Mesopotamian worldview. A systematic investigation of the world and its lawfulness presupposes a fair measure of confidence in the reasonability and likely success of such an enterprise. It was this confidence that the literate classes in Mesopotamia were unable to cultivate in a sustained manner. The animistic, cyclic world view made it impossible for them to realise that to influence or to control nature one had to be able to predict accurately its future course. They lacked faith in the possibility of such a prediction as it implied the notion of an order free from the whims of animistic forces that inspired the vision of a collapse to occur time and again. As a result, the mastery of science could not become a proud feature of the culture of a land on which zig-gurats cast their sombre omen.

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<sup>1</sup> The Gilgamesh epic is another all too clear example. For a scholarly translation see R.Campbell Thompson, *The Epic of Gilgamesh* (London: Luzac & Co., 1928)



# Ancient Greek Culture: The Labyrinths of the Lonely Logos

For all the scientific achievements that took place during the six or seven Hellenistic centuries, this long period does not seem to equal in creative power the much shorter Hellenic phase of Greek scientific thought<sup>1</sup>. In more than one respect the feats of Hellenistic science were methodical (though very valuable) elaborations on themes, discoveries, and syntheses made in Hellenic times. Thus Euclid's *Elements*<sup>2</sup> represented to a great extent the concluding phase of the spectacular emergence of scientific geometry<sup>3</sup> to which no less than sixty known Greek geometers contributed during the previous four or five generations<sup>4</sup>. Of particular note are: Thales of Miletus (ca. 624-548BC) who is reputed traditionally to be the "first true mathematician": the originator of the deductive organi-

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<sup>1</sup> The convenient dividing line of the death in 323BC of Alexander the Great (and of his tutor Aristotle in the following year after leaving Athens) is usually taken as the end of the Hellenic era and the start of the Hellenistic one, which blended Hellenic and oriental elements and whose cultural centre was Alexandria rather than Athens. The first Olympic Games, year one of the Greek calendar, were held in 776BC, and the philosophical schools were finally closed by Justinian in 529AD. The "Heroic Age" lay mostly in the fifth century BC, and the fourth century (with the deaths of Socrates in 399BC, the "last Pythagorean", Archetas, in 365BC, and Aristotle in 322BC) was inspired by Plato. In these footnotes and also the text I use extensive additional material from Carl B. Boyer, *A History of Mathematics* (New York: John Wiley, 1968).

<sup>2</sup> Composed in about 300BC in Alexandria. It was an introductory textbook covering "elementary" mathematics: Euclid made no claim to originality, and more advanced subjects were treated in other works. Even so, the *Elements* (containing 13 books) were not completely understood again in modern times until the nineteenth century. Euclid also wrote treatises on conic sections (*Solid Loci*, superseded by Apollonius' work and now lost), and one (*Porisms*) which may have represented an ancient approximation to an analytical geometry. His *Phaenomena*, on spherical trigonometry for use by astronomers, can be shown to be a textbook relying heavily on a textbook tradition.

<sup>3</sup> The *Elements* systematically uses geometrical notations and proofs: but it includes much material equivalent to algebra and the theory of numbers (integers). In particular, there is an extensive (and difficult) discussion of incommensurability (that is, irrational numbers) in book X: philosophically this is very interesting since incommensurability coloured the entire Greek mathematical enterprise, which was stunned in the fourth century BC by a discovery that effectively demolished the basis for the Pythagorean faith in whole numbers. That irrational numbers were found so early is not surprising since their existence is very easy to demonstrate. For example, to prove that  $\sqrt{2}$  is irrational assume the opposite, that it can be expressed by some fraction  $\sqrt{2}=p/q$ . Now we insist that  $p/q$  are not both even: that is, if  $p/q=14/10$  we rewrite it as  $p/q=7/5$ . Now square both sides:  $2=p^2/q^2$ . But then  $2q^2=p^2$ : that is,  $p^2$  is even, and therefore  $p$  is even (since the product of odd numbers is odd). So let us write  $p=2r$ , and then  $p^2=4r^2$ . But then  $q^2=2r^2$ : that is,  $q^2$  is even, and therefore  $q$  is even. This violates the original assumption and therefore  $\sqrt{2}$  is irrational. This proof was certainly known to Aristotle in an equivalent form.

<sup>4</sup> Thus, books I & II and a large part of book IX are thought to be from the Pythagorean school, III & IV are presumed to be largely from Hippocrates of Chios. Book V contains the axioms about ratio from Eudoxus and Archimedes. Book XII gives Eudoxus' careful proof that the areas of circles are as the squares on the diameter, using the method of exhaustion which is nearly equivalent to our calculus. Book XIII is on the five regular solids, and is ascribed to Theaetetus.

sation of geometry. The aphorism: “Know Thyself”, comes from Thales.<sup>1</sup> Pythagoras of Samos (ca. 580-500BC) gathered a school around himself, whose motto was said to be: “All is Number”.<sup>2</sup> Pythagoras’ Theorem was known and used by the Babylonians, but the proof is credited to Pythagoras, who is known as the “Father of Mathematics”.<sup>3</sup> Anaxagoras (died 428BC) regarded as his aim in life the study of the nature of the universe: he wrote the first scientific bestseller, *On Nature*, which could be bought in Athens for only a drachma. Plutarch tells us that while Anaxagoras was imprisoned (for asserting that the sun was not a deity but a huge red hot rock) he tried to square the circle<sup>4</sup>. However, around 430BC Hippocrates of Chios was able to construct a quadrature of lunes, probably being the first to use the indirect method of proof.<sup>5</sup> Hippias of Elis (a contemporary of Socrates who died 399BC) was a Sophist<sup>6</sup> who did square the circle using a special curve known as the trisectrix of Hippias, or a quadratrix.<sup>1</sup> Archytas (ca. 428-365BC) duplicated the cube with a difficult

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<sup>1</sup> Tradition holds that he proved the “Theorem of Thales” (the angle in a semicircle is a right angle), and ancient opinion is unanimous in regarding him as an unusually clever man and the first philosopher – the first of the Seven Wise Men. He was regarded as “a pupil of the Egyptians and the Chaldeans”. He is supposed to have predicted the solar eclipse of 585BC. But the eclipse story seems unlikely since the Babylonian tables of eclipses, which he was certainly familiar with, were not in a form to be useful for Greece, since the eclipse shadow covers a very small portion of the earth’s surface.

<sup>2</sup> The Pythagorean school of thought was politically conservative and with a strict code of conduct. Vegetarianism was enjoined upon the members, apparently because they believed in the transmigration of souls. Perhaps the most striking characteristic of the Pythagorean order was the confidence it maintained in the pursuit of philosophical and mathematical studies as a moral basis for the conduct of life. The very words “philosophy” (“love of wisdom”) and “mathematics” (“that which is learned”) are supposed to have been coined by Pythagoras himself to describe his intellectual activities. The Pythagorean purification of the soul was accomplished in part through cultist rites reminiscent of worshippers of Orpheus and Dionysus; but the harmonies and mysteries of philosophy and mathematics also were essential parts in the rituals.

<sup>3</sup> The point here is that the Babylonians knew much but proved nothing. The Greeks learned the Babylonian arts, but then supplied proofs of the correctness of the procedures. The new emphasis in mathematics was due primarily to the Pythagoreans. With them mathematics was more closely related to a love of wisdom than the exigencies of practical life.

<sup>4</sup> That is, constructing a square with an area identical to that of the circle. One of the three famous problems of antiquity. Here we have the first mention of a problem that was to fascinate mathematicians for two millenia. This is a type of mathematics quite unlike that of the Egyptians and Babylonians. It is not the practical application of a science of number to a facet of life experience but a theoretical question involving a nice distinction between accuracy in approximation and exactitude in thought. The other two problems were the duplication of the cube and the trisection of the angle, from about the same time. The idea was to solve these problems with only straight-edge and compass: this is impossible, but it was only in the eighteenth century that both  $\pi$  and  $\pi^2$  were proved irrational (by Lambert in 1770 and Legendre in 1794), and in the nineteenth century that  $\pi$  was demonstrated transcendental (by Lindemann in 1882: transcendental numbers cannot be constructed as roots of polynomial equations, and therefore cannot be constructed with Euclidean tools). Of course, the Greeks knew they were unable to solve these problems with straight-edge and compass, but they proceeded to use other fruitful methods to construct solutions.

<sup>5</sup> That is: Either the theorem is true or it is not true. If you demonstrate that the assumption of falsity is absurd you establish the theorem. A lune is a figure bounded by two circular arcs of unequal radii. This is the first rigorous quadrature (“finding a square of the same area”) of a curvilinear area in the history of mathematics.

<sup>6</sup> This is the Hippias that the Pythagorean Plato satirises in his dialogue of the same name. Socrates is reported to have described Hippias as handsome and learned, but boastful and shallow. But the Platonists were uncompromisingly opposed to the Sophists, who openly supported themselves by tutoring fellow citizens, not only in honest intellectual endeavour but also in the art of “making the worse appear the better”.

trix.<sup>1</sup> Archytas (ca. 428-365BC) duplicated the cube with a difficult three dimensional construction involving a cone and a torus.<sup>2</sup>

Zeno the Eleatic (fl. ca. 450BC) believed in the unity and permanence of being, contrasting with the Pythagorean ideas of multiplicity and change. He proposed a series of paradoxes to prove the inconsistency in the concept of infinite divisibility.<sup>3</sup> His arguments seem to have had a profound influence on the development of Greek mathematics, comparable to the discovery of the incommensurable, with which it may have been related. Originally, in Pythagorean circles, magnitudes were represented by pebbles, or *calculi*, from which our word “calculation” comes, but by the time of Euclid there is a complete change in point of view. Magnitudes are not in general associated with numbers but with line segments. It seemed to be that geometry rather than number that ruled the world.

Democritus of Abdera (ca. 460-370) is today celebrated as a proponent of a materialist atomic doctrine. It is believed that he used methods equivalent to the calculus to give a demonstration of the result that the Egyptians knew, that the volume of a pyramid is one third of the product of the base and the altitude. Archimedes ascribed this result to him, but criticised him for lack of rigour. However, Democritus was extremely unpopular with the Platonists and the Aristotelians of the next century, and fell into disregard.

The second century BC was the “Golden Age” of Greek mathematics. Euclid of Alexandria (*Elements* was composed around 300BC), Archimedes of Syracuse (287-212BC) and Apollonius of Perga (ca. 262-190BC) were the leading mathematicians. Euclid’s work has already been described. Archimedes is known even to children today for his principle of bouyancy<sup>4</sup>, but his main contribution was in the rigour of the proofs he supplied for results that we obtain today with the calculus.<sup>5</sup> The *Conics* of Apollonius is his only work to survive

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<sup>1</sup> Called a trisectrix since it could be used to trisect an angle and a quadratrix since it could be used to square the circle. But of course it could not be constructed only with straight-edge and compass. The earliest demonstration extant of the quadratrix property is from Dinostratus (fl 350BC). Dinostratus’ brother Menaechmus used conic section curves (the hyperbola and parabola) to square the cube.

<sup>2</sup> Archetas’ most important contribution though may have been in saving his friend Plato’s life by intervening with the tyrant Dionysius. Archetas was the autocrat in Tarentum, but he was just and restrained, regarding reason as a force working towards social amelioration.

<sup>3</sup> Thus the paradox of Achilles and the tortoise argues that motion is impossible under the assumption of the infinite subdivisibility of space and time. Achilles races against a tortoise who has been given a headstart. But by the time he has reached the tortoise’s starting position the tortoise has moved on. And so on ad infinitum. It was only in the nineteenth century that the problem of infinity was rigorously addressed by mathematicians. And only in the twentieth century did the quantum theory finally prove that, after all, natural units are not infinitely subdivisible. The method Zeno used was dialectical, anticipating Socrates in this indirect mode of argument: starting from his opponent’s premises, he reduces these to absurdity.

<sup>4</sup> His hydrostatic principle is in *On Floating Bodies*. The discovery of the mathematical proofs of this from a simple postulate of fluid pressure is undoubtedly the occasion of the “Eureka” story. The principle is more subtle than the common expression of it: *Any solid lighter than a fluid will, if placed in a fluid, be so far immersed that the weight of the solid will be equal to the weight of the fluid displaced* (I.5); and there is a corresponding converse: *A solid heavier than a fluid will, if placed in it, descend to the bottom of the fluid, and the solid will, when weighed in the fluid, be lighter than its true weight by the weight of the fluid displaced* (I.7)

<sup>5</sup> His *Quadrature of the Parabola* was concerned chiefly with the “method of exhaustion” (equivalent to our integral calculus) which he used to find areas of conic sections. It was in this book that he explicitly stated the assumption needed to rigorously handle the infinitesimals of this method: the “axiom of Archimedes”. I quote this to show the precision and

in the original Greek. His masterpiece, it is a work of extraordinary breadth and depth. However, he was also a celebrated astronomer, and (almost certainly) the system of cycles and epicycles used by Ptolemy<sup>1</sup> (fl.127-151AD) was due to him. Half a century after Apollonius, Hipparchus (fl.150BC) discovered the precession of the equinoxes.

Plato had held geometry in the highest esteem, and it was in a sense a Platonic imprint on Greek astronomy that its main achievements remain restricted to the largely geometrical parts: the investigation of the form and size of celestial bodies and of their paths across space. It was no coincidence that what happened in astronomy took place in physics too. Its lasting advances were made in statics where a straightforward application of geometrical considerations came naturally. But to advance from statics to dynamics required insights other than geometrical, and at this point even an Archimedes failed to break out from the conceptual confines of his scientific background, though he came tantalisingly close to formulating the basic propositions of infinitesimal calculus: the calculus is essential for making meaningful progress concerning the true dynamics of the inanimate world.

But the Greeks did not believe that, ultimately, the world was inanimate. Plato asks the question in the *Timaeus*: “In the likeness of what animal did the creator make the world?” The question forms part of a paragraph where Plato probes into the ultimate nature of the cosmos, and he makes no secret of the fact that the intelligibility of the world depends on thinking about it as being the perfect

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subtlety of his thought: *The excess by which the greater of two unequal areas can, by being added to itself, be made to exceed any given finite area.* He was able to prove with this method that the volume of a sphere was  $\frac{4}{3}\pi r^3$  and that its surface area was  $4\pi r^2$ . He was able to find the area of an ellipse (but failed to find the areas of ellipse segments, which involve transcendental functions). He came very near to formulating the idea of the limit of a function in his derivation of the volume of paraboloidal segments. With a spiral curve (which he attributed to Conon of Alexandria) he was able to both trisect the angle and square the circle. He was interested in the large as well as the small: he boasted that he could write down a number larger than all the grains of sand that could fill even Aristarchus of Samos’ heliocentric universe, which had to be large enough to make stellar parallax unobservable (the Greeks had speculated about a Copernican universe and abandoned the idea on account of the – to them incredible – sizes of the universe that this idea involved). Incidentally, Aristarchus had measured the distance of the Earth from the sun, and Eratosthenes of Cyrene (both of these were contemporaries of Archimedes) measured the size of the earth. In the context of very large numbers Archimedes mentioned a principle that anticipated logarithms by a millenium. Also, his *On the Equilibrium of Planes* is a beautiful mathematical exposition of the physics of levers: the oldest known book on mathematical physics.

<sup>1</sup> The computation by Ptolemy of a long list of trigonometrical values and their skilful use in his great planetary system was an achievement of first rank. Ptolemy’s analysis of the motion of the moon was in fact so exact as to lead him to the discovery of two recondite aspects of the moon’s dynamics: its evection and nutation. It was Ptolemy’s introduction of the deferent giving the planets non-uniform circular motion that allowed him to obey Plato’s injunction to “save the phenomena” so exactly, and which Copernicus was unable to accept. However, it turned out that the Copernican system needed just as much *ad hoc* complication to achieve an accuracy comparable to Ptolemy’s, and only the introduction by Kepler of ellipses (and the siting of the sun at an ellipse focus, with his second law giving a coherent geometrical interpretation of the equivalent of the deferent motion) which was able to re-introduce an elegant simplicity. The *Almagest* is so called from its Arab appellation “The Greater” to distinguish it from the lesser treatise of Apollonius. Its title was *Mathematical Syntaxis*.

animal. With his definition of intelligibility<sup>1</sup> Plato merely echoed his master, Socrates, who clearly saw that in the brilliant speculations of the Ionians only inert matter existed, the configurations of which were ruled by chance. In such an account of the world, if taken consistently, there was no room for right and wrong, for moral responsibility and decision, or to recall Socrates' own problem, for obeying the voice of one's conscience even at the price of death. The details of Socrates' struggle with this issue is movingly told in the *Phaedo*, a work whose significance for the future course of science cannot be overestimated. To justify his own personal stance Socrates outlined a completely new type of physics in which questions about purposes dominated. According to Socrates, the decisive scientific questions did not concern the size, shape and location of the earth, but whether it was *best* for the earth to be of a given size and shape, and to be at a specific region of the cosmos. To save the meaning of what was typically human in the realm of existence one needed, so Socrates concluded, a reformulation of the methods and objectives of physics.

The task of carrying out this programme fell to Aristotle, whose extraordinary feats in biology were in a sense responsible for his failure in physics. It was he who turned zoology into a scientific discipline in his *History of Animals*, and laid lasting foundations for comparative anatomy in his *On the Parts of Animals*.<sup>2</sup> His acumen as a biologist is perhaps even more brilliantly displayed in his *On the Generation of Animals* which remained until modern times the authoritative compendium on fertilisation, embryology and the birth and raising of the offspring. Nothing shows better the value of this book than that some of its inevitable errors went undetected until the nineteenth century.

However, the cultivation of the study of many aspects of the living organism invited a methodology which took its start from the purposeful nature of biological systems. The emphasis on goals and purposes served biology only too well throughout its long history, and is staunchly defended by prominent biologists even in the age of molecular biology and operational method. But in the days of Aristotle the espousal of final causes was far more than a methodological expedience. The realm of final causes stood then for the bedrock of intelligibility. The result was that investigation of any realm, living or not, was not considered satisfactory without attributing purposes to phenomena of every kind, ranging from the fall of stones to the motions of stars.

The whole emancipation of science from the shackles of organismic or Aristotelian physics<sup>3</sup> depended upon achieving a depersonalised outlook on nature in which stones were not claimed to fall because of their innate love for the centre of the world. With Aristotle however, the world (at least in its sublunary<sup>4</sup> part)

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<sup>1</sup> "The deity, intending to make this world like the fairest and most perfect of intelligible beings, framed one visible animal comprehending within itself all other animals of a kindred nature".

<sup>2</sup> On reading this in William Ogle's masterful translation, Darwin felt impelled to register his admiration for Aristotle, the biologist: "I had not the most remote notion what a wonderful man he was. Linnaeus and Cuvier have been my two gods, though in very different ways, but they were mere schoolboys to old Aristotle."

<sup>3</sup> The origins, claims, fallacies and tenacious hold of organismic physics on human thought are discussed in detail in S.L.Jaki, *The Relevance of Physics* (Chicago: University of Chicago Press, 1966)

<sup>4</sup> The Pythagorean distinction between the perishable sublunary world (cosmos) and the imperishable superlunary world (ouranos) is important to note as it became an article of faith almost universally accepted by subsequent generations of Greek philosophers.

appears like a huge animal breathing, growing, decaying, subject to the cycles of birth and death for eternity.

As the idea of cyclic returns in the universe had a distinctly biological or organismic hue, Aristotle found it much to his liking. In addition, Aristotle, always eager to arbitrate among the older philosophical dicta, relished the frequent occurrence of some form of a cyclic concept in the teachings of his forbears. Probably all schools of pre-Socratic philosophy subscribed in one way or another to the belief that the universe was to perish and resurge at regular intervals.<sup>1</sup> In any case, there is no doubt about the early popularity among the Greeks of the idea of a cyclic universe. Here is a characteristic Stoic passage:

When all the planets return with respect to both latitude and longitude exactly to the same point where they were located in the beginning when the world was formed for the first time, they all will become the cause of the extinction and destruction of all beings. Then, as the planets retrace exactly the same route which they had already traversed, each being that had already been produced during the previous period will re-emerge once more in exactly the same manner. Socrates will exist again, and Plato as well, and also each man with his friends and fellow citizens; each will suffer the same trials, will manage the same affairs; each city, each village, each camp will be restored. This reconstitution of the Universe will occur not once, but in a great number of times; or rather the same things will reoccur indefinitely to no end. As to the gods, who are not subject to the [cosmic] destruction, it is enough for them to witness only one of these periods to know henceforth everything that should occur in subsequent periods; nothing shall indeed occur that may differ from what had already been produced; all things reappear in the same manner, with no differences whatever, not even the slightest ones.<sup>2</sup>

The Stoics represented in classical antiquity the last important philosophical school to formulate a – highly interesting – physics (and cosmology) in line with their philosophical postulates<sup>3</sup>. But although they had valuable ideas about physical process they failed to develop them into real physics. As the basic Stoic aspiration was vitalistic and monistic, they had to assume a concept of being in which everything fused into one all-encompassing living continuum. So they looked for replicas of heavenly cycles in earthly processes. And the most

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<sup>1</sup> Thus, among the Ionians, Anaximander considered the infinity in space and time as a matrix that gave birth to an infinite succession of worlds: “From the infinite eternity comes the destruction, in the same way as does generation issued from it long before: all these generations and destructions reproduce themselves in a cyclic manner.” For Anaximander time itself was constituted by the succession of these cosmic destructions and regenerations. According to another Ionian, Anaximenes, the world is eternal but “it is not the same world that exists forever; the one which exists is now one world and another later; its generation takes place anew after certain periods of time.” Actually, with each subsequent century the evidences in this respect become more direct, specific and numerous. Among the Pythagoreans it was Philolaus, Alcmeon, Archytas, and Oenipodus who were recalled in later sources as proponents of the idea of the cyclic constitution of the cosmos. See: H. Diels (edited by W. Kranz), *Die Fragmente der Vorsokratiker griechisch und deutsch* (Dublin/Zurich: Weidmann, 1968).

<sup>2</sup> The 4<sup>th</sup> century Christian bishop Nemisius, reporting the doctrine of Chrysippus and his teacher Cleanthes. Chrysippus fused the Stoic teaching into a great system of thought. Chrysippus also wrote a book *On the Cosmos* (now lost) in which the Stoic belief in the numerical recurrence of individuals was stated most explicitly. On the views of the various representatives of Stoic thought, the primary source is the collection of Stoic fragments edited by J. von Arnim, *Stoicorum veterum fragmenta* (Leipzig: B.G. Teubner, 1903-24). This quote is in Vol. II, p. 190.

<sup>3</sup> see for example, S. Sambursky, *The Physical World of the Greeks*, (London: Routledge & Kegan Paul, 1956), and S. Sambursky, *The Physics of the Stoics*, (New York: Macmillan, 1959)

fundamental of these cycles was the period determined by the successive and simultaneous return of all planets to the same point of the zodiac. This period, the Great Year<sup>1</sup>, was for the Greek mind a circular barrier that deprived it of insights and aspirations without which science could not reach a self-sustaining stage<sup>2</sup>.

Epicurus, the leader of the Stoics' chief competitors for philosophical hegemony, is best remembered in the history of physical sciences as one who refocused attention on the merits of Democritus' atomism, a favorite target of the Peripatetics and the Stoics.<sup>3</sup> But his truly schizophrenic attitude towards science is much less frequently recalled. He believed that the chance collisions of atoms underlay all phenomena, especially the production and dissolution of worlds. But he also went to the extremes in noting that ascribing a strictly unique and specific form of physical causality to celestial phenomena "would cause the greatest disturbance in men's souls". Only by admitting more than one cause in explaining the motion of the heavens can one live "free from trouble"; "to assign a single cause for these occurrences ... is madness"; "it were better to follow the myths about the gods than to become a slave to the destiny of the natural philosophers: for the former suggests a hope of placating the gods by worship, whereas the latter involves a necessity which knows no placation".

And by "natural philosophers" he primarily meant the astrologers. Within the realm of Greek science there had never been more than a tenuous distinction between the practice of astronomy and astrology. By Epicurus' time astrology was already on the way to becoming a dominating and intellectually most respectable preoccupation of the Hellenistic world, with the result that a Ptolemy could, without any fear of criticism, consider his treatise of astrological divination, the *Tetrabiblos*, a work of far greater importance than his compendium of mathematical astronomy, the *Almagest*.

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<sup>1</sup> There are various celestial cycles, a lunar cycle of 19 years (Meton, a contemporary of Pericles), 76 years (Calippus, fl.340BC), 304 years (Hipparchus, fl.130BC) and 2434 years (attributed to Aristarchus by Censorinus). Astronomical estimates of the "Great Year" (defined as the period of return of all the planets to their Zodiacal positions) were 59 years (Oenopidus, fl.520BC) or 77 years (Democritus). However, the Great Year was a philosophical concept, since the Greeks knew that their measurements were not sufficiently accurate to put any weight on the astronomical values. Neither Hipparchus nor Ptolemy connected the Great Year with the precession of the equinoxes. Heraclitus thought the Great Year was 10800 years, probably through Babylonian and Hindu influence, being the product of 30 (a "world day") and 360 (the number of days in an ideal year). Plato is thought to have proposed 36000 years, from poetic analogies. See Sir Thomas Heath, *Aristarchus of Samos the Ancient Copernicus* (Oxford: Clarendon Press, 1913). Cicero is reputed to have assigned 12954 years to the length of the Great Year, see P.R.Coleman-Norton, *Cicero's Doctrine of the Great Year*, in *Laval Théologiques et Philosophiques*, 3 (1947) pp.293-302; Macrobius (fl. 410AD), on the other hand, specified 15000 years for the Great Year, see *Macrobius, Commentary on the Dream of Scipio*, transl. William Harris Stahl (New York: Columbia University Press, 1952)

<sup>2</sup> The problem of the failure of Greek science to become a self-sustaining enterprise is usually referred to in a more or less cursory manner in any major work on the subject. The only modern analysis of ancient Greek science in which careful attention is paid to the influence of the belief in the Great Year on the fortunes of Greek scientific thought is Pierre Duhem's *Le système du monde: histoire des doctrines cosmologiques de Platon à Copernic* (Paris: Hermann, vols.1-V, 1913-15; vols.VI-X, 1954-59)

<sup>3</sup> He also added the molecular theory to it: an important modification. See: *Epicurus, The Extant Remains*, transl. & notes, with short critical apparatus, by Cyril Bailey (Oxford: Clarendon Press, 1926).

The *Tetrabiblos* refers explicitly to the great cycle determined by the return of all heavenly bodies to the same position<sup>1</sup>. Ptolemy defined astrology as the art of prognostication through astronomy, and no judicious reader of the *Tetrabiblos* can fail to note that all events and human characteristics can only be cyclically repetitive in a system where the motion of the planets ultimately determines everything.

By the second century AD astrology reigned supreme in the intellectual climate of the Hellenistic world, and so did the belief in the inexorability of eternal returns. It is no wonder that the works of the poets and philosophers of Roman times are full of revealing references to the Great Year<sup>2</sup>. Cicero, for one, clearly betrayed an awareness of the despondency exuding from the doctrine of the Great Year, though as a true Stoic he tried to face the inevitable prospect with saddened courage. In the closing sections of his *De republica*, which contains the famous "Dream of Scipio", Cicero took note of the Great Year to warn that no statesman should expect perennial fame as his reward. The world is subject to periodic catastrophes which reduce to ashes all cultures and obliterate all memory and fame. For Cicero the basic unit of time is the period separating the conflagrations and he calls it emphatically *the year*.

A hundred years later the same acceptance of the Great Year is in evidence in the writings of Pliny the Elder and Seneca, two Romans who paid special attention to scientific topics in the early phase of the Empire. Pliny's mention of the Great Year (which constituted in his eyes the fundamental form of the universal influence of planetary motion on all events on earth) is short but highly expressive of the bondage in which the idea of a closed and cyclically repeating universe held the best minds<sup>3</sup>. In his turn, Seneca was far more prolific on the matter, giving a graphic description of the burial of all mankind in a single day: "All that the long forbearance of fortune has produced, all that has been reared to eminence, all that is famous and all that is beautiful, great thrones, great nations – all will descend into the one abyss, will be overthrown in one hour." The despondency which Seneca felt over the inevitable prospects of the dissolution of all human achievements and over the unavoidable dominance of base instincts ("vice can be acquired even without a tutor") is to be kept in mind for a proper evaluation of his often quoted words about scientific progress<sup>4</sup>.

For Marcus Aurelius, the great philosopher-emperor of late Roman times, the highest aim of human efforts consisted in one's conscious acceptance of being a pebble in the gigantic, cyclic torrent of the universe. That torrent rushed through all humans, now producing them, now burning them to ashes and in an un-

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<sup>1</sup> In Ptolemy, *Tetrabiblos*, ed. & transl. by F.E.Robbins (Cambridge, Mass.: Harvard University Press, 1964) Book I, chap.2 (pp15-17)

<sup>2</sup> It is only on rare occasions that the poets looked forward optimistically, as Virgil did in the famous fourth *Eclogue*. Such passages, collected by A.O.Lovejoy & G.Boas, *Primitivism and Related Ideas in Antiquity* (New York: Octagon Books, 1965) constitute a trickle as compared with classical texts conveying the contrary outlook. *Primitivism* also includes a detailed discussion of cosmic cycles in Plato's and Aristotle's thought.

<sup>3</sup> See H.Rackham, *Pliny, Natural History* (Cambridge, Mass.: Harvard University Press, 1938) Book II, ch.6

<sup>4</sup> John Clarke, *Physical science in the times of Nero: Being a translation of the Quaestiones Naturales of Seneca* (London: Macmillan, 1910). Also see Seneca *De Cometis*: "The day will yet come when the progress of research through long ages will reveal to sight the mysteries of nature that are now concealed. ... Nature does not reveal all her secrets at once. We imagine we are in her mysteries. We are, as yet, but hanging around her outer courts."



counted number of times: “How many a Chrysippus, how many a Socrates, how many an Epictetus hath Time already devoured?” The Great Year was a most powerful reminder of the ultimate futility of all efforts. Marcus Aurelius’ memorable advocacy of Stoic resignation rested on the consideration that only the fleeting moment of the present counted: “These two things, then, must needs be remembered: the one, that all things from time everlasting have been cast in the same mould and repeated cycle after cycle, and so it makes no difference whether a man see the same things recur through a hundred years or two hundred, or through eternity: the other, that the longest liver and he whose time to die comes soonest part with no more the one than the other.”<sup>1</sup>

The last great figure of ancient Greek philosophical tradition was Simplicius. By this time Christian thinkers were making well argued suggestions that terrestrial and heavenly matter were the same, that the motion of bodies did not require a continuous contact between the moved and the mover, that processes were not ultimately circular but one-directional, and that the motion of stars did not really rule man’s mind and his relation to nature. In his commentaries<sup>2</sup> on Aristotle’s cosmology, physics and metaphysics Simplicius had only scorn for these suggestions. He had no patience with the first tenet of the Christian creed, the belief in a personal, rational Creator who made the universe *out of nothing* and *in time*. Absolute beginning could hardly appear reasonable to one who insisted that the Pythagorean concept of time resting on the idea of eternal returns represented the most satisfactory synthesis and analysis of time.

In the seven or eight centuries of what we could call the Greek scientific project enormous advances were made that still influence us today. Yet the Greek thinkers were consistently baffled by the intellectual labyrinth that they had created for themselves. Simplicius reveals in stark directness the predicament of the Greek Logos, its lonely wanderings, and its strange shunning of a new light which unexpectedly came to diffuse over the confines of its mighty labyrinth.

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<sup>1</sup> The quotations are from Marcus Aurelius’ famous ‘Meditations’: *The Communings with Himself of Marcus Aurelius Emperor of Rome together with his Speeches and Sayings*, revised text and a translation into English by C.R.Haines (London: W.Heinemann, 1916)

<sup>2</sup> *Simplicii in Aristotelis categorias commentarium*, edited by K.Kalbfleisch (Berlin: G.Reimer, 1907); *Simplicii in Aristotelis physicorum libros quattuor posteriores commentaria*, quoted in the translation of S.Sambursky, *The Physical World of Late Antiquity* (New York: Basic Books, 1962)

## ***The Beacon of the Covenant***

Why did science fail to develop in half a dozen great cultures, why did it come to a standstill in Greece after a splendid start, and why did it finally emerge more than a thousand years later in clearly identifiable circumstances? We have to look beyond individual achievements into the mentality underlying the decisive role of Christian monotheism, without being distracted by the widely shared conviction about the fundamental opposition between the religious and the scientific orientations<sup>1</sup>. The purpose of this entire work is of course to demonstrate the opposite: that the Christian worldview has been an essential underpinning of the scientific enterprise.

The ancient nomadic Hebrews and puny Israel clinging to their position on a hazardous crossroads of great civilisations had no scientific achievements to their credit. How could they have done? Barely a generation went by over one and a half millenia without their land being overrun by one foreign army or another. However, not only did they survive as a nation but they also succeeded in handing down from generation to generation an outlook on the world that set them radically apart from their neighbours.

This was all the more remarkable as the Israelites shared their neighbours' belief in a flat earth floating on water, and in a firmament resting on columns located at the extremities of dry land. One would look in vain, however, for a deification of nature in the Hebrew interpretation of the external world. The most ancient parts of the Bible already show that for the Hebrews, external nature was an irrefragable evidence of a supreme, absolute, wholly transcendent Person, the Lord of all. They emphasised the idea of the utter dependence of everything on one single Being, who stood absolutely alone, unchallengable in His control of historical process.

In the Biblical view God is primarily and ultimately a person, whose most unique characteristic is to reveal His unspeakable transcendence in His most immediate concern for the children of Abraham. He is the "God of Abraham, Isaac, and Jacob"; that is, the God of the Covenant, or a God who freely binds Himself to the welfare of mankind. And Abraham's sole beacon in his nomadic wanderings was the unflinching confidence that God would not fail to accomplish His part of the Covenant. It was in such a perspective that the external nature or cosmos was reflected upon in the Bible. There the universe is a dwelling place for man, a persuasive evidence of God's loving care.

The creation story in the first chapter of Genesis is a most lucid expression of a faith in the rationality of the universe (coming as it did from the mind of a single Creator) without which the scientific quest of man could not turn itself into a self-sustaining enterprise. For all the Mesopotamian flavour of Genesis ch.1 (and there is nothing original in the list of the principal parts of the world), its

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<sup>1</sup> A typical case is the discussion of the world view and culture of ancient Israel by P.Dupont-Sommer in R.Taton (ed.) *History of Science: Vol.I, Ancient and Medieval Science from the Beginnings to 1450*, translated by A.J.Pomerans (New York: Basic Books, 1963)

author uses unusual skill to drive home some very uncommon points. These are the absolute sovereignty and precedence of God over any and all parts of the world<sup>1</sup>, the infinite power of God who brings things into existence with sheer command, and His overflowing goodness which can only produce an intrinsically good world of matter, both in its entirety and in its parts.

When Genesis ch.1 is read, as it should be, with an eye on the *Enumah Elish*, the Babylonian creation myth, one cannot help being overawed by the diametrically opposite thrust of the two accounts about the origin of the universe<sup>2</sup>. It is through that implicit contrast that Genesis 1 offers its unique message: it is not the chaos, but God who is primordial, and to such a limitless extent that the unsavoury details of the emergence of gods from the chaos are not even considered worthy of rebuttal. Nor is any word wasted on arguing over the Babylonian dualism of matter and spirit, evil and good. The goodness of God, the maker of all, is simply asserted with the air of a matter-of-fact certainty that stands above all questioning.

Of particular note in this context is the account of the second day, the separation of the dry land from the “waters” which are the standard symbol of chaos and confusion, of the absence of purpose and the merciless dissolution of all. God pointedly does *not* call the waters “good”. The sovereignty of God over the waters is an important theme pervading the Bible. In the oldest Psalm Miriam sings triumphantly about Pharaoh’s demise in the Red Sea: *Sing to the LORD<sup>3</sup>, for he is highly exalted / The horse and its rider he has hurled into the sea*, and Moses elaborates: *You blew with your breath, and the sea covered them*. David sings similarly in Psalm 18:

I love you, O LORD my strength  
The LORD is my Rock, my Fortress and my Deliverer ...  
I call to the LORD, who is worthy of praise, and I am saved from my enemies  
The cords of death entangled me, the torrents of destruction overwhelmed me  
...  
In my distress I called to the LORD, I cried to my God for help ...  
The earth trembled and quaked, and the foundations of the mountains shook  
They trembled because he was angry ...  
The LORD thundered from heaven, the voice of the Most High resounded ...  
The valleys of the sea were exposed  
And the foundations of the earth laid bare at your rebuke, O LORD ...  
He reached down from on high and took hold of me  
He drew me out of deep waters

Jonah asserts the same truth from the bowels of the great fish in the depths of his extremity:

In my distress I called to the LORD, and he answered me  
From the depths of the grave I called for help and you listened to my cry  
You hurled me into the deep, into the very heart of the seas  
And the currents swirled around me

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<sup>1</sup> Thus light is created *before* the sun, the moon and the stars: light comes from God, not the sun. Worship of the heavenly bodies was strictly forbidden, and thus the sun and moon are not even named, but simply called “the greater and lesser lights”.

<sup>2</sup> Another contrast is length. The Genesis account (extending into Ch.2, v.3) is terse, having only 731 words in the Hebrew text, where the Babylonian extends over hundreds of lines on each of at least half a dozen clay tablets.

<sup>3</sup> I use LORD to render the Hebrew Tetragrammaton, the Name of God: YHWH, or Yahweh, which means “I am that I am”. God’s non-contingent self-existence was understood by the Hebrews from the earliest times even if Moses was the first to have this specific explanation (Exodus ch.3, v.14).

All your waves and breakers swept over me  
I said, I have been banished from your sight  
Yet I will look again towards your holy temple  
The engulfing waters threatened me, the deep surrounded me ...  
To the roots of the mountains I sank down, the earth beneath barred me in forever  
But you brought my life up from the pit, O LORD my God

The singer of Psalm 42 echoes Jonah, and it is clear that this is no dry philosophical truth, but a deep underpinning strength at an existential level:

As the hart pants after the water brooks, so panteth my soul for thee O LORD

...

My tears have been my food day and night  
While men say to me all day long, "Where is your God" ...  
Deep calls to deep in the roar of thy waterfalls  
All thy waves and breakers have swept over me  
By day the LORD directs his love  
At night his song is with me, a prayer to the God of my life  
I say to God my Rock, why hast thou forgotten me?  
Why must I go about mourning oppressed by the enemy? ...  
Why art thou downcast, O my soul, why so disturbed within me?  
Put thy hope in God, for I will yet praise him, my Saviour and my God

The second main message of Genesis 1, the message about man, should also be considered. The universe is depicted principally as an abode where man can develop his unique potentialities. These derive from the fact that only man is said to be the image of God, in sharp contrast to other creation stories imbued with pantheistic tendencies. The Hebrew cosmic view is subordinated to the destiny of mankind. That destiny is unique, coming as it does from God, the unique source of existence. Consequently, the universe too, being in its ultimate meaning an abode for man, is not an agglomerate of capricious events and processes but something which is complete because of the co-ordination of all its parts to its wholeness. This completeness is explicit in the concluding verses of the story: "the heavens and the earth were completed in all their vast array", followed by the description of the rest of God on the seventh day. These images would henceforth serve as the classical evocation of the final spiritual and cosmic completion of the Covenant in a new heaven and a new earth.

The second creation account of Genesis is hardly a cosmogony in the usual sense of the word. Its central theme, made absolutely clear at the outset, is about man: "When the LORD God made the earth and the heavens, and no shrub of the field had yet appeared on the earth, and no plant of the field had yet sprung up, for the LORD God had not sent rain on the earth, and there was no man to till the soil ..." The primary topic of the narrative is the making of man by God, an act which included the preparation of the whole of nature for them.

In this account, with its total lack of "scientific" detail, there is a highly elevated mentality which constitutes the very climate of scientific thinking. It is animated by that hallmark of scientific reasoning: an uncompromising consistency of explanation. There is only one effective cause, the power of God through which the heavens and the earth and everything in it has been formed. The LORD God is not challenged or complemented by any force or principle. The account exudes a clear atmosphere undisturbed by what turns all other ancient cosmogonies into dark and dispirited confusion: the infighting among the gods and the lurking in the background of an irreconcilable antagonism between spirit and matter, good and evil. The snake, the symbolic instigator of evil, is

itself utterly dependent for its existence upon the LORD God, and so is man who is seduced into defying God's command. Evil, unlike in most other cosmogonies, is here strictly circumscribed in its power and extent by God's sovereignty and goodness. The head of the snake will be crushed by the seed of the woman. Nothing could be more alien to the biblical outlook than the prospect of an endless tug-of-war between opposite cosmic and moral forces. The absolute sovereignty, rationality and benevolence of God leaves no room for a senseless replay of the greatest of all happenings, the formation of the heavens and the earth and of man's position as God's special handiwork.

Such a unique story became a unique source of inspiration. Thus in Psalm 8, the LORD's cosmic power and care for man are juxtaposed:

O LORD, our Lord, how majestic is your name in all the earth  
You have set your glory above the heavens ...  
When I consider the heavens, the work of your fingers  
The moon and the stars which you have set in place  
What is man that you are mindful of him  
The son of man that you care for him ...  
You made him ruler over the works of your hands ...

Again in Psalm 19 we find the same perspective of the lawfulness of the heavens forming a spectacular backdrop to the highest form of law: the law of the LORD showing the path of happiness to men:

The heavens declare the glory of God, the skies proclaim the work of his hand  
Day after day they pour forth speech, night after night they display knowledge ...  
The law of the LORD is perfect, reviving the soul ...  
The precepts of the LORD are right, giving joy to the heart  
The commands of the LORD are radiant, giving light to the eyes ...  
They are more precious than gold, than much pure gold  
They are sweeter than honey, than honey from the comb ...

The sovereignty of the LORD was patently incompatible with any pantheon of gods. Nevertheless, as compared with the religions of the various Canaanite tribes, to say nothing of the religions of mighty Egypt and Assur, the LORD's religion was a rather abstract and humble affair. No idols were permitted in Israel: *Who may ascend the hill of the LORD?* asks David in Psalm 24. He answers: *He who has not lifted up his soul to vanity*, that is, who has not prayed to idols. The chief attractiveness of idols lay in their concreteness and in the natural expectation that such gods could be swayed by the sweetness and glitter of sacrificial gifts. And they were attractive to the nation of Israel from patriarchal times through the Exodus from Egypt, the times of the Judges and the Northern and Southern kingdoms<sup>1</sup>. For a historian of ideas, few topics could be as full of suspense as the fate of this idea of monotheism which a relatively few tried to establish in its pristine purity on the wavering minds and loyalties of the vast majority, in a cultural context steeped in idolatrous, polytheistic and naturalistic proclivities.

One of the most cataclysmic and catalytic events in Jewish history was the destruction of Jerusalem in 585BC, and the 40 year long captivity in Babylon. By

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<sup>1</sup> Rachel stole her father's "household gods" (Genesis:31,19), both Aaron and Micah made idols (Exodus:32; Judges:17&18). The Northern kingdom ("Israel") fell to the Assyrians in 722BC, prior to this there were repeated efforts by the prophets to persuade the people to relinquish idolatry, notably Elijah's flamboyant challenge (1Kings:18). The Southern kingdom ("Judah", and hence "Jewish") fell to the Babylonians in 596BC, but with a fifth column of anti-idolatrous prophesying present continuously for the previous century including Isaiah, Hosea and Jeremiah.

all counts of probability the faith in the LORD, the Lord of all, should have completely disintegrated through those traumatic events and trials. What else could have more effectively proved the illusory character of a God than his apparent inability to protect his own city and nation from total devastation? What else could have more efficiently undermined the isolated faith of a few tens of thousands in the sole Maker of heaven and earth than the lengthy and oppressive exposure to the cult of the gods of Babylon, the very embodiment of power, success and refinement?

What actually happened constitutes a most baffling chapter in cultural history. Jewish monotheism emerged from the cauldron of captivity in a far more robust and in a far more incisive form. The confrontation with the pantheon of Babylon channelled startlingly new vigour into the faith in the LORD as the sole God of all. This confident faith is represented well by the biting satire which Isaiah (ch.44) uses to ridicule the popular making and worship of wooden idols:

They never think, they lack the knowledge and wit to say:  
“I burned half of it on the fire, I baked bread on the live embers  
I roasted meat and ate it;  
And am I to make some abomination of what remains?  
Am I to bow down to a block of wood?”  
A man who hankers after ashes has a deluded heart and is led astray  
He will never free his soul or say, “What I have in my right hand is a lie”

The uniqueness of this satire lies in the exposure of the mental blocks produced by idolatry. A comparable counterpart of it is simply non-existent in any other ancient literature, religious or philosophical. The same holds true of that soaring monotheism which generated the courage to decry idolatry: the most pervasive, the most hallowed, but also the most detrimental practice of all ancient cultures. Isaiah’s style rises to its highest level as he describes the LORD’s power beside which all forms and symbols of strength fade into nothingness:

O thou that tellest good tidings to Zion, get thee up into the high mountain  
O thou that tellest good tidings to Jerusalem, lift up thy voice with strength  
Lift it up, be not afraid, say unto the cities of Judah:  
*Behold, thy God*  
Behold, the Sovereign LORD comes with power, and his arm rules for him  
Behold, his reward is with him and his work accompanies him  
He tends the flock like a shepherd<sup>1</sup>, he gathers the lambs in his arm  
He carries them in his bosom, and gently leads those with young.  
Who has measured the waters in the hollow of his hand  
And marked off the heavens with the breadth of his hand  
And held the dust of the earth in a basket  
And weighed the mountains in scales and the hills in a balance?  
Who has understood the mind of the LORD or instructed him as his counselor?  
Whom did the LORD consult to enlighten him and who taught him the right way?  
Who was it that taught him knowledge or showed him the path of understanding?<sup>2</sup>

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<sup>1</sup> The juxtaposition of Sovereign and shepherd as attributes of God is not as abrupt as it would seem since "shepherd" is a David motif: “[David] shall shepherd my people Israel and shall become their ruler” (2Samuel 5:2). This was an important theme strongly developed by David: “The LORD is my shepherd” (Psalm 23:1) is only the most well known of many examples.

<sup>2</sup> J.A.Motyer comments on this in his authoritative *Isaiah* (Leicester: Inter Varsity Press, 1993): In Babylonian mythology the creator god Marduk could not proceed with creation without consulting ‘Ea, the All-Wise’, but the Lord works with unaided wisdom (see R.N.Whybray, *The Heavenly Counsellor in Isaiah 40:13,14*, Cambridge: CUP, 1971). In both Babylonian and Canaanite creation stories the creator must overcome opposing forces

... Do you not know? Have you not heard? ...  
 ‘To whom will you compare me, or who is my equal?’, *Holy* keeps saying<sup>1</sup>  
 Lift up your eyes<sup>2</sup> and look to the heavens: Who created<sup>3</sup> all these?  
 He who brings out the starry host  
 And calls them each by name by the greatness of his might  
 And as one strong in power<sup>4</sup>: not one of them is missing ...  
 Do you not know? Have you not heard?  
 The LORD is the everlasting God, the Creator of the ends of the earth  
 He will not grow tired, and his understanding no-one can fathom  
 He gives strength to the faint and increases the power of the weak  
 Even youths grow faint and weary, and young men in their prime stumble and fall  
 But those who hope in the LORD will renew their strength  
 They will soar on wings like eagles  
 They will run and not be weary  
 They will walk and not be faint

The justification for quoting such a lengthy passage lies in its conceptual and emotional richness. It throbs with a living unity making the ancient tree of the monotheism of the Covenant blossom into a magnificent new foliage. The old part was the emphasis on the unity of cosmic and human history based on the sameness of the Maker of the world and the Shepherd of his people. The new foliage was the triumphant confrontation with the idolatrous great cultures and the ensuing bold assertion that idolatry deprived man of basic insights into the fundamental characteristics of the world.

The confrontation with the Hellenistic world came in the middle of the second century BC. There was a full-scale religious persecution during which every observance of the ritual laws of the Covenant was savagely punished by death. Those ready to die based their course of action precisely on the consideration that the doctrinal and spiritual heritage of the Covenant was the highest form of understanding available to man which had to be maintained in its pristine purity whatever the price. The touchstone of that purity was the faith in the Maker of heaven and earth.

The immense bearing of that faith on single human destinies comes through with overpowering force and clarity in the final words of seven brothers arrested with their mother and put to death. In these words the conceptual riches of the faith in the LORD, the Lord of all, are unfolded step by step. The oldest brother

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before the way opens for the work of creation. To the contrary, the Old Testament not only tells the story of creation in a way that demands a monotheistic doctrine of God (Gen.1) but also uses the concept of creation to point to the fact of only one God (Ps.96:5). Here the Creator was alone both for the work of creation and also for the wisdom needed for the work.

<sup>1</sup> ‘*Holy* keeps saying’: that is ‘the Holy One keeps saying’. Isaiah was the first to use the phrase ‘the Holy One of Israel’ as a name for God, and here he uses the adjective *Holy* as a noun without either the definite article or the pronoun – literally *Holy*. (Motyer, *op.cit.*)

<sup>2</sup> The words *lift up* are used of astral worship in Deuteronomy 4:19, which was a temptation to Israel also in this period (see 2Kings 17:16 and 21:3) and an immense preoccupation in Babylonian religion. But impressive as the stars are, they are creatures. They may bear names in their respective cults, but their real names are those by which the Creator summons and directs them. They exist and are in place only by his will. (Motyer, *op.cit.*)

<sup>3</sup> *Created* is the verb *bara* that the Old Testament (unlike cognate literatures) reserves for the action of God, to express those acts which by their greatness or newness (or both) require a divine agent (Motyer, *op.cit.*). It is the word used in Genesis ch.1: it would be anachronistic to assign to it the meaning “create out of nothing”, this was articulated much later in the Hellenic world, and adopted by the Jews, as we shall see.

<sup>4</sup> *As one strong in power*: (lit.) ‘abundance of power’ emphasising that this is a personal exercise of sovereignty (Motyer, *op.cit.*).

recalls God's Covenant with Moses, as the sure token of his ultimate mercy. The second, third and fourth brothers refer to the foundation of the Covenant, to the creating God, the King of the world, and the Lord of heaven, whose purpose in creating will not be defeated by evil designs. Consequently, the final resurrection of the faithful is mentioned by them as the deepest consequence of the creation of man by God. The fifth and sixth brothers also speak as those who are really in a position to make accusations, revealing thereby a courage which astonishes the king and his attendants.

The most astonishing part of the story is the attitude of the mother who keeps encouraging each of her sons in the span of one single terrible day with the words: "I do not know how you appeared in my womb; it was not I who endowed you with breath and life, I had not the shaping of your every part. It is the creator of the world, ordaining the process of man's birth and presiding over the origin of all things, who in his mercy will most surely give you back both breath and life, seeing that now you despise your own existence for the sake of his laws." She did not waver when the king offered to save her youngest son if he showed readiness to reject the faith. The king even tried to engage the help of the mother to achieve his aim but the mother had her own brand of persuasion. Bending over her son she uttered words never before registered: "My son, have pity on me; I carried you nine months in my womb and suckled you three years, fed you and reared you to the age you are now (and cherished you). I implore you, my child, observe heaven and earth, consider all that is in them, and acknowledge that God made them out of what does not exist, and that mankind comes into being in the same way. Do not fear this executioner, but prove yourself worthy of your brothers, and make death welcome, so that in the day of mercy I may receive you back in your brothers' company."<sup>1</sup>

What Aristotle so explicitly rejected, the "creation out of nothing", Jewish thinkers embraced as the proper expression of the sovereignty of God. And as was formerly the case with the confrontation in Babylon, the pressure of trial produced priceless benefits both with respect to doctrine and to the impressiveness of existential testimony.

Jewish thinkers also had close contact with Hellenistic learning in Alexandria, the cultural hub of late antiquity, where there was a sizeable Jewish population by this time. They appreciated the knowledge that the Greeks could offer. But they also appreciated that only in the perspective provided by the Covenant can man grasp the uppermost of all knowledge, which is about the ultimate destiny of mankind and cosmos alike. Contemplation of the attributes of the LORD provides one with insights that reach far beyond the purely intellectual realm. These insights instruct man in the wholeness of his attitudes, sharpen his judgment about the intangibles and imponderables of life, and strengthen his will to follow the path of righteousness and virtue<sup>2</sup>. So, in the *Book of Wisdom's* commentary on the Plagues of Egypt, the author points out that God's power could have inflicted all these punishments in one single devastating blow, but such would not have been in line with the procedure typical of God who interacts in history in the same manner as he rules the cosmos: "They could have

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<sup>1</sup> 2Maccabees 7 (the book of Maccabees is in the Apocrypha, which is printed in the Jerusalem Bible and in the New English Bible)

<sup>2</sup> This is why true wisdom is described as the "breath of the power of God", the "emanation of the glory of the Almighty", the "reflection of the eternal light", and the "untarnished mirror of God's active power". Wisdom 7:25-26 (the book of Wisdom is in the Apocrypha)



dropped dead at a single breath ... But no, you ordered all things by measure, number, weight”<sup>1</sup>. The importance of this passage is in its subsequent impact. The ordering of all things by measure, number and weight served as inspiration and assurance for those who in late antiquity assumed the role of champions of the rationality of the universe. A thousand years later the expression was gladly seized upon by those who daringly started out on the road to unfold the marvels of God’s handiwork along the lines of quantitative enquiry.

What is strikingly new in the *Book of Wisdom* is the penetrating analysis of the social and cultural ills generated by idolatry. Thus, idolatrous honours accorded to kings dim the critical sense of the governed for the abuses of those who govern. Idolatry turns upside down the scale of values, to the extent that what patently constitutes an external and internal turmoil would appear as the normal course of events, with the result that the idolator gives “to massive ills [such as follow] the name of peace”:

With their child murdering initiations, their secret mysteries  
Their orgies with outlandish ceremonies  
They no longer retain any purity in their lives or their marriages  
One treacherously murdering the next or doing him injury by adultery.  
Everywhere a welter of blood and murder, theft and fraud  
Corruption, treachery, riots, perjury  
Disturbance of decent people, forgetfulness of favours, pollution of souls  
Sins against nature, disorder in marriage, adultery, debauchery<sup>2</sup>

This description will appear to be hopelessly biased to those who keep reconstructing Hellenistic antiquity from a very narrow segment of it represented by the best in its literature and scientific achievements. They then seek an answer to the puzzling decay of scientific and cultural efforts of late antiquity in causes that have relatively little to do with it. They strangely overlook in that particular historical context the general truth that effective cultivation of science needs an atmosphere if not of actual honesty and virtue, at least an atmosphere in which crime, falsehood, vices of all kinds are clearly recognised for what they are. For it is the very soul of science to call a fact a fact in all truth and honesty. Such an attitude cannot emerge in the relatively narrow field of scientific pursuit if parodies of facts, norms, and values are taken for genuine along with much of the gamut of human experience. Historians of science would do well to meditate at length on this. From the terse statement, “The worship of unnamed idols is the beginning, cause and end of every evil,”<sup>3</sup> there is much to be learned even about that evil which caused science to wither away in late antiquity.

Scientific breakthroughs, or new scientific instruments, are never easy to make. But they should seem child’s play when compared with the task of bringing about a never-before-experienced cultural – or rather, moral – climate in which the good, right, and truthful are accorded, in principle at least, unconditional respect. Not many would deny that no-one ever changed the world for the better as much as Jesus Christ, whose Good News about the love of God spread across a world lost in polytheism and idolatry. He took the centre of the Law of Holi-

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<sup>1</sup> Wisdom 11:20-21. This is only one instance of the ready assimilation of a typically Greek philosophical or scientific idea. But also, part of the Holiness code in Leviticus ch.19 (“be holy, because I, the LORD your God am holy”, v.1) is the solemn injunction to use “honest” measures of “length, weight and quantity” (v.35).

<sup>2</sup> Wisdom 14:23-26

<sup>3</sup> Wisdom 14:27

ness: *Love thy neighbour as thyself*<sup>d</sup>, that was accepted as the counterpart of the First Commandment, and said this about it:

If you love those who love you, what credit is that to you? Even sinners love those who love them. If you do good to those who are good to you, what credit is that to you? Even sinners do that. And if you lend to those from whom you expect repayment, what credit is that to you? Even sinners lend to sinners, expecting to be repaid in full. But love your enemies, do good to them, and lend to them without expecting to get anything back. Then your reward will be great, and you will be Sons of the Most High, because he is kind to the ungrateful and the wicked. Be merciful, just as your Father is merciful.

Love is considered by Jesus to be a part of the reasonableness of the Holy God, rooted in the very fact of Creation itself. So in one of his few recorded prayers he opens “full of joy through the Holy Spirit” with the invocation of the Creator, “I praise you, Father, Lord of heaven and earth ...”<sup>2</sup> He makes this reasonableness very concrete when he heals the sick, most explicitly in the case of the Gaderene madman whom he left “clothed, and in his right mind”<sup>3</sup>. And he expected to be hated by the world “without reason”<sup>4</sup> since by his holiness he shows up their wickedness.

The Good News about Jesus Christ is that the power of God that he exerted when he created the world still infuses every part of his creation: he raised Jesus from the dead as the “firstfruit of his salvation” and he is now “telling everyone everywhere that they must repent, because he has fixed a day when the whole world will be judged, and judged in righteousness, and he has appointed a man [Jesus Christ] to be the Judge. And God has publicly proved this by raising this man from the dead.”<sup>5</sup> Many have discovered in the risen Christ the supreme evidence of God’s love, mercy, and the proof of the reasonableness of all he made both in space and time, that is, in cosmic and human history. To keep this in mind is of crucial importance if one is to grasp the impact of Christianity on human culture. The insistence of Christianity on the rationality of nature, and on the ability of the human mind to recognise the Creator of nature, was never meant to be an isolated philosophical proposition.

What still animates Christianity is the conviction spelled out by St.Paul that “Christ is the image of the unseen God” in a most unique sense, and that only in Christ are deposited the ultimate rationality and purposefulness of everything in heaven and on earth. “It is the same God that said, ‘Let there be light shining out of darkness,’ who has shone in our minds to radiate the light of the knowl-

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<sup>1</sup> Leviticus 19:18,34: these injunctions are both followed immediately by the solemn pun, “I am the LORD” (“LORD” means “I am that I am”). The chapter starts with the reasoning and solemn injunction, “Be holy because I, the LORD your God, am holy”. The first Commandment (Ex.20:3 and Deut.5:7) is elaborated in Deut.6:4,5: *Hear O Israel, the LORD our God, the LORD is one. Love the LORD your God with all your heart and with all your soul and with all your strength,* and Jesus commented, *and with all your mind* (Matt.22:37; Mk.12:30; and in Lk.10:27 this reading is credited to an expert in the Jewish Law)

<sup>2</sup> Luke 10:21

<sup>3</sup> Mark 5:15; Luke 8:35

<sup>4</sup> John 16:25, quoting Psalms 35:19; 69:4

<sup>5</sup> Acts 17:31. The Day of Judgement is also a major theme in the Bible, from the *Dies Ira*, the Day of Wrath of Zephaniah 1:15 to Jesus’ sheep and goats of Matthew 25:31-46, from the Mountain of God of Isaiah 25 (‘... On this mountain he will destroy the shroud that enfolds all people ... he will swallow up death forever ...’) to the City of God in Revelation 21 (‘... He will wipe every tear from their eyes. There will be no more death or mourning or crying or pain, for the old order of things has passed away ...’).

edge of God's glory, the glory on the face of Christ." This is why Paul felt entitled to declare that by God's doing, Christ "has become our wisdom and our virtue and our holiness and our freedom." Thus, for the Christian, the ideal of perfection is tied to the ideal of the "perfect man in Christ," that is, a man who searches not just for narrow logic but for the understanding (in its broadest sense) that gives justice to the facts of nature as well as to the facts of history, and that satisfies man's senses as well as his innermost aspirations.

The Christian certitude about the rationality of nature and about man's ability to investigate its laws, owes its vigour to the concreteness by which Christ radiated the features of the creative God through the fulness of rationality which is God's love. "I am certain of this," wrote Paul, that "neither death nor life, no angel, no prince, nothing that exists, nothing still to come, not any power or height or depth, nor any created thing, can ever come between us and the love of God made visible in Christ Jesus our Lord." The sad consequence of man's refusal to recognise God from the created world makes a "nonsense out of logic" and to the darkening of the mind: "The more they called themselves philosophers, the more stupid they grew." The final stage of the process was the wholesale erosion of public and private honesty and morality.<sup>1</sup>

Obviously, neither the God of the Covenant nor his works can be trapped in endless cycles and blind repetitions. Only a cosmos and a history which represent a once for all process, with a fixed beginning and end<sup>2</sup> in time, are compatible with his essence.

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<sup>1</sup> The quotes are from: Colossians 1:15; 2 Corinthians 4:6; 1 Corinthians 1:31; Ephesians 4:13; Romans 8:38-39; Romans 1:21-22

<sup>2</sup> He says, "I am the Beginning and the End. To him who is thirsty I will give to drink without cost from the spring of the water of life." Revelation 21:6

## ***Islamic Science: Delay in Detour***

It was at Jundishapur in Southwest Persia in the sixth century that Syriac speaking Nestorian Christians established their centre of learning where much of the Greek scientific, philosophical and literary corpus had soon become translated into Syriac. Jundishapur was hardly the hub of the world's great crossroads, but its influence reached even as far as Athens. When in 529 Justinian closed the Academy there, some of its best scholars continued their work in effective exile in Persia. But this isolation suddenly changed in 641 when Persia became engulfed in the great wave of Muslim conquest that rapidly brought the political unification of a land area extending into three continents. In 732 the Arabs were storming the walls of Poitiers, the high water mark of their conquests in France.

Where the Roman Empire was a motley collection of cultures, traditions, races, religions and crass superstitions held together by a vague political myth centred on the *Pax Romana*, the Islamic empire imposed a new religious conviction codified in the Koran. For the first time in world history a giant and vigorous empire was steeped in a conviction that everything in life and in the cosmos depended on the sovereign will of a personal God, the Creator and lord of all.

The Koran did not specifically encourage secular learning, but as a book recited day in and day out it kept sparking in the Muslim mind a love for the written word. However, Arabian intellectual curiosity predated the advent of Mohammed: there were many Arabian merchants (including Mohammed), and Arabs also acted as civil servants for states in and around the Arabian peninsula. Thus, when Jundishapur became part of the Muslim world there was no lack of Muslim Arabs who had some intellectual training and appreciation for learning.

Jundishapur continued to flourish under the rule of the Umayyads, the first Muslim dynasty that ruled from Damascus. It is a good indication of the cohesive-ness of Muslim culture and of the love of learning among the followers of the Prophet that cultural endeavour suffered no setback as major political partitions developed in the Muslim world. The Umayyads were overthrown by the Abbasids who formed the Persian caliphate in 749 and founded Baghdad in 762. The sole survivor of the Umayyads, Abd-al-Rahman, escaped to Africa and established the caliphate of Cordova in Spain. A buffer state unsurprisingly emerged between Baghdad and Cordova when the Fatimid caliphate was set up in Egypt in the first part of the tenth century.

In all three caliphates serious concern for the promotion of learning had literally monumental proofs in the newly erected "Houses of Wisdom". During the reign of al-Mamun (813-33) an academy and observatory were set up in Baghdad. The Fatimid caliph, al-Hakim, who also excelled as an astronomer, established an institute of higher learning in the new city of Cairo in 966. In Cordova the caliph al-Hakim II (961-76) amassed more than 300,000 volumes for the library which almost immediately began to attract eager scholars from the Christian West: indeed an impressive proof of the Muslim love of learning was the hospitality extended to foreign scholars.

Through the work of the Indian astronomer, Manka, visiting in Baghdad, the principal Hindu astronomical works were translated into Arabic during the reign of the second Abbasid caliph, al-Mansur (754-75). About the same time Arabs became acquainted with the art of Chinese papermaking, and the manufacture of paper started in the Muslim world in a paper mill erected in Baghdad in 794. Systematic collection and translation of the Greek scientific and philosophical corpus got under way during the caliphate of Harun-al-Rashid. It was in large part the magnitude of this undertaking that stimulated the foundation of the Academy of Baghdad in 828.

Arab efforts to translate the Greek scientific and philosophical works excelled both in scholarly carefulness and in the resolve not to miss any documents. For example, Hunayn ibn-Ishaq (c.809-877) who, with his son and nephew, was the famed translator of the enormous medical and philosophical output of Galen<sup>1</sup>, travelled all across the Middle East to locate one book, and his method was to use at least three different manuscripts of the same work to permit a fair reconstruction of the original. Galen's domination of medical practice and teaching in the medieval East and in the West well into the Renaissance was due to Hunayn's translations. "The greatest clinician of Islam and of the Middle Ages"<sup>2</sup> was al-Razi (865-925), who came from Hunayn's school of medicine. Al-Razi is best remembered for *A Treatise on the Smallpox and Measles*<sup>3</sup> which has been reprinted more than forty times during the last four hundred years, contains the first clear description of the major symptoms of the two diseases and shows its author as a keen observer and respecter of facts.

The work of Arabic mathematicians contradicts the often voiced view that the eventual decline of science among the Arabs was due to the practical bent of their minds. Ability to systematize and gist for abstract analysis are already evident in the work of Al-Khwarizmi (died c.850)<sup>4</sup>. Tabit ibn-Korra (836-931) was the renowned translator of the works of Euclid, Apollonius, Archimedes and Ptolemy. He was also a original mathematician: a fine chapter on the solutions and properties of cubic equations has survived. Omar Khayyam, the world renowned poet, was also the author of an algebraic treatise in which he successfully solved cubic equations by exploiting Apollonius' work on conic sections<sup>5</sup>.

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<sup>1</sup> See G.Bergstrasse, *Hunain ibn Ishaq über die syrischen und arabischen Galen-Übersetzungen*, (Liepzig: F.A.Brockhaus, 1925). Hunayn also revised his translations as years went by and better translations came into his possession.

<sup>2</sup> Thus G.Sarton, *Introduction to the History of Science*, Vol.I: *From Homer to Omar Khayyam*, (Baltimore: The Williams & Wilkins Co., 1927) p.609

<sup>3</sup> Translated from the Arabic by William A. Greenhill (London: printed for the Sydenham Society, 1848). In the introduction by the translator 35 printings of the work in Greek, Latin, English, French and German between 1498 and 1787. He also wrote the medical encyclopaedia, *Kitab al-hawi*, that is, "Comprehensive Book", fittingly called since it included the whole of Greek, Syriac and early Arabic medical knowledge in addition to ample material from Persian and Indian medical sources. This was printed no less than five times in Latin translation between 1486 and 1542. See also "Science and Medicine", by M.Meyerhof in *The Legacy of Islam*, edited by Sir Thomas Arnold and Alfred Guillaume (London: Oxford University Press, 1931)

<sup>4</sup> His *Hisab al-jabr w'al muzaqalah* (*The Algebra of Mohammed ben Musa*, translated and edited by F.Rosen, London: printed for the Oriental Translation Fund, 1831) enjoyed great popularity in the medieval West. Quadratic equations are analysed at length, and rules for the calculation of square roots are among its subjects.

<sup>5</sup> *The Algebra of Omar Khayyam*, translated with commentaries by Daoud S.Kasir (New York: Columbia University, 1931). Omar pointed out that this work is original to himself, drawing attention to "certain very difficult introductory theorems, the solution of which has eluded ... those who have attempted it".

Al-Battani (877-918) was probably the most outstanding Arab scholar in the eyes of medieval and Renaissance men of science. It is due to his influence that Hindu contributions to trigonometry, such as the replacement of chords by the sine, had become firmly established<sup>1</sup>.

Muslim science made notable contributions to those parts of science which had, in the historical context at least, little or nothing to do with the laws of the physical world at large. Such was undoubtedly true of the Arab cultivators of mathematics and we have already mentioned the scientific contributions of influential physicians. It was in the field of Islamic medicine that Islamic science displayed its most sustained efforts, revealed most of its realistic sense for the facts of observation, and served evidence of its practical genius.

A good example of this is the pioneering and creative work of Arabic scholars in optics and ophthalmology. Ibn-al-Haitham (965-1038) was known as Alhazen by the medievals and wrote the *Kitab al-manazir*, the “Book of Optics”. A remarkable feature of his work was his emphasis on experimentation. He extended the investigation of the laws of reflection from plane to concave and parabolic surfaces, locating the focus of a paraboloid and discovering spherical aberration. He used the camera obscura and experimented with magnifying glasses, coming close to the modern theory of convex lenses and understanding much more than Ptolemy about refraction.

Ibn-Sina (980-1037) is far better known as Avicenna, the famed philosopher who was a strict Aristotelian. But he was bold enough to turn against the authority of Euclid and Ptolemy and claim that rays of light travel from the luminous object to the eye<sup>2</sup>.

The most incisive Arabic ophthalmologist was Ibn-Rushd (1126-98), better known as Averroes, who was also the most resolute advocate that Aristotle’s philosophy and world view probably ever had. Averroes broke new grounds for ophthalmology with his explanation of the role of the retina in the functioning of the eye.

An outstanding tradition is well represented by the caliph Ibn-abi-al-Mahasin whose treatise on ophthalmology, the *Kitab al-kafi fi al-Kuhl* (“The sufficient treatise on collyrium”, c.1265), is a systematic account of the anatomy of the eye, its diseases and treatments, including detailed discussion of some operations. The caliph had an unrivalled reputation as an eye surgeon for removing cataracts even in cases where one eye was already lost. The last notable product and fine capstone of Arab ophthalmology was the *Kitab al-umda*, written by al-Shadhili around 1375. Its novel details concerned the development of trachoma and the description of cancer of the eyelid.

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<sup>1</sup> He derived the formulas  $\sin\alpha = \tan\alpha / \sqrt{1+\tan^2\alpha}$  and  $\cos\alpha = 1 / \sqrt{1+\tan^2\alpha}$  (and hence the identity  $\sin^2\alpha + \cos^2\alpha = 1$ ). The creativity of the trigonometrical work of Abu-al-Wafa (940-c.997) is shown by his derivation of the sine rule:  $\sin(\alpha+\beta) = \sin\alpha\cos\beta + \sin\beta\cos\alpha$ . See A.von Braunmühl, *Vorleungen über Geschichte der Trigonometrie* (Leipzig: B.G.Teubner, 1900-1903), vol.I, pp.54-61; and Carra de Vaux, “Astronomy and Mathematics”, in *The Legacy of Islam*, pp389-90

<sup>2</sup> Avicenna’s million-word long *Qanun* (“Canon”) served for centuries as the standard textbook in Arabic medical teaching. It is a storehouse of fine observations and pathological information.

Notwithstanding the brilliance of Islamic scholarship in these fields, in physics Aristotle (“the first Teacher”) cast his long shadow. For al-Farabi<sup>1</sup> (c.870-950), “the second Teacher”, the most vexing problem had to do with the concept of creation. He struggled with the Aristotelian doctrine that the universe was a necessary being in every respect except perhaps for the place it occupied. This was in diametrical opposition to the Koranic position: “He rules supreme, that is, He has the power to make a being non-existent, namely, to deprive of existence those beings which as such deserves annihilation; for everything vanishes except He.”<sup>2</sup> Al-Farabi correctly saw that in order to solve the dilemma, a distinction should be made between beings that are necessary and being that are only possible with respect to existence. But al-Farabi failed to reserve for God exclusively the category of necessary beings. For him, following Aristotle, the heavenly regions and immaterial beings were also eternally and necessarily produced by God, or rather, *emanated* from Him. He, and most Muslim scientist-philosophers of any distinction, came under the full sway of the Aristotelian doctrine of the eternity and necessity of the heavens. While Arab scientists could give a half hearted or equivocal support to the creation out of nothing, the idea of creation in time found no real echo among them.

A trust in the possibility of a beginning in time was needed in more than one sense to achieve emancipation from the straightjacket of Aristotelian physics and its idea of motion. Avicenna had few rivals either as a physicist or as a metaphysician among the Arabs. But the single most puzzling paradox of Islamic science is this: Avicenna the physicist elaborated a critique of a special aspect of Aristotelian motion, and Avicenna the metaphysician nevertheless locked Muslim thought in the tracks of strict Aristotelianism astonishingly effectively.<sup>3</sup> Avicenna really believed in the identification of the heavenly bodies with God.<sup>4</sup>

Muslim thinkers failed to go beyond the Aristotelian position as they reflected on the Creator as the source of the laws of the physical world. Their view of the nature of the superlunary led unerringly, as it had for the Greeks, to an astrological cosmology. Al-Kindi (fl.850), the great encyclopaedist of the ninth century world, was a staunch defender of astrology<sup>5</sup> and the mentor of Abu-Mashar (fl.870), the most famed of all Arab astrologers. Abu-Mashar carried the art of

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<sup>1</sup> Al-Farabi wrote a treatise on music where musical theory is reduced to a study of the various fractions of a chord of unit length and the correlation among those fractions. Since the addition and subtraction of intervals corresponds then to the multiplication and division of fractions, one has at hand a correlation of notes which obeys a logarithmic law. Arab mathematical talent was also instrumental in giving to the Hindu numerals and decimal notation a more explicit form, in which it could successfully challenge the cumbersome Roman numerals and arithmetic.

<sup>2</sup> Al-Farabi’s *Philosophischer Abhandlung* (Leiden: E.J.Brill, 1890) after Sura XXVIII, v.88 in the Koran: “Everything shall perish except Him self.”

<sup>3</sup> G.Sarton, in *Introduction to the History of Science* said that for the fundamental questions of science, Avicenna’s impact “discouraged original investigations and sterilised intellectual life.”

<sup>4</sup> This is Averroes’ comment, in *Tahafut al-Tahafut* (“Incoherence of the Incoherence”), translated from the Arabic with introduction and notes by Simon van den Bergh (London: Luzac, 1954)

<sup>5</sup> See O.Loeth, “Al-Kindi als Astrolog,” in H.Derenbourg *et al*, *Morgenländischer Forschungen: Festschrift Herrn Professor Dr.H.L.Fleischer zu seinem fünfzigjährigen Doctorjubiläum am 4.März 1874* (Liepzig: F.A.Brockhaus, 1875). It is interesting that al-Kindi was a vehement critic of *al-khemi*, the Arabic name for the study of materials and compounds which came to stand for alchemy, the very embodiment of obscurantism. The cultivation of “chemistry” was denounced time and again as a largely worthless enterprise by some of the leading Arab scholars.

casting horoscopes for individuals and nations to its logical extreme. His “Book on the Revolution of Birth Years” is a painfully repetitious series of statements on how the fate of nations, rulers, religions and individuals is determined by the position of the various planets along the twelve signs of the zodiac.

Infatuation with cosmic and celestial cycles also meant a tacit or at least sub-conscious acceptance of a deterministic role of the celestial world on terrestrial processes and human affairs. This in turn could not fail to undercut man’s urge to explore the world, ferret out some of the secrets of its working, and try to dominate it. It is typical that the manifold absurdities of Abu-Mashar’s work did not receive an immediate and well deserved rebuttal among Muslim scholars.

We have already mentioned al-Biruni (fl.1000) as a scholar, himself the paradigm of learnedness among Muslims, who was scathing of Hindu scholarship. It had to wait for well over a century for al-Biruni to denounce “the follies committed by Abu-Mashar”<sup>1</sup>. For al-Biruni, his Muslim faith firmly imposed the finiteness of the world in time and prevented him from attributing a divine eternity to the heavens. The belief in an absolute and cosmic *end* was as much a basic part of Muslim orthodoxy as was the belief in an absolute *beginning* for creation. Al-Biruni also censured as a “foolish persuasion” the view of those for whom “time has no *terminus quo* at all”. But the very same faith did not make him affirm the absolute beginning of the world as a creation out of nothing, nor did the same faith make him perceive something specific about the Creator as the source of law and consistency in the physical world. And although he warned that the idea of the Great Year<sup>2</sup> had no real support in astronomy (since the planetary cycles were actually incommensurable) he nevertheless claimed that it was perfectly reasonable to compute cycles and to list the horoscope significance of each day from ancient calendars. And he wrote a voluminous treatise on astrology<sup>3</sup>: compressed between the opening and closing praise of Allah is a systematic presentation of all the information needed for the successful practice of a craft that had nothing to do with the veracity of the true God.

In astrology there was no room either for God creating freely, or for man acting freely and with responsibility. Of course, the Koran did not advocate astrology, which represented the very opposite to its impassioned insistence on the sovereignty of God. It nevertheless remained an eagerly practised art throughout the Muslim world. It should be a cause of some reflection that the Koran failed to inspire a single, extensive, rationally argued treatise against astrology. This is a striking illustration of the more general fact that the Koran did not provide the necessary mental encouragement and guidelines for a rational approach to the universe. The reason for this lies in the overly voluntaristic and moralistic tone

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<sup>1</sup> In his famous *The Chronology of Ancient Nations*. The subtitle of the English translation by C.E.Sachau reads: *An English Version of the Arabic Text of the Athar-ul-Bakiya of Al-biruni, or “Vestiges of the Past”* (London: W.H.Allan, 1879)

<sup>2</sup> Astrology and astronomy remained in the closest union so far as most Arab scholars were concerned, and inside that unity speculation about cycles retained a place of honour. An illustration of this is the specific connotation which grew around the words *tasyrat*, *intiha’at* and *fadarat* in Arab astronomical literature. All three came to stand in one way or another for the Great Year, or world year, or great cycle. For further details see the scholarly discussion by Edward S. Kennedy, “Ramifications of the World-Year concept in Islamic astronomy,” in *Actes des dixième Congrès International d’Histoire des Sciences, Ithica 26 VIII 1962 – 2 IX 1962* (Paris: Hermann, 1964)

<sup>3</sup> *The Book of Instruction in the Elements of the Art of Astrology*, by Abu’l-Rayhan Muhammed ibn Ahmad al-Biruni. Translation facing the Arabic original by R.Ramsay Wright (London: Luzac & Co., 1934)



of the Koran, and more particularly, in its emphasis on the will of the Creator. In the Koran no conspicuous effort is made to tie the sovereign decisions of God to His nature, that is, to His rationality. In other words, the will of God seems to be above any norm, however sound and intrinsically just such a norm may appear to human reasoning.

By the time of the Jewish Moses ben Maimon, better known as Maimonides (1135-1204) the heyday of the Islamic empire had passed: its science had come to a standstill, and even its days were numbered as its western and eastern flanks were soon to be lost. The Christians retook Cordova in 1236 and Seville in 1248, and ten years later the Mongolians devastated Baghdad. Maimonides, who was born in Cordova and became the caliph's physician in Cairo, is best known for his great philosophical work, the *Guide for the Perplexed*<sup>1</sup>, in which he offered a careful balance between faith and reason.

On the one hand Maimonides gave a penetrating critique of the abuse of reason by official Muslim theology, which leaned heavily towards occasionalism. Faith in the God of the Koran was not to inspire the picture of the universe in which laws and causal connections dominated. The most, Maimonides noted, that the theologians<sup>2</sup> were willing to admit about lawfulness in the universe was that it resembled human habits, such as the customary riding of the king of a city through its streets. Still, a king could readily break his habits, and so could any or all parts of the universe shift to a different "habit". Maimonides pointedly remarked: "the thing which exists ... only follows the direction of habit ... On this foundation their whole fabric is constructed."

On the other hand as we have seen, Muslim scientist-philosophers, under the influence of Aristotle, had fallen under the sway of necessitarianism. But precisely because of the biblical doctrine of creation, Maimonides could not follow the theologians and call into doubt the universality and permanence of physical laws. He kept insisting on the all-encompassing influence of the starry heavens on everything in the sublunary world, save, of course, man's freedom to act.

The defence of the permanency of the laws of nature was seen by Maimonides as a most natural corollary of the main purpose of his book: the full exposition of the scriptural account of the creation and its defence against philosophical objection. Clearly, for devout Jews it would be anathema to believe, with Aristotle, that "the Universe came into existence, like all things in Nature, as the result of the laws of Nature." As he concisely put it, with respect to the fixity of the laws of nature one had to agree with Aristotle "in one half of his theory". His explanation of this summarized an age-old faith, but its wisdom was also the voice of the future:

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<sup>1</sup> Translated from the original Arabic text by M.Friedländer (2<sup>nd</sup> rev. ed., 1904; New York: Dover, 1956)

<sup>2</sup> Thus, the influential mystic al-Ghazzali (1058-1111), known as Hujjatu-l-Islam ("Islam's convincing proof") wrote a book attacking the scientists which became a milestone of Muslim thought not only by its contents but also by its evocative title: *Tahafut-al-falisyah* ("Incoherence of the Philosophers", translated into English by Sabih Ahmad Kamali, Lahore: The Pakistan Philosophical Congress, 1958). He asserted that human reason had to stop at the observation of simultaneity, and forgo the obvious inference to causality: "... all these things are observed to exist *with* some other conditions. But we cannot say they exist *by* them ... On the contrary, they derive their existence from God ... So it is clear that existence *with* a thing does not prove being *by* it."

For we believe that this Universe remains perpetually with the same properties with which the Creator has endowed it, and that none of these will ever be changed except by a miracle in some individual instances, although the Creator has the power to change the whole Universe, to annihilate it, or to remove any of its properties. The Universe had, however, a beginning and a commencement, for when nothing was yet in existence except God, His wisdom decreed that the Universe be brought into existence at a certain time, that it should not be annihilated or changed as regards any of its properties, except in some instances; some of these are known to us, whilst others belong to the future, and are therefore unknown to us. This is our opinion and the basis of our religion.

This was also the basis on which the future of science was finally secured, when for the first time in history a whole culture espoused the genuinely Biblical doctrine of Creation as its very spiritual and intellectual foundation.

## The Sighting of New Horizons

Adelard of Bath (1075-1160) was one of those eager mediaevals who went on long and arduous journeys in the quest for learning. He travelled across the Muslim world as far as Aleppo and through his efforts as a translator medieval Europe got its first access to Arab trigonometry, to the description of astrolabes, and to Euclid's geometry<sup>1</sup>. His contacts with Muslim scholars certainly made him familiar with their frustrating struggle to reconcile faith and reason. This struggle was also occurring in Christendom: many of Adelard's contemporaries denied God, or identified Him with Nature. The high Middle Ages were intellectually a turbulent era and it is not surprising that pantheistic, atheistic and agnostic ideas were present. But while orthodoxy could be imposed violently, man's inner assent proved itself to be doggedly resistant to enforcement.

Adelard's *Quaestiones Naturales*<sup>2</sup> easily marks the true dawn of medieval science. It is written as a dialogue between the author and his nephew, who begins with the insistence that the spontaneous appearance of plant life in a dishful of dried soil was strictly miraculous. But Adelard incisively rejoins with a firm vindication of the prerogatives of both the Creator and His creation: "It is the will of the Creator that herbs should sprout from the earth. But the same is not without a reason either." For his nephew the natural explanation based on the doctrine of the four elements left something to be desired, to be remedied only by a recourse to God's universal effectiveness. But Adelard replies:

Whatever there is, is from Him and through Him. But the realm of being is not a confused one, nor is it lacking in disposition which, so far as human knowledge can go, should be consulted. Only when reason totally fails, should the explanation of the matter be referred to God.

During the Middle Ages, genuine devotion for miracles was second only to a rampant craving for the miraculous, and nature had enough mysteries of its own to feed appetites eschewing the exigencies of reason. But the autonomous character of nature and the possibility of its extensive rational investigation was re-

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<sup>1</sup> The most satisfactory modern, general survey of sciences during the Middle Ages is A.C.Crombie, *Medieval and Early Modern Science* (Garden City, N.Y.: Doubleday, 1959), which is the second, revised edition of his *From Augustine to Galileo: The History of Science A.D.400-1650* (London: Falcon Press, 1952). Shorter but less incisive is Part III, "The Middle Ages", by G.Beaudeau in R.Taton (ed.), *History of Science*, Vol.I, *Ancient and Medieval Science*, translated by A.J.Pomerans (New York: Basic Books, 1963). An enormous storehouse of information is the ten volumes of L.Thorndike, *History of Magic and Experimental Science* (New York: Columbia University Press, 1923-58), which covers the first seventeen centuries of our era. All modern discussions of medieval science stand in debt to Pierre Duhem's *Le système du monde: Histoire des doctrines cosmologiques de Platon à Copernic* (Paris: Hermann, 1913-55) in ten volumes. The complete absence of references to medieval science in *The Legacy of the Middle Ages*, edited by C.G.Crump and E.F.Jacob (Oxford: Clarendon Press, 1926), is a telling indication of the myopia that until recently dominated scholarship about scientific thought during the so-called Dark Ages.

<sup>2</sup> A critical edition of the *Quaestiones Naturales* was published by M.Müller in *Beiträge zur Geschichte und Theologie des Mittelalters*, Vol.31, Fasc.2 (Münster in W.: Aschendorff, 1934). On Adelard's life and scientific work, F.Bliemetzrieder, *Adelard von Bath* (Munich: Max Huber, 1935).

peatedly emphasised by Adelard, although his belief in the world as a product of an infinitely intelligent Creator also made him aware of the subtleties of nature that would not yield readily to the probings of human intellect.

Mediaeval man was also tempted by fatalism, whose chief vehicle was astrology<sup>1</sup>. The eleventh and twelfth centuries witnessed an onrush of translations into Latin of Arabic astrological treatises<sup>2</sup> and even of pieces of Hermetic literature<sup>3</sup>. Where science aspires to a reliable, although partial, grasp of the workings of nature, astrology claims a complete insight into the recondite intricacies of nature and human destinies. Medieval investigators of nature fell short of their goals in the measure in which they fell under the sway of astrology.

Thirteenth century writers lived in an age groping for a way out of the jumble of phenomena, but which did not wholly succumb to the magical and irrational in its quest for understanding. Their discourses on the parts and the whole of the universe typically mixed insights and rumours, sound principles and fantastic tales, critical sense and baffling credulity, reason and magic.

The best single illustration of this is probably the *De universo*<sup>4</sup> of William of Auvergne, Bishop of Paris (c1180-1249). The incessant references to the magical in the *De universo* have been the subject of an informative study<sup>5</sup>, but the same cannot be said about the equally pervasive presence there of the Christian doctrine of Creator and creation. William carefully refutes the notion of the Great Year, recognising that this represents the furthest reaching embodiment of the non-Christian world view<sup>6</sup>. He checks the craving for the miraculous explanation of various phenomena with a comment: "You should not trust the procedure of the inexperienced who in all cases, whose causes they do not know and are unable to investigate, take a facile recourse to the omnipotence of the Creator and call all such things miracles."<sup>7</sup> And he also criticised the necessitarianism of the orthodox Muslims: "Similarly, you must part with those who in such matters take refuge in almighty God's most imperious will, and wholly abandon these questions as insoluble, and feel themselves at ease when they say that the Creator willed it that way, or that His will is the sole cause of such things." The fatal error of such a stance had to do with the failure to distinguish between final

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<sup>1</sup> An early case in point is that of Bernard Silvester (fl. c. 1150) from the School of Chartres, whose *De mundi universitate libro duo sive megacosmus et microcosmus* (edited by Carl.S.Barach and Johann Wrobel (Innsbruck: Wagner, 1876) is full of astrological pantheism.

<sup>2</sup> These included Ptolemy's *Tetrabiblos*. See on this Theodore O. Wedel, *The Medieval Attitude towards Astrology, particularly in England* (New Haven, Conn.: Yale University Press, 1920), a study which though factually informative presents the conflict of Christianity with astrology as a clash between faith and science!

<sup>3</sup> The Hermetic literature, dating from the 1<sup>st</sup> to the 3<sup>rd</sup> centuries AD, purported to be the wisdom of Hermes Tremegistus ("Hermes Thrice-Lord"), the Latin name for the Egyptian god Thoth. This literature was translated into Arabic, and strongly influenced the orthodox Muslims, as evidenced by the prominence given to it in the encyclopedic summary of knowledge (the *Rasa'il*) compiled by the *Ikhwan al Safa* (the Brethren of Purity). Lengthy sections of this are available in German translation by F.Dieterici, *Die Naturanschauung und Naturphilosophie der Araber im zehnten Jahrhundert: Aus den Schriften der lauteren Brüder* (Berlin: Verlag der Nicolai'schen Sortt.-Buchhandlung, 1861).

<sup>4</sup> See *Opera omnia* (Paris: apud L.Billaine, 1674)

<sup>5</sup> See Thorndike, *History of Magic and Experimental Science (op.cit.)* on Arabic occult science and Latin astrology in the ninth, tenth and eleventh centuries.

<sup>6</sup> The six proofs and refutations presented had one thing in common: a very defective information about nature and its workings. Nevertheless, William was dissenting from massive ancient authority on the basis of the doctrine of Creation.

<sup>7</sup> This is in the context of a debate on how dogs can recognize thieves from a distance!

and secondary causality: “They err intolerably, first, because they assign only one solution to all such phenomena; second, because when asked about the cause, they refer to the remotest cause, although such questions are so varied that they cannot be settled by one single solution.”

Robert Grosseteste (c.1168-1253), Bishop of Lincoln, was a most influential figure of medieval scientific thought.<sup>1</sup> His treatises have a rationally clear atmosphere uncharacteristic for the age.<sup>2</sup> He could not have been more explicit about anchoring his methodology of science in the notion of God as Creator. He developed the application of his methodology in the course of his investigations of the rainbow,<sup>3</sup> including such seminal programmes as induction, falsification and verification.

Grosseteste considered all scientific measurements made by man to be intrinsically imperfect, as they are based on conventional units and not on counting the infinitely small, indivisible units (points) contained in every extension:

For how are we to know the number or quantity of that line which the first Measurer has measured? That quantity he reveals to no man, nor can we measure the line by means of infinite points, because they are neither known nor determined (*finita*) to us, as they are to God by whom they are comprehended. Whence this method of measuring is for us as uncertain as the first ... Therefore there is no perfect measure of continuous quantity except by means of indivisible continuous quantity, for example by means of a point, and no quantity can be perfectly measured unless it is known how many indivisible points it contains. And since these are infinite, therefore their number cannot be known by a creature but by God alone, who disposes everything in number, weight and measure.<sup>4</sup>

For Thomas Aquinas (1225-1274), the ultimate *raison d'être* of the cosmos consisted in its subordination to man's unique and supernatural destiny. Motivated by the sad predicament of Muslim theologians and philosophers, and by their highly unsettling impact on a Christian Europe going through its birth-pangs, he made a gigantic effort to bring reason and faith into a stable synthesis.<sup>5</sup> His polemical *Summa contra gentiles* (1257), aimed at countering the occasionalism and fatalism contending with one another within Muslim theology and philosophy and centred on questions about the Creator and the nature of human intellect. The *Summa theologica* (1273) is a work in which synthesis,

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<sup>1</sup> As amply evidenced by A.C.Crombie's magisterial monograph, *Robert Grosseteste and the Origins of Experimental Science 1100-1700*, Oxford: Clarendon Press, 1953)

<sup>2</sup> His still unedited treatises *Hexaameron* (in the British Museum) and the *De universitatis machina* (in the Cambridge University Library) are further documentary indications of the measure in which his scientific methodology depended on the idea of the Creator as a wholly rational, personal Planner, Builder and Maintainer of the universe.

<sup>3</sup> In his *De lineis*. His critique of Aristotle's and Seneca's explanation of the rainbow by reflection and his original account of it by refraction represented an indispensable step towards the adequate solution offered less than a century later by Theodoric of Freiburg (d. 1311). He emphasised that the rainbow could be studied by approximating the clouds by a single water-filled sphere, a powerful suggestion towards the recognition of the role of individual raindrops in the process.

<sup>4</sup> This is from the very able summary of Grosseteste's thought by William of Alnwick, regent-master of the Oxford Franciscan House in the 1310s. We would still agree essentially with this today, notwithstanding some quibbling with the details.

<sup>5</sup> The classic treatment of this is that by E.Gilson in his *History of Christian Philosophy in the Middle Ages* (New York: Random House, 1955), pp.361-86, with extensive bibliography. The Muslim philosophical struggles, against which Aquinas' efforts should be viewed, are well presented in Majid Fakhry, *Islamic Occasionalism and its Critique by Averroes and Aquinas* (London: George Allen & Unwin, 1958)

not polemics, dominated. It is difficult to overemphasise its importance in the history of Western theology. However, in both of these books Aquinas went to surprising lengths in accepting Aristotle's cosmology. Thomas' resolve to give reason its due in the highest possible measure meant an overly generous acceptance of the Aristotelian system, the epitome of rational explanation of the world at that time. In fact, Aquinas departed from Aristotle only in cases where the Christian creed allowed under no circumstances for a compromise. In particular, he rejected the Greek claim about the endless cyclical rejuvenation of the cosmos, noting that the new heaven and new earth were supernatural, "just as grace and glory are above the nature of the soul".<sup>1</sup>

Aquinas is notable for his lack of appreciation for experimental investigation, but this was not a particular characteristic of his contemporaries. His master, Albertus Magnus (1200-1280), was a notable experimenter<sup>2</sup> and Roger Bacon (1220-1292) published his *Opus majus* in 1267<sup>3</sup>.

Aristotle had his share of critics long before the mediaevals, but the pantheistic necessitarianism of his synthesis had never received a broad and effective challenge before Christianity developed into an all-pervading cultural matrix during the Middle Ages. It was this matrix of a commonly shared belief that was nurtured in part by a uniform educational system, consisting of universities, cathedral schools and monasteries, the like of which neither Greece, nor Rome, nor any ancient great culture was ever able to produce. And it was in the context of this belief that the rejection of the autonomy of philosophy espoused by Aristotle was firmly established in the late thirteenth century<sup>4</sup>.

It was on the 7<sup>th</sup> March 1277 that Etienne Tempier (d.1279), Bishop of Paris, condemned a list of 219 propositions. This decree is a classic manifestation of the firmness of mediaeval Christians already in possession of the Greek philosophical and scientific corpus. They made their stand in the conviction that their

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<sup>1</sup> Aquinas' acceptance of Aristotle can be seen in, for example, the chapter on "The Quality of the World after the Judgement" (Question 91, from which the quote in the text was taken). This topic, central to Christian understanding, meant a most acute confrontation with the very heart of Aristotle's cosmology and theory of motion. The presence of cyclic features in the world was an unassailable truth for Aquinas, who firmly reasserted the efficient causality of a rotating sky on everything in the sublunary world. He found no fault with the generic return of physical patterns, including plants and animal species. He also went along with Aristotle on the point that the cosmos would *of itself* go on forever through endless begettings of individuals. But God would not leave the cosmos to itself since "the elect are in a certain number preordained by God, so that the begetting of men will not last forever." Also, the Great Year could not be determined by the period of the precession of the equinoxes (or by any other method) since this would allow the calculation of the moment of the world's end, in contradiction to the Gospel.

<sup>2</sup> On Albertus Magnus's scientific programme and accomplishments see the twenty two essays in *Angelicum* Vol.XXI (1944).

<sup>3</sup> Bacon (ca.1219-ca.1292). *The 'Opus Majus' of Roger Bacon*, edited with an introduction and analytical tables by John H. Bridges (Oxford: Clarendon Press, 1897). A short, delightful, and still scholarly introduction to Roger Bacon's life and work is *Roger Bacon in Life and Legend*, by E. Westercott (New York: Philosophical Library, 1953). Bacon's science is the topic of the majority of essays in *Roger Bacon: Essays contributed by Various Writers on the Occasion of the Seventh Centenary of his Birth*, collected and edited by A. G. Little (Oxford: Clarendon Press, 1914).

<sup>4</sup> This view is emphatically put by A.N.Whitehead, the celebrated mathematician, when he pointed out, in a lecture to a distinguished audience at Harvard, that "the faith in the *possibility* of science" was "generated *antecedently* to the development of modern scientific theory" and is a "derivative from mediaeval theology", *Science and the Modern World: Lowell Lectures, 1925* (New York: The Macmillan Company, 1925) (my emphases).

belief in the “Maker of Heaven and Earth” imposed on them radical departures from some basic assumptions of Greek learning and world view. What was ultimately at stake was man’s rather newly acquired awareness of the contingency of the world with respect to the source of all rationality, the transcendental Creator<sup>1</sup>.

The rejected propositions included: the eternity of the world; the periodic recurrence of everything; that our world was necessarily unique; that the superluminary material was animated, incorruptible and eternal; the impossibility of rectilinear motion for celestial bodies; that their actual motion was sparked as if by animal desire; that the celestial orbs were like organs equivalent to the eyes and ears of the human body, although thinking of them as part of celestial machinery was permissible; that the stars have a determining influence on individuals from the moment of birth; and that the “first matter” was necessarily produced from celestial matter.

All of these propositions were asserted unequivocally by Aristotelians, but were firmly rejected by the mediaeval church to safeguard the abilities and exclusive rights of the Creator. A good case can be made for this 1277 decree as being the starting point for a new era in scientific thinking, and there is no doubt that the rise of classical physics depended on the rejection of Aristotelian physics<sup>2</sup>. The next century saw tremendous advances in physics, among the most pivotal of which were the mediaeval anticipation of the concepts of inertia and momentum; the mediaeval assertion of the possibility of a three dimensional infinite vacuum; the groping for quantitative in addition to qualitative accounts of physical processes; and finally, the realisation of a basic need for experimentation if progress was to be made in understanding and conquering nature.

A particularly good example is that of John Buridan’s (c.1295-c1360) commentary on Aristotle’s programmatic exposition of his world view: *De caelo (On the Heavens)*<sup>3</sup>. This commentary was later read by Galileo, who quoted from it nearly word for word to refute Aristotle’s explanation of projectile motion<sup>4</sup>. In the place of the Aristotelian insistence on the existence of intelligences that move the planets and stars in their spheres Buridan has the concept of “impetus” whereby a motion can be impressed on a body which then retains it, in the ab-

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<sup>1</sup> See P.Mandonnet, *Siger de Brabant et l’averroïsme latin au XIII<sup>e</sup> siècle* (2<sup>nd</sup> rev.ed.; Louvain: Institut Supérieur de Philosophie de l’Université, 1908-11). A topically arranged list of the condemned propositions is available in English in L.Lerner & M.Mahdi, *Mediaeval Political Philosophy: A Sourcebook* (New York: The Free Press of Glencoe, 1963). Siger was a leading academic at the University of Paris, a radical Aristotelian (or Averroist as he was known) who was caught by this decision. It is ironic that Roger Bacon was also imprisoned in Paris sometime between 1277 and 1279 for obscure reasons that were quite possibly related to this 1277 decree.

<sup>2</sup> This is the thesis of the last five volumes of Pierre Duhem’s monumental *Le Système du Monde: Histories des doctrines cosmologiques de Platon à Copernic* (Paris: Hermann, 1913-1955, 10 volumes). It was Duhem’s pioneering investigations of the mediaeval origins of classical physics that almost single-handedly spurred a renewed interest in mediaeval science.

<sup>3</sup> John Buridan (ca.1295-ca.1358), *Quaestiones super quattuor libris de caelo et mundo*, ed.E.A.Moody, Cambridge Mass.: The Medieval Academy of America, 1942). When Copernicus was a student at Cracow, Buridan’s works in physics were required reading (E.A.Moody in *Dictionary of Scientific Biography*, New York: Scribners, 1970)

<sup>4</sup> As noted by Moody in his introduction to Buridan’s *Quaestiones* (op. cit.). Galileo read Albert of Saxony’s *Quaestiones de caelo et mundo*, a slightly modified version of Buridan’s *Quaestiones*, in the collection of mediaeval writings in physics published by G.Lockert in Paris in 1516 and 1518.

sence of friction, forever. (Or until the Creator brings the universe to an end, another denial of the Aristotelian assertion of the incorruptibility of the heavens.) And Buridan supported his anti-Aristotelian position by saying:

that God, when He created the world, moved each of the celestial orbs as He pleased, and in moving them He impressed in them impetuses which moved them without His having to move them any more except by the method of general influence whereby He concurs as a co-agent in all things which take place; “for thus on the seventh day He rested from all work” which He had executed by committing to others the actions and the passions in turn<sup>1</sup>.

But Buridan’s originality made itself felt mainly through the writings of his most outstanding disciple, Nicole Oresme (ca.1323-1382) who in about 1375 wrote a very influential commentary on Aristotle’s *On the Heavens: Le Livre du ciel et du monde*<sup>2</sup>. In this work Oresme elaborates Buridan’s strictures on Aristotelian physics, with a clear awareness of the ultimately theological roots of the crucial difference between his thinking and Aristotle’s account of the universe. Interestingly, he made several references to the 1277 decree of Bishop Tempier, even though this no longer had any legal force as it had been revoked in 1325. It is in this book that the heavens are likened to God’s clockwork:

If we assume the heavens to be moved by intelligences, it is unnecessary that each one should be everywhere within or in every part of the particular heaven it moves; for, when God created the heavens He put into them motive qualities and powers ... thus ... the situation is much like that of a man making a clock and letting it run and continue in its own motion by itself.

For Oresme there is nothing special about the heavens, they were made by God like everything else. Like Buridan he specifically rejects the Aristotelian assertion of the divinity (and hence the incorruptibility) of the heavens: “Thus Aristotle calls the heavens a divine, and Averroes a spiritual, body because they consider them to be animated by the intelligence, which is God, that moves them, and so the heavens are divine. This we refuted in Chapter Five.” Later, Galileo will wage a sustained campaign to convince people of this same truth.

The scientific legacy of the Middle Ages included an impressive array of crucial technological inventions, such as the first mechanical clocks, that were immediately referred to as small replicas of the Creator’s great clockwork, the universe. Analysis of the motivation behind these advances often indicates with impressive explicitness, a firm faith in the words spoken in the Beginning. The Light diffused there was also the illumination that made possible the sighting of new and reliable horizons about the universe.

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<sup>1</sup> From Buridan’s commentary on Aristotle’s *Physics*. The whole context in which projectile motion is discussed is given in English translation in M.Clagett, *The Science of Mechanics in the Middle Ages* (Madison: University of Wisconsin Press, 1959). Later developments showed that Buridan was indeed a pioneering forerunner of Galileo, and the earliest representative of the mechanistic spirit of classical physics.

<sup>2</sup> Edited by Albert D. Menut and Alexander J. Denomy. Translated with an introduction by Menut (Madison: University of Wisconsin Press, 1968)



## The Interlude of "Re-naissance"

When Oresme died in 1382 the Middle Ages were already on the wane. The Italian Rinascimento<sup>1</sup> was a revival of classical antiquity whose first great figures were the friends Petrarch (1304-1374) and Boccaccio (1313-1375). The fifteen books of *The Genealogy of the Gentile Gods*<sup>2</sup> by Boccaccio was published in final form in 1373, and became the sourcebook for all Humanists who, for the next two centuries, discoursed about the world in terms of allegories. Petrarch's *Secretum*<sup>3</sup> gave an unmistakable insight into the deepest recesses of his aspirations and motivations: he anchored his own programme of spiritual perfection in the dicta of ancient Greek moralists. What attracted him to the spirit of classical antiquity consisted in the self-centred aestheticism and philosophical mysticism that dominated classical thought during much of its Hellenic period (see ch.6).

Plato was admired throughout the Renaissance, but we shall show that the Neoplatonism with which many thinkers of this period dallied was inimical to the clarity of thought needed for scientific progress. Conversely, the valuable contribution to scientific understanding was made by thinkers whose faith in the intelligibility of the world was rooted in a sincere attachment to the Christian God. We therefore specifically challenge the Voigt-Burckhardt<sup>4</sup> thesis that the Italian Renaissance forms the cradle of modern Western mentality and culture.<sup>5</sup>

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<sup>1</sup> The Rinascimento, or Renaissance, literally "rebirth". Jaki emphasises the strong philosophical currents which return to the antique belief in endless "re-naissances", hence the hyphenated "Re-naissance" of the chapter title. "Whatever there was philosophical in the Rinascimento, it was largely a reaffirmation of Neoplatonism, and of its studied neglect of a reasoned investigation of the external world."

<sup>2</sup> *De genealogia deorum gentilium*

<sup>3</sup> See *Petrarch's Secret; or, The Soul's Conflict with Passion. Three Dialogues between Himself and S. Augustine*, transl. W.H. Draper (London: Chatto & Windus, 1911)

<sup>4</sup> *Die Wiederbelebung des klassischen Altertums, oder das erste Jahrhundert des Humanismus*, G.Voigt (Berlin: G.Reimer, 1859); *Die Kultur der Renaissance in Italien*, J.Burckhardt (Leipzig: Seemann, 1860)

<sup>5</sup> Although books on the Renaissance are legion, appreciation of Renaissance science has until rather recently been considerably weakened by the claim of the Encyclopaedists that everything was dark before Galileo. The section "Renaissance" in R.Taton (ed) *History of Science*, vol.II, *The beginnings of Modern Science from 1450 to 1800*, transl. A.J.Pomerans (New York: Basic Books, 1964) is probably the best general survey, partly because it was co-authored by A.Koyré. But Koyré's well known contention that the revival of Platonism was the crucial factor in the birth of classical physics, also implies a studied neglect of the role that the Christian faith in the Creator played in that birth. Another recent work that should be mentioned is M.Boas, *The Scientific Renaissance 1450-1630*, (New York: Harper & Brothers, 1962). It should be significant that for historians of science the Renaissance starts around 1450 whereas the Rinascimento got under way much earlier and was a thing of the past by 1600. This time difference between scientific and literary Renaissance is one of the evidences about a profound difference between the two. This difference received a fine analysis in G.C.Sellery's *The Renaissance: Its Nature and Origins* (Madison: University of Wisconsin Press, 1950). On the other hand, none of the studies in *Renaissance Essays*, P.O.Kristeller and P.P.Wiener (eds.) (New York: Harper & Row, 1968), tried to trace the scientific bareness of the literary (and philosophical) Renaissance to its infatuation with Neoplatonism and to its flirtation with the idea of the Great Year.

Nicolas of Cusa ("Cusanus", 1401-1464<sup>1</sup>) published his *De Docta Ignorantia* in 1440<sup>2</sup>. The reasoning in this book is distinctly Platonic. He defends Plato's teaching against Aristotle's criticism. In fact, he makes a resolute departure from the closed Aristotelian universe, discards the absolute motionlessness of the earth, proposes the basic similarity of all cosmic bodies and claimed unhesitatingly the presence of living beings everywhere in the universe. Any of these startling propositions could have secured for Cusanus a lasting place in the history of science. But he carved for himself a special niche not only by presenting a whole array of such propositions, but by putting them forward as part of a tightly knit system of thought.

Yet whenever Cusanus spoke of Plato and the Platonists, he did so with a eye on the doctrine of Creation. He unhesitatingly laid bare the essential differences between the Platonist theory of the origination of the world and the Christian dogma of creation. Plato shared with all ancient philosophers the dictum *ex nihilo nihil fit*<sup>3</sup> and precisely because of this, so Cusanus argued, Plato's account of the ideas failed to do justice to the absolute distinctness of God from the world.

The principal Neoplatonist of the period was Marcilio Ficino (1433-1499) was the renowned and brilliant leader of the Platonic Academy in Florence<sup>4</sup>. He was the first to translate Plato in full, and also translated the Neoplatonists Plotinus, Porphyry and Iamblichus<sup>5</sup>, as well as the occult writings of Hermes Trimegistus. Modern admirers of Ficino's "soaring humanism", who could poke fun at the "nonconcept" of creation out of nothing, found no fault with the noncommittal faith with which Ficino espoused the doctrine of creation<sup>6</sup>. A portrayal of Ficino's philosophy which makes no reference to Ficino's addiction to magic and astrology comes very close to being a caricature<sup>7</sup>. Ficino's espousal of the crowning tenet of astrological lore, the doctrine of the Great Year, could hardly have been more energetic and explicit. For him it was important, just as it was for Plotinus, to discuss the number of men generated within one Great Year. Ficino spoke in a matter-of-fact style about the identical return of all forms as

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<sup>1</sup> Cusanus has been claimed by the Theosophists as the first mediaeval Neoplatonist  
<sup>2</sup> transl. G.Heron, *Of Learned Ignorance*, (London: Routledge & Kegan Paul, 1954). Cusanus pointedly anchored man's "learned ignorance" in Paul's word in 1Cor.13 about "seeing in a glass darkly" (Book I ch.11)  
<sup>3</sup> "Out of nothing is nothing made"  
<sup>4</sup> founded by Cosmo de Medici in 1462. It survived until the death of Lorenzo the Magnificent, after which it went underground  
<sup>5</sup> Late Roman philosophers: Plotinus 204-270, Porphyry c232-305, Iamblichus c250-30. Pico della Mirandola said of these in his *Dignity of Man*: "In Porphyry you will be pleased by an abundance of materials and a complex religion. In Iamblichus you will feel awe at a more hidden philosophy and at the mysteries of the barbarians. In Plotinus there is no one thing in particular for you to wonder at, for he offers himself to our wonder in every part."  
<sup>6</sup> See, for instance, P.O.Kristeller *The Philosophy of Marsilio Ficino* (translated from the German manuscript - finished in Pisa in 1938 - by Virginia Conant, New York: Columbia University Press, 1943; this work could not be published in Italy because of Mussolini's racial laws). It is no accident that Ficino's only explicit discussion of creation runs to a mere nineteen lines in the two heavy folio volumes of his collected works: *Opera Omnia* (1561), reprint edition by Bottego Erasmo (Torino, 1959) vol.1, tom.1, p.492  
<sup>7</sup> Only by ignoring such details is it justified to praise "the spectacular humanistic movement and ... the personally more novel and original literary Platonism of the Florentines" (in J.H.Randall Jr., *The Development of the Scientific Method in the School of Padua*, 1940, reprinted in his *The School of Padua and the Emergence of Modern Science*, Turin: Editrice Antenore, 1961)

one Great Year followed another. The Renaissance he represented was a return to the antique belief in endless re-naisances.

Pico della Mirandola (1463-1494) was another brilliant mind. He started the study of canon law at fifteen, and in ten years he was a master of philosophy and theology. Ficino befriended him on his visits to Florence, and introduced him to Plato, Plotinus and the Hermetic literature. In 1488, after a year in Paris, Pico published *On the Dignity of Man*<sup>1</sup>, a collection of 900 theses for disputation. In this book there is hardly a trace of the limits that could stand in the way of one's efforts to become a truly universal man. Pico was confident that all differences could be reconciled with enough good will, persistence and talent. For the universal man every philosophy and every creed was a treasure chest of practically equal worth. Cabbala and magic were as instructive as the most highly regarded branches of theology and philosophy. Perhaps it is surprising that no more than four of these theses were found to be heretical, but Pico was forced to retire from public life. Through Ficino's good services he was given a villa at Fiesole by Lorenzo di Medici.

In Fiesole, Pico changed his mind. In the year he died at the youthful age of thirty-one he completed a massive attack on astrology, the *Disputationes adversus astrologiam divinatricem*<sup>2</sup>. The *Disputationes* is a spirited effort to break through the the clutches of astrological fatalism and secure thereby the dignity of man rooted in his moral freedom. The injudiciousness of the earlier work can be seen at once, if the praise in it of Roger Bacon is contrasted with the sustained attack in the *Disputationes* on the volatile friar's support for astrology<sup>3</sup>.

Pico's repeated insistence that a Christian cannot at the same time be a Chaldean marks not only a crucial departure from the syncretistic Neoplatonist Christianity of the *Dignity of Man*. It also flies in the face of the astounding claim that Pico conquered astrology through a purely humanistic faith in the autonomy of the creative powers of man which "excludes the possibility of any determination from without, be it 'material' or 'spiritual' "<sup>4</sup>. For Pico, human freedom is anchored in the creative power of God, and one can only explain why he devoted numerous chapters to showing that astrology could be of no help whatever to Christian religion when the biblical and theological tone of his analysis of human freedom is kept in mind. The heart of Pico's work, the finest critique of astrology and its worldview written in the Renaissance, is the warning that the

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<sup>1</sup> transl. Charles G. Wallis (Indianapolis: The Library of Liberal Arts, 1965)

<sup>2</sup> E.Garin (Florence: Vallecchi, 1946)

<sup>3</sup> Roger Bacon (1220-1292) occupies a curious position in the history of science. Evaluations of his place in it range from lopsided encomiums to studied neglect. A short, delightful and still scholarly introduction to his life and work is *Roger Bacon in life and legend*, E.Westacott (New York: Philosophical Library, 1953). Bacon's science is the topic of the majority of the essays in *Roger Bacon: Essays Contributed by Various Writers on the Occasion of the Seventh Centenary of his Birth* collected and edited by A.G.Little (Oxford: Clarendon Press, 1914). Bacon's impetuous crusading to secure the service of science on behalf of the Christian faith has much of the boldness and drama that became the hallmark of Galileo's career. But in his *Opus Majus*, composed in 1267 for the Pope, he held (among many other things) that the temperament of individuals was completely determined by the influence of the stars (although individual decisions were not). In Bacon one can see the enormous lure of a worldview in which the cyclic course of celestial bodies ruled and eventually brought back whatever had happened.

<sup>4</sup> This claim was made by E.Cassirer in his *The Individual and the Cosmos in Renaissance Philosophy*, rranslated with an introduction by Mario Domandi (New York: Barnes & Noble Inc, 1963) p.119

Christian belief in creation was incompatible with astrological periods and eternal recurrences.

The Platonic Academy to which Pico belonged was certainly the most representative and novel aspect of the rebirth of letters in the fifteenth century, apart from the cultivation of poetry in the vernacular, but it had little if anything to do with scientific endeavour. For instance, Leonardo da Vinci<sup>1</sup> was strongly influenced by Cusanus, and his notebooks reveal a revulsion against magic, astrology and necromancy in his devout reverence for the Creator and his evangelical piety. Similarly, Copernicus' work owed little if anything to the literary Renaissance, let alone its unabashed paganism or to its "revolutionary" spirit. Copernicus' own thorough conservatism has remained unnoticed until quite recently.<sup>2</sup> By the time Copernicus arrived in Italy, his commitment to the heliocentric system seems to have been firmly established.<sup>3</sup> This commitment was based on the principle of simplicity, which in turn was based on Copernicus' faith in the simplicity of nature.<sup>4</sup> Such a faith, as Galileo explained later, rested on the Christian faith in the Creator, whose nature demanded that his handiwork should reflect his own perfect simplicity. Curiously, what Galileo found it so important to emphasise, many a historian of science preferred to belittle.<sup>5</sup>

Copernicus's contemporary Thomas More (1478-1535) published in the *Utopia* an extraordinarily influential book<sup>6</sup>, informed by More's deeply Christian perspective.<sup>7</sup> No single book written by an English author before the nineteenth cen-

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<sup>1</sup> Leonardo da Vinci (1452-1519). See *The Notebooks of Leonardo da Vinci*, arranged, rendered into English and introduced by E.MacCurdy (Garden City NY: Garden City Publishing Company, 1941) pp.81-87, and E.MacCurdy, *The Mind of Leonardo da Vinci* (New York: Dodd, Mead & Co., 1928) pp.213-29. The efforts to present Leonardo as a free-thinker started with Vasari's *Lives* and still characterise today the majority of studies on Leonardo. Others credit Archimedes' influence for everything valuable in Leonardo, to the exclusion of the mediaeval scientists whom he carefully studied. Examples of this are the essays and discussions commemorating the fifth centenary of Leonardo's birth: *Leonard de Vinci et l'expérience scientifique au XVIème siècle, Paris, 4-7 juillet 1952* (Paris: Centre Nationale de la Recherche Scientifique, 1953).

<sup>2</sup> Copernicus: 1473-1543. His debt to tradition was enormous, as concisely set out in H.Butterfield in *Origins of Modern Science* (London: Bell, 1949)

<sup>3</sup> See on this the findings of the great Polish scholar, L.A.Birkenmajer, reported by his son A.Birkenmajer, "Comment Copernic a-t-il conçu et réalisé son oeuvre?", *Organon: Revue Internationale* (Warsaw) 1 (1936): 123 and 126

<sup>4</sup> There was of course nothing novel in this since simplicity was an avowed ideal for ancient Greek astronomers: still, they found it impossible to abandon the evidence of their senses and their philosophical geocentrism for the the greater simplicity of a heliocentric system. In the *Almagest* Ptolemy called it ridiculous and absurd to remove the earth from the centre of the universe. Galileo later pointed out (in the *Dialogue*) that Copernicus had to commit a rape of his senses in putting forward the heliocentric ordering of planets. Curiously, neither the Copernican nor the Galilean system were any more accurate than the Ptolemean one while they relied on circular planetary orbits. And Galileo rejected Kepler's elliptical orbits as unnatural.

<sup>5</sup> For instance, "Late Mediaeval Thought, Copernicus, and the Scientific Revolution", R.Grant, *Journal of the History of Ideas* 23 (1962) 197-220

<sup>6</sup> First published in Louvain in 1516. Frequently republished and translated. There is a modern English translation facing the original Latin in *The Complete Works of Thomas More*, eds. Edward Surtz & J.H.Hexter (New Haven, Conn.: Yale University Press, 1965)

<sup>7</sup> H.G.Wells says (in his Introduction to the edition by Blackie & Son) "A good Catholic [More] was, yet we find him capable of conceiving a non-Christian community excelling all Christendom in wisdom and virtue". Contrary to Wells, Jaki points out that "the 'natural' religion of the Utopians is not an idealised reconstruction from some historical precedent, but a studied 'naturalisation' of Christian faith and morals".

tury was read as avidly.<sup>1</sup> *Utopia* represented the primary articulation of ideas that sparked off the scientific movement three generations later.<sup>2</sup> Its spirit became the "publicly avowed creed of the English scientific workers throughout the latter half of the sixteenth century".<sup>3</sup> The sixteenth century literary record in England is a clear rebuttal of the cliché which ascribes without any qualification to Francis Bacon<sup>4</sup> the first formulation of the spirit of the new scientific endeavour. It is in fact the first of its kind<sup>5</sup>, not only free of patent obscurantism and absurdities, but also one can find in it in a reasoned fashion the chief components of that creed. There is a judicious criticism of ancient literary and scientific authorities, the perception of the invaluable potential of science for social improvement, an emphasis on the sustained observation of phenomena, and the voicing of an optimistic faith in progress through learning, science, crafts, and also through socio-economic planning.

The clear reasoning of More in his *Utopia* is in marked contrast to the case of Giordano Bruno (15xx-1599) a full generation later, for whom the safeguards of reason vanished into animistic obscurantism. For, contrary to most portrayals of him, far from being a champion of reason and a voice of reputable progress, Bruno was the helpless captive of Hermetic and cabbalistic tradition<sup>6</sup>, and whose mind revelled in the denial of rational, clearly identifiable patterns. Bruno's advocacy of Copernicus was largely utilitarian, to help discredit the closed world of Aristotle. Bruno denounced mathematics whenever the occasion arose<sup>7</sup> because of his idea of a pantheistic infinity in which the infinite number of entities were forever subject to a flux of unfathomable transmutations. This fundamen-

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<sup>1</sup> A convenient illustration of this is the massive documentation by R.W.Gibson, *St.Thomas More: A Preliminary Bibliography of his Works, and of Moreana to the Year 1750* (New Haven, Conn.: Yale University Press, 1965)

<sup>2</sup> It hardly makes a favourable reflection of the standard historiography of science that More's *Utopia* is regularly omitted from the listings of the major steps that constituted the advance of scientific enterprise and spirit during the Renaissance. A short but emphatic of the *Utopia's* significance in scientific history is given in R.P.Adams, "The Social Responsibilities of Science in *Utopia*, *New Atlantis*, and after", *Journal of the History of Ideas* 10 (1949) 374-398. The significance of More's utterances on scientific endeavour is neglected in most monographs on the *Utopia*; see for instance R.S.Johnson, *More's Utopia: Ideal and Illusion* (New Haven, Conn.: Yale University Press, 1969); R.Ames, *Citizen Thomas More and his Utopia* (Princeton N.J.: Princeton University Press, 1949); or the archetype of More's Marxist interpretations, Karl Kautsky's *Thomas More and his Utopia* (New York: Russel & Russell, 1959), originally published in German in 1888. Again, the question of More's impact on science has not been taken up in any of the essays published in the first 22 issues (1963-1969) of *Moreana* (Organe de l'Association Amici Thomae Mori, Angers, France). The situation is only slightly better in this respect in P.Hofgreffe, *The Sir Thomas More Circle: A Program of Ideas and their Influence on Secular Drama* (Urbana: University of Illinois Press, 1959), and in E.Surtz, *More's Utopia* (Cambridge Mass.: Harvard University Press, 1957).

<sup>3</sup> F.R.Johnson, *Astronomical Thought in Renaissance England: A Study of the English Scientific Writings from 1500 to 1645* (Baltimore: John Hopkins Press, 1937)

<sup>4</sup> Francis Bacon's *New Atlantis* was published in 1605

<sup>5</sup> The scientific ingredient in the various "Utopias" published from the classical times to the mid-17th century is the topic of the monograph by N.Eurich, *Science in Utopia: A Mighty Design* (Cambridge, Mass.: Harvard University Press, 1967)

<sup>6</sup> As conclusively shown by Frances A. Yates, *Giordano Bruno and the Hermetic Tradition* (Chicago: Chicago University Press, 1964). Recall that Ficino had translated and printed the works of Hermes Trismegistus, the supposed ancient Egyptian wisdom books. The cabbalistic tradition diligently sought meaning in numbers, their properties and relations. In neither was scientific rationality to be found.

<sup>7</sup> As carefully pointed out in Paul-Henri Michel *La cosmologie de Giordano Bruno* (Paris: Hermann, 1962)

tal infinite substance was called by Bruno the "Great Individuum", and in the same animistic vein he spoke of planets and stars as huge animals that wander by instinct through infinite spaces<sup>1</sup>. With this idea, faith in creation, Incarnation, redemption and resurrection were as incompatible as was exact science. Although deplorable therefore, it was hardly surprising that he ended up a helpless captive of the Inquisition, by whom he was burned in 1599.

Bruno could not ignore the existential agony deriving from the absence of a real target and resting point in his infinite universe of perpetual flux. The *De gl'heroici furori*<sup>2</sup> offers as a conclusion the comparison of a snake wriggling helplessly in snow with that of a child engulfed in flames. Each would prefer the other's condition as if indeed a shift of fates would solve anything: "The same fate vexes, and the same fate torments both one and the other - that is immeasurably without mercy and unto death." But in fact not even death is forthcoming: the fundamental truth in Bruno's universe is: "All times to me are full of woe; All things time takes from me, And gives me naught, not even death".

What Bruno wanted was to become a carefree ripple on infinite waves agitated forever without any aim, any direction, any pattern. He realised that the doctrine of the Great Year even in its Hermetic form contradicted the very core of this belief since as the eternal recurrence of all it was a pattern. He therefore filled two chapters of *De immenso et innumerabilibus*<sup>3</sup> with muddled arguments against the Great Year. It is doubtful that these arguments convinced anyone. They were not even enlightening on the history of the question. Seventeenth century authors had to turn to a dissertation by Lipsius written in the 1590s for ancient views on the Great Year.<sup>4</sup> But what casts the greatest light on Bruno's obscurantism was Kepler's dismissal of the idea of the Great Year in 1596 by recalling in just a few lines Oresme's classical argument about the incommensurability of planetary periods.<sup>5</sup>

Some have made an effort to prove, for instance, Bruno's influence on the outstanding figures of seventeenth century science, overlooking both Kepler's revulsion for Bruno and the fact that Galileo never advocated an infinite universe, let alone a universe as void of all-embracing patterns as Bruno postulated.<sup>6</sup> The strict infinity of the universe was not accepted by Descartes, Boyle, Huygens or Hooke, to name only a few of the leading seventeenth century scientists. The first major scientific discourse on the infinity of the universe came only with Newton's *Principia*<sup>7</sup>, and this was not influenced at all by Bruno. Those whom

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<sup>1</sup> In *La Cena de le Ceneri*, "The Ash Wednesday Supper": the first of Bruno's best known three cosmological works, all published in 1584. There is a critical edition by G. Aquilecchia ([Turin]: Giulio Einaudi, 1955).

<sup>2</sup> *The Heroic Enthusiasts*, transl. L. Williams (London: George Redway, 1887)

<sup>3</sup> His last and longest work: *De immenso et innumerabilibus; seu de universo et mundis libri octo*, published in 1591, a year before he started his seven-year long captivity by the Inquisition. Published in *Jordani Bruni Nolani Opera latine conscripta* (Naples-Florence: Morano-LeMonnier, 1879-91)

<sup>4</sup> Dissertations xx-xxiii in Book II in his *Physiologiae stoicorum libri tres in Iusti Lipsi Opera omnia* (Vesaliae: Typis Andreae ab Hoogenhuysen, 1675) vol.IV, pp.950-964

<sup>5</sup> In *Mysterium Cosmographicum*: see ch.xxiii, "De initio et fine mundi astronomico et anno platonico", in *Gesammelte Werke* (München: C.H.Beck, 1938). It is in the last chapter of this book that Kepler set the date of creation at 3977BC, Sunday April 27th at 11am Prussian local time.

<sup>6</sup> Dorothea W. Singer *Giordano Bruno: His Life and Thought, with Annotated Translation of his Work "On the Infinite Universe and Worlds"* (New York: Henry Schuman, 1950)

<sup>7</sup> and especially the Scholium added in 1713

Bruno really inspired were the chief representatives of German Idealism and Naturphilosophie<sup>1</sup>, who were also infatuated with the idea of eternal recurrences.

We have documented here some examples of a barely concealed desire on the part of many Renaissance thinkers to bring about a "re-naissance" of classical paganism. We have shown how this was inimical to the development of science, and also how it was countered by the Christian faith in the Creator that inspired all those who contributed to what was best in science during the Renaissance.

Kepler, the last of the giants of Renaissance science, graphically illustrates the issues. He was attracted by his psychic traits to astrology, and might have developed into the crudest of "sleepwalkers"<sup>2</sup> had it not been for his faith in a rational Creator. This was the same faith that inspired him to superhuman efforts to fit theory to the data of observation. The data were the given facts of the celestial world, existing by a sovereign act and the planning of the Creator. For Kepler the theory had two aspects: it was axiomatic that the work of a rational Creator was structured along the lines of geometry, and then the task of the scientist was to find the geometrical form that accounted for the data.

Kepler was explicit about the intellectual safeguards which Christian faith provided for scientific speculation. It was in connection with the apriorism of the world view of antiquity that he wrote: "Christian religion has put up some fences around false speculation in order that error may not rush headlong".<sup>3</sup> Equally revealing is what Kepler said in the same context about the "strength of mind" based on the "highest confidence in the visible works of God" that he needed to go on with his work. He needed this strength of mind to admit the possibility of elliptical celestial orbits, since nobody had ever thought, from antiquity until and including Galileo, that these orbits could ever be anything but circular. Kepler's notion of the Creator reflected the best of Christian theological tradition, which enabled him to state that the Scriptures "never intended to inform men about the nature of things" and that the first chapter of Genesis taught "only the supernatural origin of all things".<sup>4</sup>

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<sup>1</sup> The 19th century German philosophers Fichte, Schelling, Hegel and Nietzsche are all considered in detail in chapter 13 of Jaki's book,

<sup>2</sup> Arthur Koestler, *The Sleepwalkers: A History of Man's Changing Vision of the Universe* (New York: Macmillan, 1959). In this beautiful book Koestler repeats Kepler's heroic calculations that lead him to the discovery of "Kepler's Laws", and shows that Kepler made at least two and possibly more errors in the course of arriving at the correct answer. Thus he "knew" or intuited the answer beforehand, as a man in a dream - hence the "sleepwalkers" of the title. But Koestler overlooks Kepler's Christian faith as a determinant of the foundations of his science.

<sup>3</sup> Introduction to Book IV of *Epitome astronomae copernicanae* (c1620), in *Werke* Vol.VII p.254

<sup>4</sup> In his letter of March 28, 1605 to Herwart von Hohenburg, in *Werke* vol.XV, p.182

## The Creator's Handiwork

For most phases of scientific history the selection of a starting point is a perplexing task. But Galileo (1564-1642) is certainly an inevitable choice for the honour of being the first full-blooded representative of a modern scientific mentality. In this chapter we will sketch the way in which this depended on a Christian cosmogony in the seventeenth and early eighteenth centuries, until the triumph of Newtonian mechanics in the hands of giants such as Huygens, Leibniz, the Bernoulli brothers, Euler and many others launched physics as an autonomous enterprise with its own momentum that was no longer dependent on a continuous explicit awareness of its philosophical foundations.<sup>1</sup>

Galileo is renowned for his conflict with the Church, with Brecht's image of the cardinals<sup>2</sup> refusing to look through the telescope epitomising the modern belief in the incompatibility of religion and science. The truth is far different. It involves power politics, the religious upheavals of the Reformation and the Counter Reformation, and the wars that would shortly rage through Europe as a new political equilibrium was sought. To the enlightenment of the Reformation, and the encouragement to free-thinking implied by the reformers' presumption of a right to literacy, was added the enlightenment of a series of astonishing scientific discoveries.

And these discoveries were uniformly opposed not to the Christianity of the Church but to the Aristotelianism of the Catholics. It was the Council of Trent that had re-established Aristotle as the bulwark against Protestantism, in particular (for our purposes) the scholastic theory of matter that underpinned the doctrine of the Eucharist.<sup>3</sup> It was this doctrine that Galileo challenged when he demonstrated in the Rome of 1611 the luminescence of barium sulphide recently discovered by alchemists in Bologna, who gave it the "fascinating name of solar sponge (*spongia solis*). The weak cold glow of those mineral fragments in a

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<sup>1</sup> Indeed, the very number of these major figures is an indication of the technical success of the new paradigm. Jaki goes on to trace the baleful influence of the history of the idea of a universe infinite in time and cyclical in nature in the eighteenth, nineteenth and twentieth centuries. However I will conclude with this chapter, into which I will also bring some other material.

<sup>2</sup> "On the contrary, coming to Rome in 1611, Galileo was received in triumph; all the world, clerical and lay, flocked to see him, and, setting up his telescope in the Quirinal Garden belonging to Cardinal Bandini, he exhibited the sunspots and other objects to an admiring throng." (Catholic Encyclopaedia). Brecht's *Galileo Galilei* had three versions, the first was written in German in 1938 and the last in English in 1955

<sup>3</sup> 1545-1563. The Eucharist is the sacrament instituted by Jesus Christ just before his death: "This is my body given for you, this is my blood shed for you". The Council of Trent reaffirmed the Catholic doctrine of *trans-substantiation*, that is the *substance* of the bread and wine become changed to the substance of Christ, and the appearance of the bread and wine (which are manifestly unchanged) is an *accident*, that is, something that happens not something that reveals the true essence of the substance. These categories are Aristotelian categories of matter for which today we have no sympathy and little understanding. The Lutheran doctrine of *con-substantiation*, that is, that Christ is really present "in with and under" the bread and wine, amounts to little more than a scholastic quibble which does not significantly challenge the Aristotelian categories. This challenge was emphatically thrown down by Galileo's researches on matter.



dark room, after having been exposed to sunlight, demonstrated that light was a phenomenon separable from heat and from the presence of a luminous environment. That seemed fully sufficient for Galileo to illustrate to his [Aristotelian] interlocutors - who were struck speechless by this most recent Galilean discovery - that philosophical convictions about light understood as a quality of a transparent illuminated medium were false. To separate the light: this was an audacious and unforgettable deed ...".<sup>1</sup>

Galileo had already created a stir with *Sidereus Nuncius* ("The Starry Messenger") which was published in Venice in March 1610. Here he is the first to publish drawings of the Moon and observations of the satellites of Jupiter as seen through his telescope.<sup>2,3</sup> In the next few years he is a leader in the attack upon the scholasticism of the theological establishment. In May 1612 the *Discourse on Floating Bodies* starts with a discussion of the floatation of ice and of the nature of heat and cold explicitly opposing the qualitative physics of the Aristotle<sup>4</sup>, and in a tract of 1613

Galileo denounces Aristotelian physics, accusing it of pure nominalism, and appropriates for the first time the slogan of the "book of nature" counterposed to the books of Aristotle and his commentators, as if "nature had not written this great book of the world to be read by others besides Aristotle". Aristotle's texts are described as the prison of reason. Thus, hostilities with official Jesuit philosophy begin.<sup>5</sup>

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<sup>1</sup> P.Redondi in *Galileo: eretico* (Giulio Einaudi, 1983; transl.Raymond Rosenthal and published as *Galileo: heretic*, Princeton University Press, 1987). See P.Redondi, Galilée aux prises avec les théories aristotéliennes de la lumière", in "Matière et lumière au XVIIème siècle", *XVIIème siècle* 34 (1982) pp267-283

<sup>2</sup> The first record of a telescope was the application for a patent on a spyglass in The Hague by Hans Lipperhey, October 1608. This request was eventually refused since it was impossible to keep the invention secret. Telescope observations mushroomed all over Europe: Galileo was not the only one to replicate the invention, although the quality and power of his instruments led Europe. Thomas Harriot in London anticipated Galileo's Moon drawings by several months. The observations of Jupiter's satellites were rapidly confirmed later in 1610 by Harriot, Kepler; and the Jesuit mathematicians at the Collegio Romano who the following year certify Galileo's celestial observations (although not necessarily his interpretation of them) at the request of Ballarmino, and who also honour Galileo at a banquet in May 1611. Harriot also is the first to record sunspots (in December 1610), but these were published first by Fabricius in June 1611 following observations first started in March that year. Galileo demonstrates sunspots in Rome in May 1611. Galileo has the precedence in his observations of Saturn in July 1610 and the phases of Venus in December 1610. He proposes the use of the eclipses of Jupiter's satellites as a method for solving the longitude problem in 1616.

<sup>3</sup> Paul Feyerabend points out in *Against Method* (New Left Books, 1978) that Galileo's Moon drawings owe more to the aberrations of his telescope than the real features on the Moon, for all that Galileo himself was a first class observer and experimenter. It is well known that Galileo was deeply indebted to mediaeval scientists for his dynamics, although he failed to acknowledge them, but it seems that he was ignorant (as some of his critics were not) of the substantial mediaeval advances in optics including knowledge of the aberrations of lenses and the many peculiarities of human perception; which ignorance however may have made him much more ready to engage in controversy!

<sup>4</sup> That is, the discussion of the nature of things by Aristotle in terms of their *qualities*. We barely understand this type of discussion today, since we always look for a *quantitative* description, and we prefer to ask how something behaves rather than to ask what its nature is. On the Aristotelian distinction between individual sensibles and common sensibles see A.C.Crombie, "The Primary Properties and Secondary Qualities in Galileo Galilei's *Natural Philosophy*" in *Saggi su Galilei*, vol.II (Florence, 1972)

<sup>5</sup> P.Redondi *Galileo: heretic*, (ibid.) ch.2. The significance of the "book of nature" (cf.Is.34:6 "and the heavens shall be rolled together as a scroll" or Rev.6:14 "and the heavens departed as a scroll when it is rolled together") was immediately appreciated by everyone in the in-

But for now Galileo is the darling of the establishment and the Jesuit<sup>1</sup> Cardinal Bellarmino<sup>2</sup> could only give Galileo a warning (official but secret) in 1616 not to hold Copernicanism as *true*.<sup>3</sup> Copernicus' book was also put on the Index on this occasion<sup>4</sup>. But Galileo's friend Maffeo Barberini became Pope Urban VIII in 1623 and provided enthusiastic protection for *The Assayer*, published in Rome in October 1623.<sup>5</sup> This book was a literary sensation in Rome with its literary verve, its irony, its murderous wordplay, the poetry of its allegories and its boundless intellectual passion.<sup>6</sup> Ostensibly the book was a polemic against the treatise on the comets of 1618 by Orazio Grassi, a Jesuit mathematician at the Collegio Romano.<sup>7</sup> As a matter of fact, in this matter Grassi, for all his Aristotelianism, was right and Galileo was wrong. Galileo incorrectly treated the comets as a play of light rather than as real objects. But the real purpose of the book was to be a treatise on style in physics:

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tellectual and religious world of the Reformation, see R.Hooyakaas, *Religion and the Rise of Modern Science* (Edinburgh and London 1972). The 1613 tract was the response of the Lyncean Society to the Jesuit Christoph Scheiner's 1612 tract in which Scheiner reports his sunspot observations of spring 1611. In the Aristotelian universe the sun was supposed to be perfect, so how could it have spots?

<sup>1</sup> The Jesuits were founded by Ignatius Loyola in 1540, originally with the purpose of foreign missions (particularly to the Muslims). But they soon became the spearheads of the Counter-Reformation, and the repositories of Tridentine orthodoxy.

<sup>2</sup> "In a time when cardinals maintained splendid courts, Bellarmine lived a simple and ascetic life, practicing self-sacrifice, poverty, and disinterestedness. Upon the death of Pope Sixtus V in 1590, the Count of Olivares wrote to King Philip III of Spain about possible candidates for the papacy: "Bellarmine is beloved for his great goodness, but he is a scholar who lives only among books and not of much practical ability . . . . He would not do for a Pope, for he is mindful only of the interests of the Church and is unresponsive to the reasons of princes . . . . He would scruple to accept gifts . . . . I suggest that we exert no action in his favor." The King agreed." From the Galileo Project website of Rice University, Houston, Texas

<sup>3</sup> It was permissible to treat it as an *hypothesis*, but at this time there was no *proof* of the truth of the heliocentric theory. This had to wait a remarkably long time, since stellar parallax was only demonstrated in the nineteenth century. Galileo also produced false proofs, from the tides (in 1616) and from comets (in the *Assayer* of 1623). But this is another story! In the May of 1616 Bellarmine writes to Galileo certifying that Galileo had not been on trial or condemned by the Inquisition. In April 1624 Galileo goes to Rome where his friend Pope Urban VIII assured him that he could write about the Copernican theory as long as he treated it as a mathematical hypothesis.

<sup>4</sup> In May 1620 the Congregation of the Index issued the corrections that must be made in Copernicus's *On the Revolutions* before it can be read. This effectively took it off the Index.

<sup>5</sup> Published in Italian. It was never translated into Latin and therefore had very limited circulation outside Italy. "In his *Assayer* of 1623, Galileo explained his notion of the difference between those qualities, mostly found by touch, that are inherent in bodies (weight, roughness, smoothness, etc.) and those that are in the mind of the observer (taste, color, etc.)--in other words, the difference between what we call primary and secondary qualities. In this discussion he referred to bodies that "continually dissolve into minute particles" and stated his opinion that "for exciting in us tastes, odors, and sounds there are required in external bodies anything but sizes, shapes, numbers, and slow or fast movements." An anonymous cleric filed a report with the Inquisition in which he claimed the first citation to show that Galileo was an atomist and the second to be in conflict with the Council of Trent's pronouncements on the Eucharist. The report did not lead to any action against Galileo." *The Galileo Project*, website of Rice University, Houston, Texas

<sup>6</sup> P.Redondi *Galileo: heretic*, (ibid.) ch.2.

<sup>7</sup> "The Defenestration of Prague, May 23, 1618, is a clear signal of a European war that will wreck the last hope of a Christian pacification, and project into the minds of Catholic militants images of a bloody redemptive crusade and the renewed fervour of Tridentine orthodoxy. But only the successive, frightening apparition of not one but three comets in the dark skies of Europe will adequate presage in all its horror the ferocious cruelty and biblical duration of the Thirty Years War." P.Redondi *Galileo: heretic*, (ibid.) ch.2.

'Style' - in poetry, history, the biographical and narrative genres, and drama - was being discussed everywhere in 1624. There was a new semantic programme ...Galileo proposed a new language in physics. This was not at all a question of neologisms, but rather one of new definitions and rules. In the first place he suggested a new way of talking about physical objects in general. Physics is the study of matter. ... In point of fact, *The Assayer* proposed to supplant Aristotelian physics by translating its predicative propositions, hinged on the experience of qualities, into a new language: from "the fire is hot" to "the fire transmits the sensation of heat". Such translation was no small matter, since it went from a language modelled on everyday common sense to a more elaborate and analytical, richer and more rigorous language. There were in fact two levels of words here. First of all, there were "names", such as heat, red, and sweet, which have value for the individual sensation but not for scientific knowledge. And then there are the material properties, words like shape, motion and so on, which are universally and mathematically knowable.<sup>1</sup>

The passage in *The Assayer* containing the elements for reading the book of nature is very famous:

I say that whenever I conceive of any material or corporeal substance, I am compelled of necessity to think that it is limited and shaped in this or that fashion, that it is large or small in regard to other things, that it is in this or that place, at this or that time, that it moves or is immobile, that it touches or does not touch another body, that it is one, a few, or many; nor by any stretch of the imagination can I separate it from these conditions. But that it is white or red, bitter or sweet, sounding or mute, of pleasant or unpleasant odour, I do not feel compelled in my mind to perceive it as necessarily accompanied by those conditions. On the contrary, if we were not assisted by our senses, perhaps reasoning and imagination would never apprehend these qualities. Therefore I think that taste, odours, colours and so on as regards the object in which they seem to reside are nothing but pure names and only reside in the feeling body, so that if the animal is removed all these qualities are taken away and annihilated.<sup>2</sup>

Pietro Redondi makes a very detailed and powerful case for the thesis that Galileo's eventual condemnation in 1633 was not to do particularly with his Copernicanism but was everything to do with the fundamental attack on Aristotle that *The Assayer* represented and that the Jesuits so resented. By May 1632 the Pope needed the help of the Spanish to stop the Protestant Gustavus Adolphus of Sweden from crossing the Alps and descending on Rome. And the price of the Spanish was a greater attention to the protection of orthodoxy. They would dearly have liked to arraign Galileo for heresy in his atomistic views, which struck at the heart of the Tridentine doctrine of the Eucharist<sup>3</sup> but they could hardly press this capital charge considering that the Pope himself would also be implicated. Therefore they chose a lesser charge predating the current Pope, that nevertheless will still silence Galileo.

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<sup>1</sup> P.Redondi *Galileo: heretic*, (ibid.) ch.2

<sup>2</sup> G.Galileo, *Il saggiaiore [The Assayer]*, Mascardi, Rome, 1623. Version edited by L.Sosio, Milan, 1965, p.261. For a recent discussion of this passage see R.E.Butts, "Some tactics in Galileo's propaganda for the mathematization of scientific experience", in R.E.Butts & J.C.Pitts, *New perspectives on Galileo* (Dordrecht, 1978) pp59-85 (cited in P.Redondi *Galileo: heretic*, (ibid.) ch.2)

<sup>3</sup> On 1 August 1632 the Society of Jesus [the Jesuits] severely prohibits the doctrine of atoms: see Historical Archive of the Superior General Curia of the Society of Jesus, Rome, *Fondo gesuitico* 657, cited in C.Costantini, *Baliani e i gesuiti* (Florence, 1969) (cited in P.Redondi *Galileo: heretic*, (ibid.) ch.8)

It is with this historical, ecclesiastical and scientific background that we now turn to the question of the philosophical motivations of Galileo and his scientific contemporaries and successors. Were they really the forerunners of sceptical humanism escaping from the intellectual clutches of Christianity that some modern polemicists would have us believe? Or were they themselves motivated by a sincere belief in a Creator who cared for both the world and themselves?

It was in Galileo's *Dialogue concerning the Two Chief World Systems*<sup>1</sup> that the Christian Creator in His infinite richness relishing change and diversity was contrasted with the Socratic, Platonic and Aristotelian theologies in which change was frowned upon. To Simplicio, who is more Aristotelian than Christian, the idea of a moon populated by living beings seems not only mythical but impious. But to Salviati, who represents Galileo himself in the *Dialogue*, the contrary conclusion is the one in keeping with the attributes of the "Maker and Director" of the universe: a universe populated by a great variety of beings:

acting and moving in it, perhaps in a very different way from ours, seeing and admiring the grandeur and beauty of the universe and of its Maker and Director and continually singing encomiums in His praise. I mean, in a word, doing what is so frequently decreed in the Holy Scriptures; namely, a perpetual occupation of all creatures in praising God.<sup>2</sup>

For Galileo, nature was the work and a faithful symbol of a most reasonable Supreme Being. Therefore nature, in analogy to her Maker, could only be steady and permeated by the same law and reason everywhere. From permanence and universality of the world order followed, for instance, that the same laws of motion were postulated for the earth and the celestial bodies. It also followed that regularly occurring phenomena, such as tides, baffling as they might appear, should not be assigned a miraculous cause.

The most important consequence of the permanence and universality of the world order anchored in the Christian notion of the Creator was the ability of the human mind to investigate that order. The intimate relatedness of the human mind to the Creator's was analysed by Galileo with great interest. In particular he made detailed comments on the mathematical or geometrical simplicity and truth as evident to both God and man. In perceiving the simplicity of geometrical truths, man's mind participated in a knowledge that differed from the divine only in the sense that God knows *all* geometrical truths and knows them *always*, whereas man perceives only some of them and only by a step-by-step process. If nature and mind were works of the same God they both had to reflect the very simplicity of divine truths of which the geometrical ones seemed the most palpable. This is why Galileo praised repeatedly<sup>3</sup> the *faith* of Copernicus in the simplicity of the heliocentric arrangement of the planets. As it was most emphatically asserted in Galileo's rare but significant references to scientific history, the new science had its origin in a faith intimately tied to the belief in the Creator. Salviati says: "Copernicus admires the arrangement of the parts of the universe because of God's having placed the great luminary which must give off its

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<sup>1</sup> Printed in Florence in February 1632 after years of negotiations with the censors, but the plague outbreak in Florence in the summer of 1631 has disrupted commerce and travel. Further distribution is prohibited by Papal decree in the summer of 1632 pending investigation. A Latin translation of the *Dialogue* was published in Strassburg by Matthias Bernegger in 1635. Translated into English by Stillman Drake (University of Berkeley Press, 1962)

<sup>2</sup> *Dialogue*, transl. Drake (*ibid*, 1962) p.62

<sup>3</sup> *ibid*. pp. 328, 334, 339

mighty splendour to the whole temple right in the centre of it, and not off to one side."<sup>1</sup>

Francis Bacon's (1561-1626) place in the history of science is assured with his very modern description of the method of induction as the basis of scientific work in his *Advancement of Learning* first published in 1605.<sup>2</sup> He succeeded in articulating the intellectual temper of an age which grew increasingly preoccupied with reflections on science and why a new and effective undertaking of the scientific enterprise had become possible and promising. Much of what Bacon said about the general philosophy or foundations of science was in the air, and the great popularity of his publications was due precisely to the fact that the learned among his readers found their own thoughts mirrored or further articulated. Bacon pointed to the enormous disparity which the doctrine of Creation introduced between the pagan and the Christian outlook on the world: "For as all works do shew forth the power and skill of the workman, and not his image; so it is of the works of God; which do shew the omnipotency and wisdom of the maker, but not his image; and therefore therein the heathen opinion differeth from the sacred truth; for they supposed the world to be the image of God, and man to be an extract or compendious image of the world."<sup>3</sup>

The intimate connection between pantheism and the trust of the Socratic school in divining the various forms of cosmic purposiveness is very explicit in Bacon, who sees the result of the connection as "the great arrest and prejudice of further discovery"<sup>4</sup>. Final causes (which otherwise represented in Bacon's eyes a worthy target of inquiry) turned into "remoras and hinderances to stay and slug the ship [of science] from further sailing, and have brought this to pass, that the search of the Physical Causes hath been neglected and passed in silence."<sup>5</sup> Bacon preferred the materialist philosophy of Democritus which allowed the physical causes of things to be discussed with greater clarity: "And therefore the natural philosophy of Democritus and some others, who did not suppose a mind or reason in the frame of things, but attributed *the form thereof able to maintain itself to to infinite assays or proofs of nature*, which they term *fortune*, seemeth to me ... in particularities of physical causes, more real and better enquired than that of Aristotle and Plato."<sup>6</sup>

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<sup>1</sup> *ibid.* p.268. Galileo studiously ignored Kepler's laws of planetary motion (the first two published in 1609 and the third ten years later) of which he must have been aware. Kepler warmly supported Galileo on a number of occasions. But Galileo hated the astrology that Kepler pursued with almost as much enthusiasm as his astronomy.

<sup>2</sup> *The Two Bookes of Francis Bacon of the Proficiency and Advancement of Learning Divine and Human* in *The Works of Francis Bacon*, edited by J.Spedding, R.L.Ellis, D.D.Heath (Boston: Taggard & Thompson, 1863). Bacon also prepared a Latin version in 1623. At this point mention should be made of the often quoted essays of M.B.Forster, "The Christian Doctrine of Creation and the Rise of Modern Natural Science", *Mind* 43 (1934): 446-68; and "Christian Theology and Modern Science of Nature", *Mind* 44 (1935): 439-66; 45 (1936): 1-27. He made detailed analysis of the thought of Galileo, Descartes and Bacon but of the basis of a total neglect of their mediaeval forerunners and also in the conviction that the Christian notion of God as Creator was at least as much Greek as it was Jewish. See on this p.465, note 1 in his first article. Such a position was rather dated even in the 1930s.

<sup>3</sup> *Works...* (*op.cit.*) vol.V1, p212

<sup>4</sup> *ibid.* p.223

<sup>5</sup> *ibid.* p.224

<sup>6</sup> *ibid.* p.224. But of course, with a Creator as the Final Cause Bacon certainly was not a materialist as some have had him: see for instance F.H.Anderson, *The Philosophy of Francis Bacon* (Chicago: University of Chicago Press, 1948)

René Descartes (1596-1650) was more systematic than Bacon with his method of doubt. The determination with which he pursued his goal, a mechanistic account of the universe, stamped three centuries of classical physics with the Cartesian spirit of "matter and motion". But for Descartes this merely represented the superstructure. He was equally concerned with the ultimate foundations of science. What made scientific enquiry possible, according to Descartes, was that the notion and reality of God as Creator secured a double benefit for all his creatures. The first of these was their participation in eternal reason, on which rested the very idea of physical law, and the postulate of the homogeneity of the universe and of its consistency and harmony. The other was the contingency of nature, and this seemed to be most palpable for Descartes in the countless particular characteristics of physical things and processes. The specifications of these particulars and the demonstration of a general law at work in them entailed for Descartes the overriding need for experimentation and the justification of his insistence to part with the mentality of the Schoolmen.

The idea of the Great Year was entirely discredited in the seventeenth century. Few authors even referred to it<sup>1</sup>, and many contrasted the Christian view of creation in time out of nothing with the universal pagan view that matter was eternal. For Robert Boyle (1627-91) for example, the doctrine and belief in the Creator represented the very foundation of sound reasoning about the world<sup>2</sup>, and Isaac Newton (1643-1727) explicitly endorsed the idea of Creation once for all as the only sound framework of natural philosophy<sup>3</sup>. The universe for Newton was a clockwork constructed by the Creator out of basic components created out of nothing.

For all seventeenth century scientists of any stature, discoveries of scientific laws represented evidence of the Creator, the Author of every law of nature. As we have indicated above, by the end of the seventeenth century there has been a momentous change in the political structure of Europe wrought by the Thirty Years War, mirrored by equally momentous changes in philosophy and science. Aristotle is greatly weakened if not completely dethroned, but the scientific enterprise has been definitively launched with the reappropriation of the best of Greek mathematics underpinning the discovery of calculus and its application to mechanics. With these powerful mathematical tools and the laws of Newton it appeared that the universe was at last open to quantitative understanding.

In any case the way was clear for the technical development of mathematical and experimental physics independently of the political and philosophical revolutions that filled the following centuries. We have become used to the disjunction of science and philosophy, and scientists now habitually brush aside the quibbles and the traumas of modern sceptical philosophy. Nevertheless, modern science was established by men with a Christian philosophical understanding of the nature of the world.

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<sup>1</sup> Marin Mersenne (1588-1648) was the one exception: in his monumental discussion of the biblical account of creation, the *Quaestiones celeberrimae in Genesim* (Paris, 1623), Mersenne delved into every possible ramification of the doctrine of creation. He did so in the conviction, which he expressly stated, that no phrase of greater portent was ever formulated than the one declaring that "in the beginning God created the heaven and the earth". His discussion of the Great Year showed that previous positions in the matter were well remembered at least by scholars of Mersenne's calibre.

<sup>2</sup> see *The Excellency of Theology in Works* (14 vols., Pickering & Chatto Ltd, 1999-2000)

<sup>3</sup> See the Scholium added to the second edition of *Principia* (1713), and the Queries in later editions of the *Opticks*.

## Postscript (by CJ)

It is ironic that it is only now, at a time when the value of the scientific enterprise is being increasingly questioned, that it has become clear that this enterprise is really a product of the Christian world view. God has been taken at his word: “Fill the earth and subdue it” (Gen.1:28) and men have again said, “Come, let us build us a city and a tower, and its head in the heavens, and let us make us a name” (Gen.11:4)<sup>1</sup> and “nothing will be restrained from them which they have imagined to do.”(Gen.11:6). Unfortunately, it is still true that “the wickedness of man [is] great in the earth, and every imagination of the thoughts of his heart only evil all the time.” (Gen.6:5)

Thinking that the scientific enterprise is responsible for unprecedented atrocities and for the rape of nature, and is the epitome of the hubris of man, many today are turning to other paradigms to understand what the world is and what our role in it is supposed to be. Holistic medicine and an array of alternative therapies from India and China are increasingly popular, and who can oppose these adequately with only the “Western” mechanistic philosophies? Or who would want to? We should expect that cultures which have spent millennia in introspection have valuable things to give us.

However, as our world is now shaped by science and technology it is important to have a clear understanding of the philosophical foundations of science, simply as a matter of fact. It is interesting that these foundations are still reflected today, in the attitude towards honesty for example: “Physics is a great subject for training the mind, it’s very demanding and it teaches you to be intellectually honest”<sup>2</sup> is a comment I recently happened to come across.

Actually, there is a curious schizophrenia abroad: on the one hand people berate Christianity for being naive, anti-scientific, irrational, and so on, and on the other hand they berate scientists for being inhuman, cold, eggheadish boffins.

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<sup>1</sup> I follow the syntactic structure of the Hebrew closely: note the sequence of coordinated clauses in this quote for example. It is interesting that the modern use of subordinate clauses (which will be found in the modern translations of the same passage) looking more sophisticated, actually introduces interpretative bias into the text: a more accurate translation leaves more ambiguity. Thus Tyndale in the early sixteenth century used the Biblical texts as models for graceful English prose, which at that time was an unknown art, but the later translators of the “King James” Bible at the start of the seventeenth century reverted to the more (apparently) “primitive” syntax of the original under the influence of the same highly sophisticated mind set that gave rise to the Metaphysical Poets including John Donne, who had learned to value ambiguity. In many important respects Christianity has given us modern English. I am indebted for this point to Gerald Hammond’s fascinating chapter *English Translations of the Bible* in *The Literary Guide to the Bible* (Robert Alter & Frank Kermode, eds., Fontana, London, 1997. The point is (again), there is more in the Bible than immediately meets the eye.

<sup>2</sup> David Potter, was Chairman of Psion (the microcomputer and ‘organiser’ company) and member of the Dearing Committee on the future of UK Universities, in *Physics World* **11(2)** (Inst.Phys. 1998) 13. The same issue of *Physics World* also quoted Sir John Houghton, co-chairman for science assessment on the intergovernmental panel on Climate Change: “The agreement at Kyoto is strongly rooted in accurate and honest science. . . as was the UN Framework Convention on Climate Change, which was signed at the “Earth Summit” in Rio de Janeiro in 1992 and under whose auspices the Kyoto summit was held” (p17).

Christians' basis of belief seems threadbare to the casual modern mind, but at the same time science is becoming deeply unpopular. There are many and various reasons for these contradictory trends, which include a welcome reassessment of the contributions of other cultures. But a dispiriting amount of loose thinking and false history has become enormously misleading for many. I hope this essay is able to illuminate some of these issues.