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The Concept of Time from Pythagoras to Aristotle

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The history of Hellenic natural philosophy can be epitomized as the conquest of temporal concepts by spatial. It is, therefore, perhaps not surprising that little systematic attention has been paid to Greek ideas concerning time. For the historian of science however they are not unimportant, for they may throw light on the failure of the Greeks to anticipate the scientific revolution of the 17th century.

At the dawn of Greek literature two contrasting points of view are found in Homer and Hesiod. Olympian theology in the *Iliad* is dominated by the idea of space, and morality is governed by the concept of *Moirai* (necessity or destiny), the cardinal sin being *hubris*, that is, going beyond one's assigned province. The whole conception, in the words of Cornford, is "static and geometrical; everything has its limited field with bounds that must not be passed." [1] Homer was not interested in the origin of things. His gods were not creators and he had no cosmogony [2]. On the other hand, Hesiod (who probably came slightly later) in his *Works and Days* gave an account of the origin of the world. His poem may be regarded as a moralistic study based on the time concept.

Two centuries or so later (6th century BC), the Ionian natural philosophers speculated on how the world was generated: that is, on how hypothetical unity gave rise to observed multiplicity. Broadly speaking, they came to visualize the world as a geometrical organism with a life-cycle. This idea underlies Anaximander's contention, in the only surviving fragment directly attributed to him, that all things that are created must also perish according to the ordinance of time. His disputed hypothesis of a plurality of worlds may have signified an endless succession of "Great Years". Belief in cosmic cycles was not peculiar to the Greeks. The myth of the "eternal return" was widespread in antiquity before St. Augustine focussed attention on the Christian idea of unidirectional time. Even Heraclitus adhered to it.

Unlike the Ionians, however, Heraclitus did not regard the world as a live space-filling substance. Instead, he believed it to be a soul involved in an endless cycle of death and rebirth. Whereas Anaximander's cosmogony was primarily spatial, the invasion by the elements of each other's province being an "injustice", Heraclitus maintained that the very essence of world-order is transmutation [3]. In place of the space-like concept of *Moirai*, he advocated the time-like *Way of Justice* which admits no barriers between different regions and passes through all phases of the world-cycle. A similar emphasis on time and the soul characterized the Orphic religion which appears to have provided

the mythical background of Pythagoreanism. According to Plutarch, when asked what Time (*Kronos*) was, Pythagoras replied that it was the soul, or procreative element, of the universe [4].

The extent to which Pythagoras and his school may have been influenced by oriental ideas has long been a subject for speculation. The Orphic theogonical conception of *Kronos* has much in common with the Iranian idea of *Zurvān Akarana* (unending time), and each was in fact depicted as a multi-headed winged serpent. Similarly, the basic dualism of Pythagorean philosophy (limit versus unlimited) appears to echo the Zoroastrian belief in the cosmic opposition of Ormazd (light) and Ahriman (darkness). The idea of transmigration is found in the *Upaniṣads*, although there is no evidence of any connection between Hindu beliefs and the doctrines of Pythagoras [5]. The most original feature of Pythagoras's teaching, however, is his celebrated theory that the nature, or ultimate principle, of things is to be found in number.

It has generally been held that this idea was an inductive generalization following experiments with a monochord which showed that the concordant intervals of the musical scale can be expressed by simple ratios of whole numbers [6]. This seems to be far from plausible. It is much more likely that the monochord was used to illustrate and confirm a general theory that Pythagoras had already formulated. The case for this interpretation is based on the following well-attested facts:—

(i) the Babylonians had long-believed that an object is identical with its name and that nothing exists unless it has a name [7];

(ii) they were led to associate a numerical value with each sign in their syllabary. For example, in the Khorsabad Texts in which Sargon II of Assyria presented the annals of his reign an inscription commemorating the founding of his new capital contains the passage: "16 283 cubits, the numeral of my name, I made the circuit (literally, the measure of its wall)" [8]. Sargon reigned from 724 to 705 BC.

I suggest that Pythagoras, who lived in the 6th century BC, telescoped the Babylonian doctrine of the name and its association with a numeral into the idea that everything (including abstract concepts such as justice) has a number. This explanation would not diminish his genius. What matters most with an idea is what one does with it, and as the author of the *Epinomis* claimed, "We may take it that whatever Greeks inherit from other races they turn it into something better." [9]

The Pythagorean concept of number had both spatial and temporal significance. Numbers were represented figuratively by patterns similar to those still found on dominoes and dice. This led to a powerful theory of numbers based on geometry. At first, however, time was a no less important element in Pythagorean thought and was closely associated with spatial configurations [10], as is evident, for example, in the use of the *gnomon*. Originally, this was a time-measuring instrument (a simple upright sundial). The term then came to mean the figure remaining of a square when a smaller square is cut out of it. Eventually it denoted any number which when added to a figurate number generates the next number of the same shape, the generation of numbers being regarded by the early Pythagoreans as an actual physical operation in space and time. Indeed, they identified the cosmogonical process with the generation of numbers from the initial unit, the Monad, which may have been a sophisticated version of the Orphic idea of the primeval World-egg.

An outright attack on the concept of time was made by the founding father of deduc-

tive argument and logical disputation, Parmenides, who stands in a somewhat similar relation to Pythagoras as Berkeley to Newton, although his polemics were far more effective. In his *Way of Truth* he formulated an acute criticism of current cosmogonies: "And what need could have stirred it up, starting from nothing, to be born later rather than sooner?" [11] It had been generally assumed that the universe, or at least its current cycle, had begun at some moment of time, but no reason could be given why it should have started at one moment rather than another. Plato answered this objection of Parmenides by claiming that time is coexistent with the ordered universe. But he was deeply impressed by Parmenides's logical criticism of the ideas of becoming and perishing and by his conclusion that time does not pertain to anything that is truly "real". In the *Timaeus*, space and time are treated very differently. The former exists in its own right as a given frame (the Receptacle) for the operations of the Demiurge (Reason) in producing the visible order of things, whereas time is merely a feature of that order based on an archetype (Eternity) of which it is the "moving image". Time is produced by the celestial revolution and therefore does not belong to Becoming as such but to Becoming as ordered by mind and moving according to number. Thus time was still associated with number, but it was divorced from geometry, which in Plato's view is to be regarded as "knowledge of the eternally existent" [12].

Plato's antipathy to all research that involved the temporal and the contingent led him to criticize observational astronomers and those Pythagoreans who investigated problems of musical harmony and acoustics empirically. In the *Republic* he pokes fun at the latter for wasting their time in measuring audible sounds and concords. "They lay their ears to the instrument as if they were trying to overhear the conversation from next door. One says he can still detect a note in between, giving the smallest possible interval, which ought to be taken as the unit of measurement, while another insists that there is now no difference between the notes. Both prefer their ears to their intelligence" [13].

This preference for the abstract at the expense of the concrete and temporal was the beginning of the fateful divorce between the empirical and the theoretical sciences, and in particular between Greek physics and mathematics. At the same time, in mathematics the theory of numbers was separated from geometry, following the discovery of the irrationality of the diagonal of a square of unit side [14]. Geometry, rather than arithmetic, became the fundamental mathematical technique. Even within geometry itself severe restrictions were imposed by Plato and kinematic methods were rejected, with the ultimate result that the invention of the calculus of fluxions was delayed for two thousand years.

Plato's refusal to allow the intrusion of the time concept into mathematics was, I believe, the basic theoretical reason for his otherwise puzzling veto on all geometrical constructions which cannot be made with ruler and compasses. It is often stated, or implied, that his objection was to the practical use of actual mechanical instruments. But, as usually presented, his point of view fails to make sense, for no reason is given why ruler and compasses are permitted. A veto on the use of instruments should surely include these too. The essential point, as I see it, is that, whereas, for example, the bisection of an angle is associated with a particular configuration of straight lines and circular arcs which could, in principle, be contemplated *statically*, the trisection of an angle, as performed by Hippias, like the ingenious duplication of the cube by Archy-

tas, was a construction involving a *moving* configuration of lines, that is, one which, in the absence of the modern concept of functional variation, could not be defined without reference to time [15].

Plato's condemnation of the Pythagorean association of generation with number was upheld by Aristotle [16], although his famous definition of time as the number of motion with respect to earlier and later sounds as if it were Pythagorean in origin. Unlike the pre-Parmenideans, Aristotle interpreted the first cause of anything not as its method of origin but as its sustaining principle. Instead of *physis* signifying the whole process of growth, it now came to mean the form of the fully developed thing, "for the process of generation exists for the sake of the complete being, and not this for the sake of the process." [17] The order of the universe was declared to be eternal and ungenerated [18]. Motion was interpreted teleologically as the actualization of the potential, "the fulfilment of the movable *qua* movable [19]." Although for Aristotle physics meant the study of motion and change in nature, the main emphasis was placed by him on the states of being between which change takes place, rather than on the actual course of the motion itself. Thus the static form rather than the dynamic process became the characteristic concept in his philosophy of nature.

REFERENCES AND NOTES

- [1] Cornford, F. M. *From Religion to Philosophy*. London, 1912, p. 181.
- [2] Except that in Book XIV of the *Iliad* he refers, incidentally, to *Okeanos*, the river surrounding the Earth, as the origin of all things.
- [3] "Homer was wrong in saying: 'Would that strife might perish from among gods and men!' He did not see that he was praying for the destruction of the universe; for, if his prayer were heard, all things would pass away..." (Heraclitus, Fragment 43, transl. J. Burnet, *Early Greek Philosophy*, 3rd ed. 1920, p. 136. The reference is to the *Iliad*, Book XVIII, line 107.)
- [4] Plutarch, *Morals*. Rev. and corrected by W. W. Godwin. Boston, 1870. Vol. V, Platonic Question VIII (transl. R. Brown), p. 440.
- [5] Berriedale Keith, A. *Journal of the Royal Asiatic Society*, 1909, 569-606.
- [6] He is said to have measured the *lengths* on the string of a monochord stopped by a movable bridge. It was not until much later that Archytas (c. 380 BC) guessed that the numerical ratios concerned hold between the *numbers* of vibrations (per unit time), or frequencies, of the musical notes. The lengths are inversely proportional to the frequencies.
- [7] For example, the first of the seven tablets of the creation *The Babylonian Legends of the Creation*. British Museum, 1931, p. 34-5) begins:
1. When the heavens above were yet unnamed.
2. And no dwelling beneath was called by a name...
- [8] Luckenbill, D. D. *Ancient Records of Assyria and Babylonia*. Chicago, 1927, vol. II, p. 65.
- [9] Pseudo-Plato, *Epinomis*, 987 E.
- [10] Pythagorean mathematics was originally a primitive type of mathematical physics. It embraced both *pattern* and *process*. As regards the former, G. S. Kirk (*Heraclitus*, Cambridge, 1954, p. 403) claims that the discovery of the significance of the arrangement of things, as distinct from their gross material constitution, was perhaps the most important achievement in the history of archaic speculation.
- [11] Cornford, F. M. *Plato and Parmenides*. London, 1939, p. 36-7.

- [12] Plato argues (*Republic*, 526) that the nature of geometry is "in flat contradiction with the absurd language used by the mathematicians." He complains that "They constantly talk of 'operations' like 'squaring', 'applying', 'adding' and so on, as if the object were to *do* something, whereas the true purpose of the whole subject is knowledge—knowledge moreover of what eternally exists, not of anything that comes to be this or that at some time and ceases to be." See also the discussion by Proclus, in his commentary on Euclid, on the difference between *problems* and *theorems*, referred to by T. L. Heath, *The Thirteen Books of Euclid's Elements*, Cambridge, 1956, p. 124-5.
- [13] Plato, *Republic*, 530-531 C. As for astronomy it is not altogether clear what Plato expected readers of the *Republic* to study. For, despite all his talk about ideal non-empirical objects, some passages seem to refer to actual physical astronomy. Later, in the *Laws*, he laid much more emphasis on the latter.
- [14] The later Pythagoreans attempted to evade this difficulty by an ingenious system of rational approximations based on successive solutions of the Diophantine equations $x^2 - 2y^2 = \pm 1$ (in modern notation), but this was an infinite process which could never yield a complete or perfect answer to the problem. It led to the idea of the monad (unit length) as an infinitesimal. A similar situation arose in music with the problem of exact division, e. g. bisection, of the octave (see the reference in Note 13). The logical difficulties associated with infinitesimals were exposed by Zeno of Elea, and circumvented in geometry by Eudoxus who developed the method of exhaustion.
- [15] See my *The Natural Philosophy of Time*, London and New York, 1961, p. 122-3 for a fuller account. A useful discussion from a somewhat different point of view is given by A. Reymond, *History of the Sciences in Greco-Roman Antiquity*, transl. R. Gheury de Bray. London, 1927, p. 119-120.
- [16] Aristotle, *Metaphysics*, 1091 a 12.
- [17] Aristotle, *De Partibus Animalium*, 640 a 17-19.
- [18] This point has been forcefully expressed by W. K. C. Guthrie, *Orpheus and Greek Religion*, London, 1935, p. 245: "On the cosmogonical side the Orphic and similar systems came into conflict with Aristotle on an equally fundamental point. To his mind the effect of their theogonies was to make the development of the world to a certain extent evolutionary. The most perfect was not in existence at the beginning, but appeared at a later stage. In his own terms, they made the potential prior in time to the actual, and that for Aristotle was the greatest heresy."
- [19] Aristotle, *Physica*, 202 a 8-9.