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Some Remarks on the Origins of Greek Science and Philosophy

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This is not the occasion for new and surprising theses concerning the Pre-socratics, and that is just as well, for I have no new and surprising theses to present. Instead I shall defend some old theses and try to put them in a perspective that may be useful here as a background for the more specialized papers to be presented in this volume.

Philosophy in the strict sense is pretty clearly a Greek invention; but at first sight Greek science, and above all Greek astronomy, seems to be a borrowing from the Orient, like sculpture, architecture and the alphabet. Does this mean that the older view is wrong, I mean the view presented by Tannery and Burnet, who wrote before we learned so much about Babylonian astronomy and mathematics, and who portray Greek science and natural philosophy as coming into the world *together*, one and indivisible, first in Ionia and then in southern Italy and Sicily, in the sixth and early fifth centuries BC? I want to argue that the old view is right after all, and that once we have absorbed the discoveries of Neugebauer and other explorers of Mesopotamian science, we can see that Greek science is essentially a new creation, inseparable after all from the origins of Greek philosophy in the earliest phase of these two disciplines. In short, I want to defend the traditional view that Greek astronomy and natural philosophy (and the beginnings of geography and history too) first developed in Miletus in the middle of the sixth century BC and then spread like an epidemic throughout the Greek world, first by contagion to the neighboring cities of Samos, Colophon, Ephesus and Clazomenae, then to Ionian colonies in the northern Aegean (Abdera and Apollonia); and soon, travelling with refugees and immigrants to the far west, to Croton and Metapontum, to Elea and Acragas. So within the two generations that separate Anaximan-

der from Parmenides, Ionian science had been carried across the Greek world, paralleling the diffusion of the alphabet some two centuries earlier.

Now the utility of the alphabet is obvious; but in the case of what the Greeks called *περὶ φύσεως ἱστορία* (the investigation of nature), it is not immediately clear why this should have been so widely attractive so soon. The new science had its utility, no doubt, in so far as it included map-making (probably derived from the East) and observational astronomy (certainly derived from the East). But I think it was above all the intellectual power of a new, naturalistic or rational world-view which captured the imagination of an amazingly curious, open-minded people, beginning with a handful of pioneers along the Anatolian coast and in neighboring islands, but spreading swiftly throughout those bustling Greek cities scattered across half the Mediterranean. We can form some notion of the motivation and diversity of these first two generations (from about 550 to 490 BC) in the glimpses we get of three very striking and very different personalities—Pythagoras, Xenophanes, and Heraclitus—who contributed both to the renown and to the rapid physical diffusion of Ionian natural philosophy.

I do not propose to retell this familiar story. Instead I want to concentrate on the two features which best mark the radical break with earlier world-views, both in Greece and in the Orient, and which illustrate the close links between exact science and philosophical speculation in this earliest period. I think that a clear grasp of these two features will protect us against three seductive errors which can distort our understanding of the origins of Greek science and philosophy. The first error is to see Presocratic natural philosophy as a continuous development from mythopoetic thought in Homer and Hesiod, without a revolutionary break. The second error is to see Greek astronomy (and/or mathematics) as essentially a continuation of Mesopotamian science, without radical innovation. The third error is the view championed by D. R. Dicks [1966], which treats the development of Greek observational astronomy as if it were completely independent of the speculative theories of the early natural philosophers. I have argued the case against Dicks in my response [Kahn 1970], and I refer you to this article for detailed documentation. Here I summarize some of my conclusions.

I take it for granted that the new science that arose in Ionia in the sixth century was heavily dependent upon Babylonian astronomy, much in the way that the creation of the alphabet was dependent upon Phoenician sources and the creation of Greek sculpture and architecture was dependent upon models from Egypt. (This is all part of the 'orientalizing period' of Greek culture, in the broadest sense.) Herodotus tells us of some essential borrowings in the case of Greek astronomy: 'The Greeks learned of the *πóλος* and the *gnomon* and the twelve parts of the day from the

Babylonians' [*Hist.* ii 109]. For once he is right (although his guess, in the preceding sentence, that geometry was discovered in Egypt, has not been confirmed). For example, the identity of the Morning Star and the Evening Star, which had been known in Mesopotamia for many centuries, is first attested in Greece for Parmenides [Diogenes Laertius, *Vitae* ix 23 = Diels and Kranz 1951-1952, i 224.29-31]. (The absence of Greek evidence before Parmenides is surely an accident of our meager documentation for this early period: no doubt the information passed to Italy through Ionia.) How much Babylonian lore was available in Ionia in the sixth century we cannot know. But the Milesians added something for which there seems to be no Mesopotamian precedent. This is a geometric model for the heavens, a clear-cut scheme of concentric circles and other figures by which the observed motion and changes of the heavenly bodies were to be explained. The first and crudest of these models is attested for Anaximander: a series of circles set at numerically definite distances from a disk-shaped earth in the center. The model was quickly transformed and improved by his successors. Within two generations we get the classical scheme of a celestial sphere to which the fixed stars are attached so that their observed motion is explained by the daily rotation of the sphere. (When exactly the stellar sphere was introduced is not clear from our shabby evidence, but not later than the poem of Parmenides, ca. 500 BC.) Somewhat later, but before the time of Plato, the flat, discoid earth is replaced by a spherical model for the earth as well. It is this kind of geometric model (but without the spherical earth) that permits Anaxagoras to come up with a correct optical explanation of lunar eclipse by the middle of the fifth century BC. Now the important thing is not that the early models were so crude—that is only to be expected. What was important was that a geometric model for celestial motions had been proposed, with explanatory intent.¹ At the technical

¹ By a model here I mean a good deal more than a cosmic picture of the sort that one might find in Hesiod's *Theogony*, and more also than the picture of the heavens that served in Babylonian astronomy for plotting the movement of the Sun, Moon, and planets relative to the fixed stars, since such a picture serves only to describe but not to explain the observed phenomena. Scientific astronomy in the Greek sense begins with the attempt to give such an explanation by means of a definite structure conceived in terms of precise geometrical figures and relative sizes and distances. Such a model made possible the correct explanation of the Moon's light by the time of Parmenides and the correct explanation of lunar eclipse by the time of Anaxagoras. Since we have no astronomical texts from this period, we cannot know when the various technical advances were made that are incorporated in the later theory of spherics. The ascription of five zones to Parmenides by Strabo [*Geog.* i 94 = Diels and Kranz 1951-1952, i 225] on the authority of Posidonius is probably unreliable. But the pseudo-Platonic *Erastae* 132a [= Diels and Kranz 1951-1952, i 393] implies that schoolboys in the middle

level, it is this model that essentially defines the new philosophical view of the natural world as a *kósmos*, a system governed by regularity and order. And it is this same model that brings into existence scientific astronomy in a new sense: a structured theory capable of explaining (or trying to explain) the observed phenomena of the heavens. In this sense the cosmology of Anaximander and Parmenides is closer in principle to that of Ptolemy and Copernicus than it is to Hesiod or to any of their predecessors—unless one finds a geometric model in Babylon.

The second great innovation of Greek science is the notion of mathematical proof. On this point I can quote Neugebauer [1963, 530]: 'the discoveries of the Old Babylonian period had long since become common mathematical knowledge all over the ancient Near East'. What the Greeks added was 'a fundamentally new aspect . . . , namely the idea of mathematical proof. It is only then that mathematics in the modern sense came into existence.'

What Neugebauer does not see, but what seems obvious to me, is that the idea of proof plays the same role here in the creation of Greek mathematics as the kinematic models for the heavens plays in the creation of astronomical theory. When did this fundamental innovation in mathematics begin? Neugebauer tends to date it relatively late, in the fourth-century work of Theaetetus and Eudoxus. But the reports on Hippocrates of Chios take us back earlier, to the last half of the fifth century. Hippocrates is said to have been the first author of *Elements*, that is, a presentation of geometry in deductive form; and, in a long extract from Eudemos' history of geometry, we can see him operating with the 'method of hypothesis' or explicitly recognized premisses. Before Hippocrates we have no detailed documentation, so I shall not claim this achievement for my hero, Anaximander. Of course the tradition recorded by Eudemos actually assigns the earliest geometric proofs to Anaximander's predecessor, Thales of Miletus [Friedlein 1873, 157.10–13, 250.20–251.2, 299.1–5, 352.13–18 = Diels and

of the fifth century, in the time of Anaxagoras and Oenopides, were supposed to be familiar with a structure showing the obliquity of the ecliptic relative to the celestial equator:

the boys seemed to be arguing about Anaxagoras or about Oenopides. For they appeared to be drawing circles and imitating certain inclinations by their hands <relative to one another>.

Once these two circles are drawn on a celestial sphere, a partial system of zones is given. Whoever wrote the *Erastae* thought that Anaxagoras and Oenopides were doing this kind of astronomy. I see no reason to believe that we are better informed than the author of the *Erastae* on the development of scientific theory in the fifth century.

Kranz 1951–1952, i 79.8–19]. Thales is more a figure of legend than of history, but this image of the sage who predicts an eclipse, uses geometry to measure the height of the pyramids, and also begins cosmological speculation, nicely reflects what I take to be the fundamental historical fact: that observational astronomy, speculative cosmology, and mathematical research were developing together within those small circles of intellectual activity that carried the new science from Ionia to Magna Graecia and beyond.

We cannot reconstruct the early history of mathematical proof in Greece as we can reconstruct (to a certain extent) the development of a celestial model. But we can see the two enterprises interacting or coinciding in the work of Oenopides of Chios (after Anaxagoras and before Hippocrates), who did major work in astronomy but studied certain problems in geometry 'because he thought they were useful for astronomy' [Friedlein 1873, 283.4–10 = Diels and Kranz 1951–1952, i 395.10–14] and specifically for measuring the obliquity of the ecliptic. Oenopides also contributed to speculative cosmology by explaining the Milky Way as the path previously marked out by the Sun's annual course, before it settled in the ecliptic [Achilles, *Isag.* 24 = Diels and Kranz 1951–1952, i 394.29–32]. And we can see the same interaction between observational astronomy, technical work in geometry, and philosophical cosmology (as well as map-making) in the case of Democritus, whose contribution to the mathematics of the cone and the pyramid is recognized by Archimedes [Heath 1921, i 180].

Although we cannot reconstruct the early development of mathematical proof in Greece, we can perhaps see this development reflected in the examples of philosophical arguments that happen to be preserved. The oldest and most elaborate of these arguments has reached us intact simply because it was embedded in the hexameters of Parmenides' poem. (For this one argument preserved from the beginning of the fifth century there must have been dozens if not hundreds of arguments contrived by the mathematicians but lost, because they were in prose or not even written down.) Parmenides begins with a clear statement of his premiss or first proposition, presented in the choice between a pair of contradictories, *it is or it is not*; and he gives reasons for rejecting the second alternative. He then proceeds to derive a number of attributes of Being from the single premiss *that it is*. So it must be one, unique, dense, symmetrical, immobile, ungenerated and imperishable. The argument for the attribute *ungenerated* is preserved in full. It is an indirect argument proceeding from a trilemma of assumptions: if what-is has come into being, then it must have come to be (a) from Not-Being, (b) from Being, or (c) from nothing at all. All three assumptions are shown to be incompatible with the basic premiss *that it is*

and so they must be rejected. Hence, by a series of *reductio* arguments which eliminate the alternatives, the thesis *that it is ungenerated* is established. This argument clearly parallels the form of an indirect proof in geometry. And we can recognize the same general pattern of argument over and over again in the preserved fragments of Zeno, Melissus, Anaxagoras, and Diogenes, where it is used either to defend or destroy a thesis. Either we have *p* or not-*p*. My opponents assert *p*. But look what absurd (or false or contradictory) results follow from *p*. Therefore not-*p*. Or else, I assert *p*. For just imagine the opposite, not-*p*. But if not-*p* were the case, things would be quite different (or impossible or ridiculous). Therefore *p* must be the case.²

Incidentally, I think we can also see the influence of a mathematical mode of argument in the way Anaxagoras and other thinkers such as Diogenes first construct their ἀρχή or starting-point ('all things together', plus νοῦς ready to start things rotating, in the case of Anaxagoras), and then show how the world-order develops *naturally* and *inevitably* ('by necessity') out of these initial conditions. The physical ἀρχή occupies the place of premiss or *hypothesis*; the development of the cosmic order is analogous to the derivation of theorems.

In the case of these philosophical arguments, preserved almost by chance for the whole length of the fifth century, it must remain anyone's guess how far they presuppose, or how far they prepare the way for, the use of formally similar arguments in geometry. Some scholars (notably Szabó) have argued that the development of proof by the mathematicians is essentially dependent upon the (supposedly) earlier deductive exploits of the Eleatic philosophers. In the absence of any good textual evidence for mathematical proof earlier than Hippocrates in the late fifth century, it is impossible to *refute* Szabó's thesis; but I think there is nothing to be said in its favor [cf. Berka 1980, Knorr 1981a, Bowen 1984]. Hippocrates' proof is so elaborate that it clearly presupposes a considerable tradition of some technical sophistication; and it is a sheer accident of our documentation that we cannot trace this tradition back to its origins. My own hunch is that the development of more or less rigorous proof in mathematics and in philosophical argument went hand in hand, but that the geometrical application is likely to have led the way from the beginning, even before Parmenides. In these matters it is normal for philosophy to borrow from mathematics, just as we can see Plato in the *Meno* taking over the method of *hypothesis* from geometry. But in the beginning the philosophers and the mathematicians will often have been the same people, as the tradition

² Compare Geoffrey Lloyd's remarks [1979, 25 and 71-78] on the use of *modus tollens* and *reductio* arguments in fifth-century philosophical and medical texts.

tells us of Thales and Pythagoras, and as we can see later in the case of Democritus (and of a sophist like Hippias). The real contribution of philosophy was not in the specific techniques of proof but in the very idea of proving geometric propositions: taking some things for granted, either as obviously true or temporarily assumed, in order to establish what follows from them. This seems to me just as deep and philosophical an innovation as the introduction of geometric models for the heavens.

There is a third fundamentally new idea which we can detect in the fifth century and which has been elegantly documented by Geoffrey Lloyd, the concept of nature as a uniform system implying a regularity of cause and effect. This is the doctrine asserted in *Airs, Waters, Places* 22: 'each affliction (πάθος) has its own nature and none of them occurs without a natural cause (φύσις).' As Lloyd points out [1979, 33], the origins of such a view can be glimpsed in Anaximander's fragment on cosmic justice; and a dogmatic generalization is found in the somewhat questionable 'fragment' of Leucippus [Aëtius, *De plac.* i 25.4 = Diels and Kranz 1951-1952, ii 81.3-6]; but for a full articulation we must turn to the Hippocratic treatises of the late fifth century. This again seems to me simply an accident of our documentation: the older Hippocratic treatises are the *only* non-fragmentary scientific/philosophic texts that have reached us from the fifth century. Their close connection with Ionian science seems to me clear; but I leave this topic to Geoffrey Lloyd.

What I am proposing, then, is the traditional view of the origins of Greek science and philosophy in the emergence of a closely connected bundle of diverse but interrelated activities in the sixth and fifth centuries BC, before the systematic specialization and separation of the disciplines that becomes more characteristic of scientific work in the fourth century and later. There may well have been astronomers and mathematicians in the fifth century who were not also natural philosophers, but the more typical case is that of Oenopides and Democritus who worked in all three fields. Socrates is probably the first philosopher whose conception of his calling is essentially independent of work in astronomy and cosmology; and, according to the biographical sketch of the *Phaedo*, that was not true even of Socrates in his youth.³ The close connection between philosophy, science, and mathematics is just as characteristic of Greek philosophy in its first century and a half as it is of the initial period of modern philosophy in the 17th century.

³ The only possible precedent for Socrates that comes to mind is Protagoras, but his rejection of a realist view of truth seem unthinkable without the traditions of Eleatic ontology and Ionian cosmology. Socrates may well have been fascinated by natural philosophy in his youth, but there is no trace of this in his own positive conception of philosophy.

And it is this essential interconnection which is exemplified in the two key ideas which I have emphasized: geometric models for the heavens and the development of deductive proof. If we bear these two ideas in mind, we will not be tempted by either of the three errors to which I referred in the beginning: to see Presocratic cosmology as a continuous development from Hesiodic mythopoeetry; to see Greek science as a mere borrowing from the East; or to see the development of scientific astronomy as essentially independent of speculative cosmology, as Dicks and Neugebauer would have us do. It is really painful to see a great scholar like Neugebauer saying, in his masterful *History of Ancient Mathematical Astronomy* [1975, 572], that there is 'no need for considering Greek philosophy as an early stage in the development of science. Its role seems to me only comparable to the influence on science of the Babylonian creation myth or of Manichean cosmology'. I think it would be difficult to find a more profoundly mistaken view in any serious book ever written on our topic. I can only put it down to an extraordinarily narrow construal of science and to a morbid dislike of speculative theory on Neugebauer's part.

More interesting, and perhaps more prevalent, than the line taken by Dicks and Neugebauer is the related error of exaggerating the continuity between Ionian science and its poetic antecedents. Of course, the early natural philosophers were men of their time and place; their language and much of their conceptual equipment were inherited from the Greek past. But their debt can be overestimated and their originality masked by reading back into Homer and Hesiod some of the most characteristic ideas of the Milesians and their followers. There is a Cambridge tradition for this, going back to Cornford and still visible in Kirk and Raven (even in the second edition of 1983) and in some of Guthrie's work.⁴

Thus Kirk and Raven claim that in 'the naive view of the world' in Homer 'the sky is a solid hemisphere like a bowl' [Kirk, Raven, and Schofield 1983, 9]. If there had been such a clear geometric model before the Milesians, the invention of the stellar sphere would have marked a relatively trivial advance in a continuous tradition. But in fact there is no trace of the notion of a celestial hemisphere or bowl in Homer or in any poet earlier than Parmenides; in so far as οὐρανός in Homer has any definite shape, it is that of a flat roof or a steep incline rising to the zenith [Kahn 1985, 138-140]. But the very notion of a clear geometric model composed of circles and spheres (as distinct from an anthropomorphic structure like a house or a tent) is alien to mythopoetic thought as we find it in Homer and

⁴ But this tendency is not limited to Cambridge. Wade-Gery of Oxford once wrote an essay [1949, 81] in which he described Hesiod as 'the first Presocratic'. And compare, for example, Solmsen 1950.

Hesiod. Even more seductive is Cornford's misreading of χάος in Hesiod as a somewhat distorted version of the Polynesian myth of the separation of heaven and earth. Thus we find in Kirk and Raven: 'For Hesiod's source, at all events, the first stage in the formation of a differentiated world was the production of a vast gap between sky and earth' [Kirk, Raven, and Schofield 1983, 41]. Cornford found an echo of this supposed source in some verses from Euripides [Frag. 484]: 'Heaven and earth were once one form; but then when they separated from one another, they gave birth and brought all things to light'. But of course Euripides is quoting not Hesiod but Empedocles or Anaxagoras or some other natural philosopher. To project this view back into pre-Milesian mythopoeetry is once more to make the revolutionary novelty of Milesian cosmology invisible. It is also to make hash of Hesiod, for whom χάος, the primeval gap, came into being *first of all*.

This is not the occasion for a more sympathetic reading of the *Theogony*, along the lines of Paula Philippson's study [1936] or of Norman Brown's sensitive interpretation [1953]. I want only to remark that Cornford's reductive approach to Hesiod, reading not the text of the poem but looking through it to find the more primitive 'source', has the effect not only of disguising the radical novelty of Ionian cosmology but also of doing an injustice to Hesiod's own speculative achievement. He set out to imagine what there could have been first of all *in the beginning*, before anything had taken shape. Different mythic poets conceive this beginning in different ways. Hesiod's ploy was to imagine an enormous gap, a vacant, yawning hole with no sides. In the genealogical language of mythopoeetry, the negative character of this primordial chasm is revealed by its offspring, infernal darkness (Erebus) and black Night. What we have then is a kind of black hole, into which things could only fall and be lost. The first positive item to appear is 'broadbosomed Earth, a safe seat for all things forever'. Earth is a safe seat because it prevents things from falling into the dark chasm below. Hence everything positive and solid will now be produced from Gaia. Her first product is the starry Heaven 'equal to herself, to cover her all around'. So the world now has an upper floor, and Gaia now has a mate. This story has a beautiful coherence of its own, which is to all appearances Hesiod's own creation. And if some of the succeeding misadventures of Gaia and Ouranos *do* have a non-Greek source, this has nothing to do with a primeval Polynesian 'clinging together', and also nothing to do with the cosmologists' quite different attempt to understand how a differentiated universe could emerge *in a natural way* from the initial hypothesis of an undifferentiated mass, whether this mass is described as ἀνείρων or as 'boundless air' or as 'all things together'.

In conclusion, let me say one word about the demarcation between science and philosophy, I can be brief, because in the period before Socrates there is no such demarcation. The investigation of nature (περὶ φύσεως ἱστορία) comprises both. Looking back from our point of view, we might see the prefiguration of a distinction between philosophy and science in the division between the two parts of Parmenides' poem: the Way of Truth, which presents a metaphysical account of Being, and the Way of Opinion, which describes the genesis of the natural world. When we come to Plato's *Timaeus*, we can see the transformation of this dichotomy into something resembling our distinction between a philosophical account of reality (in the doctrine of Forms) and Plato's own version of Ionian natural philosophy or physics, as a 'likely account'. But that lies outside my *propos*.

I should add that I have considered only the internal history of Greek science and philosophy in its earliest phase. The external history—the social, economic, and political conditions of this momentous innovation—would require another paper. But I would have nothing substantial to add beyond the very instructive parallel between the emergence of rational thought about the physical universe in the sixth century and the contemporaneous development in Greek political life—the parallel that was (to my knowledge) first usefully drawn in J.-P. Vernant's *Les origines de la pensée grecque* [1962], and then convincingly developed in the last chapter of Lloyd's more recent study [1979]. I can add only one final question. If one accepts the thesis developed by Jasper Griffin [1977], as I am inclined to do, then the author of the *Iliad* must be seen as having made a systematic attempt to eliminate, suppress or play down all of the more strikingly miraculous and monstrous elements in the older epic tradition. That means that the Greek tendency to think of the circumstances of human life in 'naturalistic', non-magical terms can be seen at work already in the late eighth century. In this perspective it is Homer and not Hesiod who might properly rank as the first Presocratic. Now can we trace back to the time of the *Iliad* that political and sociological parallel which works so well for the sixth century? If not, is this too an accident of our documentation? Or is this evidence for a more Weberian view of the essential autonomy of intellectual history?