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The Presocratic Origins of Cosmological Theory

The beginnings of cosmological theory, with the accompanying arguments, hypotheses and speculations, are to be found in the evidence from the Presocratics, a general term for the early Greek philosophers of the sixth century BCE. Although the last of these are contemporary with Socrates they are classed together because of their common interest in cosmological problems, in particular in theories of matter, of space and of time. Only fragments of the original wording, and later commentaries on them, survive, but it is still possible to admire the daring and originality of their thinking about the world around them.

Aristotle wrote a history of early philosophy in a work known as *Metaphysics Alpha*. In the section on the Eleatics (986a-987b) he said that Xenophanes looked up at the whole sky and "one-ified", making up a verb *henizo* to mean that Xenophanes supposed "everything is one thing", a forerunner to "a theory of everything". Aristotle disparages the result here, but the language used is significant. At the beginning of serious cosmological theory there was a search for an interconnection in a threefold diversity: (i) What, basically, is everything made of? (ii) Are there spatial limits? And (iii) Is there a beginning in time (and a corresponding end)?[1]

The first people to ask such questions are known as "Presocratics" in that they almost all preceded Socrates.[2] The originators in the early sixth century BCE – Thales, Anaximander and Anaximenes – were from Miletus, on the western coast of Asia Minor. Xenophanes started from that region but travelled "up and down the land of Hellas". Then came Heraclitus from Ephesus, and, in the west, Parmenides and Zeno from Elea in south Italy and Empedocles in Sicily. Melissus was from the island of Samos,

from where Pythagoras had earlier migrated to Italy. Anaxagoras again was from the Ionian coast and visited Athens (where his book was on sale on the market). The atomists Leucippus and Democritus were from Abdera in northern Greece, and Democritus visited Athens, where he was disappointed to find that no one had heard of him. Philosophy travelled swiftly with these pioneers, from east to west of the Mediterranean world, the islands and the northern coastline, and only reaching Athens in the time of Socrates. The civilisations of Babylon and Egypt were much older, and they had centuries of astronomical records, but what might account for the sudden outburst of brilliant and original *theories*, concerning space, time and matter in the Greek world of the sixth century BCE?

The foundation of colonies in the Greek world, the expansion of trade and the exchange of ideas as well as goods facilitated independent thought. Another contribution to this development was the establishment of democracies which fostered argument, reflection and decision-making as constitutions were drafted and laws voted on. Effective verbal expression became crucial, and, with the adaptation of the Phoenician alphabet and the spread of literacy, what was thought and said in the language could be written down, and was available to be studied at leisure, published abroad and criticised. Heraclitus put his book in the city temple as part of the city's treasure, and Anaxagoras' work was available in Athens. The Greeks were generally fiercely competitive, and in a range of areas. There were the games, at Olympia and elsewhere, where to be first was rewarded with a simple olive wreath, but the glory was priceless, expressed perhaps in a victory ode on return home.[3] Music and poetry also had their own rival events, and plays were composed and produced to win prizes. For the Greeks, to be best was a way of life, and this self-awareness, and the desire to be better than anyone else gave a sharp edge that could be found in their philosophy. "I'm telling you this," says Parmenides' goddess to her young student as she introduces a new (and admittedly false) cosmology "so that no one's thinking shall outpace you".[4] Most of the other Presocratics, and in particular Anaximenes, Heraclitus, Empedocles, Anaxagoras, Zeno and Democritus, saw themselves in a competitive tradition, knowledgeable about previous works in "physics"[5], and ready to defend, criticise, modify or reject their predecessors' achievements.

Cosmic Matter

The preliminary to questions of space and time is to understand what there actually *is*, as the basic "stuff" of the universe. The first Greek philosophers viewed the problem as the search for a "first principle" which became known as *archē* (beginning) and *stoicheion* (element), indicating what has been in the past and continues to exist in a fundamental form. Anaximander from Miletus began the enquiry in the sixth century BCE. According to Aristotle he posited to *apeiron* (the limitless), an attempt at a new language for a new idea, to represent what is neutral, without limit in space or time, or defined by any quality. And for the first time it was recognised that a lack of temporal limit works both ways. Eternity means no beginning or end; a blow to the standard contemporary religion of gods who were thought to be born, but are then *athanatoi* – "deathless". From the *apeiron* Anaximander suggested that a "seed" (*gonimon*) arose, from which opposite qualities, viewed as "things", emerged, and eventually produced a cosmos.

The concept of *apeiron* was so neutral as to be almost meaningless, and Anaximander's successors – Anaximenes and Heraclitus – preferred a *characterised* substance for a basic principle. Anaximenes defined his principle as air (*aēr*), all-pervading, and, as "breath", essential for life. The one original sentence we have from him reads: "As our soul, which is air, maintains us, so breath and air surround the whole cosmos." And by a *process* of thickening and thinning individual objects show their differences. Heraclitus followed Anaximenes in explaining a diverse world in terms of an underlying everlasting principle in constant movement, but he gave it the quality of fire: "This kosmos, the same for all, no one of men or gods have made, but it ever is and will be ever-living fire, kindling in measures and being quenched in measures."[6] The perpetual motions and transformations, in different placings and at different times, were predicated as essential for the maintenance of the whole, which Heraclitus illustrated enigmatically with the example "you cannot step into the same river twice" (fragment 91), and the apparent contradiction "changing it rests" (fr.84a).[7]

The search so far for a single entity such as air or fire or the characterless *apeiron* to explain permanence through change was brought to a halt by the logic of Parmenides. Parmenides represents himself as a young man, driven in a chariot by the daughters of the Sun, to hear a revelation from an unnamed goddess. She explains to him that it is not sufficient to proclaim what things are made of and how they seem to change, but a more basic principle needed

to be established first to meet her "hard-hitting challenge". However, as soon as her own premise of just "it is" was compromised in the smallest degree in the assumption of two principles, a cosmology (labelled "deceptive and untrue") could be constructed. From such a pair, which she labelled light or fire and night, came the first understanding of a theory of elements: "the whole is full of light and unclear night, both equal, since nothing is without either" (fr.9). In the neighbouring island of Sicily Empedocles picked up on this concession, and, despite appearances, reduced everything to a proportionate mixture of *four* basics – earth, air, fire and water, as fr.17.34-35: "These are the only real things, but, as they run through each other, they become different objects at different times, yet are throughout forever the same."

There were two diametrically opposed reactions to Empedocles' theory of everything being made from four basic elements, one was to suggest that "everything is in everything", the other that there is one thing and no-thing. Anaxagoras proposed maximum plurality and diversity in his first blunt statement: "all things were together" (fr.1), followed by: "everything is in everything" (fr. 6). He scorned a theory of a set number of elements or variations on a basic substance to explain the vast variety of phenomena, and claimed instead (i) that everything *is* in everything, (ii) that everything *was* there in the beginning, and (iii) that the universe *will be* ever expanding. This theory is similar to that of an original "microdot" which explodes into a "separating-out" of phenomena in an ever-continuing cosmos. The second reaction to Empedocles' four elements came from the atomists, who posited an infinite number of characterless atoms (i.e. "uncuttables") in incessant movement in an infinite expanse of void.[8]

Cosmic Space

In the Homeric poems, the *Iliad* and *Odyssey*, there was generally a simplistic portrayal of cosmic space. The earth was viewed as a circular disk around which flows the freshwater river Ocean; the vault of the sky above is a hemisphere, with a matching realm of Tartarus below. The chief god Zeus controls the sky, Poseidon the sea and Hades the region below, whereas Iris, goddess of the rainbow, bridges sky and earth in her role of messenger. However, a distinction between air closer to earth, and the bright blue sky above (called *aithēr*) had been made.[9] Air at ground level appeared as mist or fog, but above was the bright blue cloudless sky, the home of the gods. At night the region twinkled with complex star formations, which rose from

Ocean in the East and set in the West, moving round in the river by day for the next night's rising. The post-Homeric poet Hesiod used a genealogical model to explain the arrangement of creatures of the earth and meteorological formations. Of particular interest is his naming of the vague initial area before there was anything as *Chāos*, a word that connects with *chanon* "yawning", "open (mouth)", and *chasma* "gap", a fair attempt to describe what there was before anything else.[10]

Anaximander recast the *Chāos* of Hesiod as *to apeiron*, neuter and negative, with no internal *peras*, i.e. limiting factor, but being a vast characterless origin of all things, extending endlessly in space and time. Within it arose a "seed" of opposites, hot and cold, dry and wet in particular, the hot rising to form a flame that split off into the circles of sun, moon and stars, the cold concentrated as central earth with mist between. The war of attrition between opposites balance out to give repeated sequences of bright days and dark nights, hot, dry summers and cold wet winters. Anaximander also came to two remarkable conclusions – the first that the earth does not "fall down" because it is freely suspended in a central position with no reason to go one way or another, and secondly that the earth could not be flat but possibly three dimensional, and he gave it the shape of a cylinder with life on the surface opposite to ours, literally "antipodes", with feet opposite on opposite surfaces. The structure of the world grew like an organism from a seed, but when established followed simple mathematical laws.[11] Anaximenes gave to the limitless cosmos of his predecessor the attribute of air/breath extending outwards as sky, and being also the air that is breathed, essential to human life and *psychē*.[12] The structure of a universe with a central earth, surrounded by water as sea, with air and fire (home to sun, moon and stars) above came to be the accepted pattern of the universe, the "whole", and became standardised with the four elements of Empedocles as its material.[13]

The "hard-hitting" arguments of Parmenides' goddess brought the ongoing Presocratic practice of devising a cosmology to an abrupt halt, and henceforth these arguments had to be taken into account. If a basic "is" (*esti*) is accepted, then logically its opposite ("is not", *ouk esti*) is to be rejected. Applied temporally *esti* rules out *ouk esti* and with it a beginning from, or destruction into, what is not; spatially *esti* is complete with no gaps of *ouk esti* internally or at the periphery; movement, change and plurality are also ruled out.[14] Parmenides went on to build his own cosmology by showing with minimum change (two things rather than one) a cosmos could be generated. Empedocles posited four entities – earth, air, fire and water – and

gave to each the characteristics of Parmenides' *esti*, namely being unchanging, ungenerated and, indestructible. He went further, and identified Parmenides' *ouk esti* spatially, taking this to mean there could be no *kenon*, "empty space": "It is impossible for there to be a coming into existence from that which is not, and for what exists to be completely destroyed cannot be fulfilled, nor is to be heard of" (fr.12).[15] For Empedocles the elements are sempiternal; there can be no genesis from what is not, nor destruction of what there is, in any temporal or spatial sense. As a *plenum* (i.e. a "full") what there is occupies all available territory, so that there is no place for nothing. Outside this *plenum* however, there does exist what in later terminology was called *argē hylē*, or "inert matter".

Parmenides had denied existence ("*is*") to "is not", and Empedocles clarified this as *kenon*, impossible in a *plenum* structure of elements packed together. The response of the atomists was to proclaim that "is not" exists as firmly as "is": no-thing is as real as thing. What exists are *atoma* (unlimited numbers of uncuttable units), moving at random through an infinite extent of space. The present galaxy arose as a consequence of a rotation of a group of atoms, and it was obvious that other world orders would be forming and disintegrating elsewhere. This was comparable in some respects to the epic world of Homer's *Iliad*, where the violence and heroism depicted was basically no more than an arrangement of alphabet letters with spaces in between.[16] For a cosmos to have a centre and boundary was meaningless in atomic theory. Infinite emptiness has no centre, and there was a puzzle to counter the suggestion of a boundary to the cosmos: suppose one went to the end and stretched out a hand or stick – if it is obstructed you are not at the edge, and need to go further, and if there is no obstruction there is no boundary.[17]

The question of *movement* in space was raised in some of the famous "paradoxes" of Zeno of Elea, the young defender of Parmenides. Zeno explained that the purpose of his puzzles was to support Parmenides against those who mocked him for the apparently ridiculous consequences of having only one existing entity. Zeno pays the mockers back by showing the absurd conclusions that follow from the seemingly obvious assumptions that there is more than one thing in existence, that they have size and weight, and that they move. The four puzzles on spatial movement became so famous that they were referred by title only: (i) "the stadium", (ii) "the arrow", (iii) "Achilles and the tortoise" and (iv) "moving blocks". The first asked how a set distance could be crossed since, once the half-way point was reached, there would always be a further half-way point and so on: how could an infinite

number of half-way steps be covered in a finite time? This was elaborated in (iii) – if the tortoise is given a head-start Achilles cannot overtake it, as he would always first have to reach the mark the tortoise had left over ever-decreasing distances. In (ii), the moving arrow is stationary in its own length at any moment in its flight; the flight is a sum of such (stationary) moments and so is not moving. In the fourth puzzle, when blocks of equal length pass in opposite directions at equal speeds a set time appears to be equal to half itself. These puzzles or "paradoxes" have a long history of later engagement with problems of spatial and temporal infinitesimals.[18]

Cosmic Time

With Zeno and his predecessors, the question of spatial limit was connected with that of time in that beginnings and ends were complementary. As the cosmos might be bounded or boundless in space so its birth would be complemented by its destruction in time, or, logically, there would be no beginning or end. The mythical inheritance of divine beings who were born and were then *athanatoi*, i.e. "deathless", became unacceptable. For example, the *apeiron* proposed by Anaximander, was taken to be always existing, but from it emerged at one stage the "seed" from which the present world order appeared. Similarly the "air" posited by Anaximenes had no beginning or end but still was involved in the world that arose from the original "whirling", for it is to be identified with the air and breath that keeps living things alive within in it. In the case of the "ever-living fire" of Heraclitus successive generations arose from this first principle as it was kindled and reduced in measures. At certain times and in certain places the fire could be "quenched" into water and earth and ignited back again but there was an overall balance secured by logos, given in fr.30: "This order, the same for all, no one of men or gods has made, but it always was and is and will be – ever-living fire, kindling in measures and extinguished in measures". The new interpretation of the divine is then to be understood in this way: "God – day night, winter summer, war peace" (fr.67).[19]

Once again Parmenides brought his predecessors' ways of thinking to an abrupt halt with a strong, and logical, denial of any temporal beginning or end:

> How could 'what is' later perish? How could it come into existence? For if it came to be in the past or if it is going to exist at some time in the future it is not – so generation is extinguished and destruction incredible. (fr.8. 22-25).

And Parmenides has another argument here to re-inforce this conclusion, later known as "the principle of sufficient reason: "If it did come from nothing, what compulsion was there for it to arise later rather than earlier? Therefore it must be all at once or not at all." If there is *no sufficient reason* to begin a task this week rather than next, it will never be done. Parmenides' successors answered him in different ways. Anaxagoras for example faced up to the "principle of sufficient reason" by affirming that there *was* a universal Mind (*Nous*) controlling generation. This is not divine or moral or teleological but it does have knowledge and power, and ensured an ordered cosmos from an initial rotation:

> All that has life Mind controls, and Mind controlled the rotation of the whole, so as to make it rotate from the beginning. First it began the rotation from a small area, but now rotates over a wider area *and will continue to rotate ever more widely*. (fr.8)

In this beginning "all things were together", when at some indefinite moment and for no apparent reason a vortex was started by the universal principle. Then bright and dark, hot and cold, dry and wet were separated out and red-hot stones were flung from the centre to form constellations.[20] Here is the theory of an expanding universe with no limit imposed either in the time available or the space covered.

For Empedocles, the four elements are sempiternal, but in their interchange within the *plenum* "as they run through each other they become different objects at different times, yet are forever the same" (fr.17.27-35). The direction of movement was determined by opposed principles of attraction and repulsion (which he called Love and Strife) which resulted in the elements moving together into constructs or separating. But, in addition, Empedocles introduced the notion of *cyclic* time. The foundation for this assumption was in the obvious turning of night and day, the seasons and the year, with the possibility of a Great Year, when everything returned to an earlier starting point. On its astronomical definition the Great Year is the period of time it takes the sun, moon and five "wanderers" (the planets Mercury, Venus, Mars Jupiter and Saturn) to complete their rotation and return simultaneously to a similar earlier position against the background of the fixed stars.[21] The Pythagoreans also had the idea of "life cycles" when the soul was thought to migrate through a series of mortal lives. Lives might even be repeated in exact detail in endless repetition, as in the example recorded by Eudemus:

> If you believe what the Pythagoreans say, everything comes back in the same numerical order, and I shall deliver this lecture again to you with my staff in my hand as you sit there in the same way as now, and everything else shall be the same. (*Physics* fr.51)[22]

The ordering of the large scale cyclic events underlying Empedocles' cosmology has been much debated. It would seem that variations were possible within a general pattern of all the elements coming together under the force of attraction and forming a harmonious sphere (which he was ready to call "god") and then being pulled apart by a separating force (in which our present world formation should probably be placed). Eventually, however, the forces of attraction and repulsion will be reversed, and everything is brought together again, the cycles being endlessly repeated.

So far the pluralists had recognised just the one world order in which we live, but the atomists took the arguments to their logical conclusion. If, as they believed, there is an infinite amount of material and an infinite extent of space, then it is likely that there will be innumerable world-orders (*cosmoi*) arising and disintegrating within it at different times and in different spaces. Through the empty space some *cosmoi* are starting and increasing in size, others are at their peak and others disintegrating. The presentation is of "whirls" starting up randomly in space and attracting more and more matter; the initial density cools from a great heat, and cosmic clumps are transformed into galaxies.[23]

With Democritus the early speculation on matter, time and space comes to an end as cosmology in the fifth century BCE is seen as irrelevant to human affairs, and gives way to new interests in politics and ethics, centred on Athens. Socrates was dissatisfied with Anaxagoras for having nothing to say about *moral* forces, the sophists concentrated on rhetoric and success in public life, Protagoras proclaimed that "*man* is the measure of all things", and the chorus in Sophocles' *Antigone* sang of many things being awesome, but none more awesome than humanity and human achievements. Cosmic questions of matter, time and space were generally ignored until the great myth of Plato's *Timaeus*, by the research of the mathematicians in his Academy and then, in the fourth century by Aristotle's works on metaphysics, meteorology and *De Caelo*.

Notes

1. On the evening I am writing this (8-9-16), there is a relevant BBC TV programme in a series on "The Beginning and End of the Universe". Cf. Parmenides fr.8.19: "How could what there is perish? How could it come into existence?"
2. The latest, Democritus, was a contemporary of Socrates in the fifth century BCE, but his physical theories on atomism were a culmination of previous theories, and belong with them.
3. Pan-Hellenic competitive games were an annual event on a rota of Isthmian, Nemean, Pythian and Olympic.
4. Parmenides fr.8.60-61.
5. Physics, ta physika in the original sense of studies concerned with nature, cosmology in particular.
6. Heraclitus fr.30. The "measures" are both temporal and spatial – at different times and in different places fire is kindling and being quenched but is never completely dominant or destroyed.
7. Cf. also "you cannot step into the same river twice" (frs.12, 91).The tag panta rhei "everything is in a state of flux" is attributed to Heraclitus by Plato and Aristotle as a summary of his opinion here.
8. The contrast is between "is" (for atom) and "is not" (for void), one as real as the other.
9. Cf. the highest pine tree on Mount Ida reached through air to aither, Iliad 14.288.
10. From Chaos the mists of Tartarus emerged, and Hesiod attempts to measure the height above and the depths below with a bronze anvil, falling nine nights and days, reaching earth on the tenth, and, if it fell from earth, would fall another nine nights and days, and come to Tartarus on the tenth, Theogony 721-5.
11. He used a simple (wrong) calculation connected with the powers of 3, for moon, star and sun "rings" as 9, 18 and 27.
12. Psychē ("soul"), the shade; that leaves the body for Hades at death ow is gaining a role in life as the principle of thought and emotion.
13. The combination of the universe as a living complex structured according to mathematical rules also characterised the ongoing cosmology of the Pythagoreans, and the Pythagorean Philolaus took the momentous step of moving the earth from its central position, and replaced it with a central fire, the "hearth of the cosmos", with a "counter-earth" revolving round it, the earth beyond that, and then sun, moon and planets with the fixed stars at the periphery. It was the Pythagoreans too, who, with their interest in mathematics, music and astronomy, posited the "harmony of the spheres". Since sun, moon and stars move in fixed circles at varying speeds, sounds would inevitably arise, and in harmony according to the mathematical distances and musical ratios (cf. Aristotle De Caelo 290b).
14. Parmenides fr.8, passim: "generation and destruction have been cast out …remaining the same and in the same it abides by itself and so stays firm … there is and will be nothing apart from what it …being equal to itself it rests uniformly in its limits." Space is compared to a "well-rounded sphere" in that "equally balanced about the centre in all directions it cannot be more here and less there than what-is, since it is all continuous; being equal to itself on every side it rests uniformly in its limits"(fr.8.42-49).

15. In the second (fallacious) part of his poem, in which the minimum of two basics are assumed, the laws of the physical structure, based on the twin elements of fire and night, are bound by the same necessity that guaranteed the validity of the earlier metaphysics: "You shall know also of the surrounding ouranos, from where it grew and how necessity led and bound it to hold the limits of the stars" (fr.9).
16. The same word stoicheion was used for "element" and "alphabet letter".
17. The most detailed version of the puzzle is at Lucretius 1.968-73, where the imagery of a Roman declaration of war is used, where an official went to the limit of home territory and threw a spear over the boundary into enemy territory. If it is stopped, it is not the boundary, if not there is no boundary.
18. The four attacks on motion are only given in summary form in Aristotle, and elaborated in his commentators, cf. Simplicius on Aristotle Physics 239b. Zeno himself is reported to have been involved in a conspiracy against the local tyrant, refused to reveal the names of his co-conspirators, and was tortured to death (cf. Diogenes Laertes 9.5.26). The Wikipedia article on Zeno of Elea has clear illustrations of the paradoxes, and some account of the history of possible, but often unsuccessful, solutions. They were called 'subtle and profound' by Bertrand Russell, and stimulated the writing of his Principia Mathematica.
19. The Stoics, who followed Heraclitus in the main, interpreted his theory of fire as evidence for ekpyrösis, i.e. a periodic world conflagration followed by a fresh start, but this is not Heraclitus' actual theory, cf. fr.94: "Sun will not overstep its measures, otherwise the Erinyes, ministers of justice, will find him out".
20. This was too extreme, and Anaxagoras was prosecuted by the Athenians for impiety for calling the sun "a red-hot stone" but there was probably a political motive behind the charge, based on his friendship with Pericles.
21. The awareness of suck a cycle for the totality of the planets goes back to the observations recorded in ancient Egypt and Mesopotamia. The principles were detailed in Plato's Timaeus.
22. The fragment continues: "it is also then reasonable to claim that time is the same, for if a movement is one and the same, and the before and after in identical sequences are the same, then this will also be true of number and time as well." It is impossible to date the exact arguments (reported by Porphyry Life of Pythagoras 19), and the conclusion that, when time is measured by the numerical sequence of events staying the same, then the history of what happens in each cycle will be endlessly repeated. Certainly the Stoics tied in a periodic conflagration (ekpyrösis) with the numerical sequence of identical events, and endless recurrence in the cycles.
23. Cf. Diogenes Laertius 9.31-32 on Democritus.