III
Science and Speculation

(a) *Material monism*

Anaximenes, the third of the Milesians, is by general consent a poor man's Anaximander: his theories were those of his master. An innovator in detail, he was an imitator in all essentials. And the two main innovations he can be credited with prove him to have lacked the vigour and temerity of Anaximander: he allowed the earth to rest in archaic luxury on a cushion of air; and he smirched the metaphysical purity of Anaximander's unlimited principle by turning it into a mass of gross, material air.

I dissent from that orthodox assessment. First, Anaximenes' two acknowledged innovations are both, I think, improvements on Anaximander's theories. Anaximenes, who evidently studied astronomy with some assiduity,[1] perceived the scientific untenability of Anaximander's argument for the earth's stability, even if he did not question the philosophical adequacy of his version of the Principle of Sufficient Reason. And his own airborne earth is, as I have already argued (above, p. 27), no mere regression to the childish position of Thales. Again, Anaximenes, who wrote in 'simple and economical' language (Diogenes Laertius, II.3=**13 A 1**), will have seen that Anaximander's 'rather poetical' style disguised a somewhat vague and perfunctory thought as far as the first principles of cosmogony go; and his own theory has the modest merit of replacing Anaximander's indeterminate principle and uncertain cosmogonical operations with a plain, intelligible stuff and a pair of familiar and comprehensible processes.

Second, our evidence, such as it is, suggests that Anaximenes was the more thorough, the more systematic, the more rigorous, and the more scientifically inclined of the two men. Ancient opinion favours this assessment: Theophrastus devoted a monograph to Anaximenes' theories (Diogenes Laertius, V.42); and in the fifth century Anaximenes was taken as the paradigm Milesian.[2]

> Anaximenes said that the principle is unlimited air (**19:** Hippolytus, **A 7**).

Anaximenes, like Thales and Anaximander, was presented in the Peripatetic tradition as a 'material monist', as a thinker who accepted as the fundamental axiom of cosmology:

(1) There is some single stuff which is the material principle of everything.

It is time to keep a promise made on an earlier page and to look more closely at the claims and credentials of 'material monism': was it, as Aristotle thought, the prime Milesian doctrine?

As it stands, (1) is Aristotelian in its mode of expression: 'principle' or *archê* (in non-philosophical Greek, 'beginning' and sometimes 'rule') was indeed used in a philosophical context by Anaximander (see above, p. 32); but it probably did not assume

its Aristotelian sense of 'explanatory principle' until much later. 'Matter' or *hulê* (non-philosophically, 'wood') was in all probability an Aristotelian invention. But, as I have already remarked, these linguistic points are of no great significance: Aristotle sometimes uses as a synonym for *hulê* the phrase *'to ex hou'* ('the thing from which': e.g., *Phys* 195a19); and he often expresses the proposition that *X* is *hulê* of Y by a sentence of the form '*Y* is from *X*'. Such non-technical expressions were of course available to the Milesians; and it may be conjectured with confidence that the men whom Aristotle takes for monists uttered sentences of the form:

(2) Everything is from *X*.

Finding sentences of the form (2) ascribed to the Milesians, Aristotle interpreted them by way of (1). His interpretation cannot be accepted without ado: (2) may, but need not, express material monism; for '*Y* is from *X*' may express more than one relation between *X* and *Y*. Aristotle was fully aware of the fact: in *Metaphysics* Δ 24 he catalogues several of the ways in which 'being from something *(to ek tinos)* is said' (1023a26; cf. 1092a22–35). Five of these ways can be stated and illustrated as follows: if Y is from *X*, then either

(i) *X* is the stuff of which *Y* is made (as a statue is made *from* bronze); or

(ii) *X* is the source from which *Y* comes (as plants grow up *from* the soil); or

(iii) *X* is the agent which generated *Y* (as a child comes *from* his parents); or

(iv) *X* is the event which causes *Y* (as a battle may arise *from* an insult); or

(v) *X* is replaced by *Y* (as day comes *'from'* night, or a tan *'from'* pallor).

Modern commentators add a sixth way: *Y* is from *X* if

(vi) *X* is the stuff from which *Y* was made (as paper is made *from* rags).

(vi) is distinguished from (i) as originative from constitutive stuff.

In ordinary English the distinction is sometimes expressed by a contrast between 'from' and 'of'. Thus the paper I write on was made from rags; but I will not say that it is made of rags (for I am not writing on rags). The wine I drink was made from grapes; but I will not say that it is made of grapes (for I am not drinking grapes). Again, the pane I gaze through is made of glass; but I will not say that it was made from glass (for no glazier processed glass so as to turn it into windowstuff). The diamond I cut the pane with is made of carbon; but it was not made from carbon (for no alchemist transmuted carbon into diamond for me).

The question, then, is this: Are we to interpret Milesian utterances of (2) by way of (i), as Aristotle would have it? or rather by way of (ii) or (iii) or (iv) or (v) or (vi)? A scholar who rejects Aristotle's interpretation will suppose that Thales and his successors were engaged in cosmogonical speculation and not in constituent analysis, that they were concerned to discover the original stuff from which the world was put together, and not to divine the underlying materials of its present furnishings. Aristotle believed in an eternal cosmos, rejected cosmogony, and was an exponent of constituent analysis; naturally he read his own interests, and interpretation (i), into the Milesians; and the doxography naturally followed Aristotle. But what is natural may also be wrong; and the Peripatetic version of Milesian monism may be an anachronistic invention, not an historical truth.[3]

That view is supported by two general considerations: first, (1) is wildly implausible in itself, and would hardly have presented itself spontaneously to the Milesian mind; second, (i) was, so to speak, philosophically unnecessary in the days of innocence before Parmenides, and would not have been embraced by the Milesians as an unhappy but inevitable presupposition of cosmogony.

The first consideration I find unconvincing: does interpretation (vi) really give a more 'plausible' thesis than (1)? Is it much more plausible to suppose that everything started from some one stuff than to suppose that everything is ultimately composed of some one stuff? Both views have the same point of appeal: simplicity. And both face the same difficulty: the amazing diversity of things in the world around us.

The second consideration requires further exposition. Aristotle says that the monists, because they posit a single material principle, 'think that nothing either comes into being or perishes' (*Met* 893b12 =**A 12**); 'they say that so-called simple coming into being is alteration' (*GC* 314a8): change is nothing but an alteration in the properties of some piece of the basic stuff. Now that view of change would only have been resorted to, it is asserted, after Parmenides and his Eleatic followers had argued for the impossibility of generation and destruction. Hence material monism presupposes the cogitations of Elea and cannot have been advanced in Miletus.

The philosophical content of this argument will exercise us later. Here it may be said, first, that the Aristotelian inference is by no means obvious. It assumes a strict, Aristotelian, analysis of generation; and even with that analysis it is only valid on the further assumption that bits of the basic stuff cannot themselves be generated. Aristotle is eliciting a thesis to which, in his view, the Milesians were committed: although he asserts that they 'say' that generation is alteration, he means only that 'it is necessary for them to say' it (*GC* 314a10), that they are committed to it. He does not mean that they expressly asserted it; still less that they stated it from an uncannily prescient desire to pre-empt Parmenidean objections.

Nor, secondly, is there any reason to believe that only Parmenidean worries could provide a motive for monism: a straightforward yearning for simplicity will lead in the same direction and provide explanation enough of any *nisus* towards monism.

Are there, on the other hand, any general considerations that support the Aristotelian interpretation? One line of argument suggests that if the Milesians intended (vi) then they also intended (i); for the distinction between (vi) and (i) seems, in some cases at least, to be illusory. If my table was made *from* wood, then it is made of *wood*. If a cake was made *from* flour, milk and eggs, then it is made *of* flour, milk and eggs. And in general, if *Y* was made from *X*, then it is made of *X*. Aristotle's mode of argument at *Metaphysics* 983b6–27, where he introduces material monism, seems to show both that he accepted the inference himself, and that he ascribed it to the Milesians. Two fragments of Xenophanes, separately transmitted, read as follows:

> Everything which comes into being and grows is earth and water **(20:21 B 29)**.
>
> For we all come to be from earth and water **(21: B 33)**.

It is plausible to conjoin these lines: **B 33** supports **B 29,** and Xenophanes makes an explicit inference from originative to constitutive stuff—from (vi) to (i).

Now if *Y* was made from *X* by a ϕprocess, then it is easy to infer that *Y* consists of *X* ϕly processed, and hence that *Y* consists of *X*. But the validity of the inference depends on the nature of the ϕprocess: if ϕing involves abstracting, say, the inference is evidently invalid: Bovril is extract of beef, not beef; salt is produced from brine, but is not brine. Aristotle made the point; and he also observed, implicitly, that it is easy to

confound valid and invalid versions of the inference (*Top* 127a17). Can we, then, suppose that the Milesians tacitly inferred from 'The cosmos was made from *X*' to 'The cosmos is made of *X*'? The plausibility of the supposition depends, in part at least, on the nature of the cosmogonical process: if the cosmos was constructed like a cake from its ingredients, the supposition has something to be said for it; if the cosmos was extracted like gold from ore, the supposition is implausible. Clearly, the Milesians must be approached individually; and we must ask of each cosmogony whether it suggests an Aristotelian reading.

Thales said:

(3) Everything is made from water.

According to Hippolytus, Thales held that:

> Everything is composed from it [sc. water] as it thickens and again thins out (**22**: *Ref Haer* I.2; cf. Galen, **11 B 3**).

Now if *Y* comes from *X* by 'thickening' or 'thinning', by condensation or rarefaction, then surely *Y* is made of *X*. If ice is condensed water, if it is made from water by a process of condensation, then it is made of water; and in general, if everything is made from water by condensation or rarefaction, then everything is made of water. Thus Hippolytus' report speaks for an Aristotelian interpretation of (3). It has been urged that the Aristotelian interpretation does not fit Thales' account of the earth's stability (**A 12** : above, p. 9); but I see no force in that. Hippolytus' report is, however, weak evidence: it may only be a doxographical conjecture. Prudence leads to a confession of ignorance; we know too little about Thales to judge the sense in which he intended (3).

The case of Anaximander is more complex. His principal claim is:

(4) Everything is from the unlimited.

The cosmogonical process is referred to as a 'separating out' (*ekkrinesthai*: Aristotle, *Phys* 187a20=**12 A 16**) or a 'separating off' (*apokrinesthai:* Simplicius, **A 9**; pseudo-Plutarch, **A 10**). Pseudo-Plutarch contains the fullest account of Anaximander's cosmogony:

> And he says that something generative of hot and cold was separated off from the eternal thing at the generation of this universe; and a sort of sphere of flame from this formed around the air about the earth, like a bark round a tree; and when this was broken off and shut off in certain circles, the sun and the moon and the stars were formed **(23: A 10)**.

Thus first the 'unlimited' principle ('the eternal thing') gives rise to 'something generative'; then this generative stuff or process produces 'the hot' and 'the cold', i.e. the basic materials of the cosmos which are characterizable by means of those 'opposites'; and finally the furniture of the heavens is formed from the basic materials.

The cosmos was thus made from—and probably is made of—the basic materials. But what is the relation between the 'unlimited' principle and the materials? Was 'the unlimited' simply a generating agent, and should (4) be understood in terms of (iii)? But then from what were the basic materials made? Was 'the unlimited' rather the 'reservoir or stock from which all Becoming draws its nourishment',[4] and is (4) to be understood in

terms of (ii)? But that suggestion is incoherent unless we assume that (4) is also to be read in terms of (vi), so that the 'unlimited' principle is a mass of *Urstoff* from which (by some entirely unknown operation) the basic materials are produced. The doxography was evidently perplexed: Simplicius, having said that the 'unlimited' is an Aristotelian substrate, adds that Anaximander 'does not produce generation by an alteration in the element, but by a separating off of the opposites' **(A 9),** so that the 'unlimited' is not a substrate after all. The Peripatetics did not know what to make of Anaximander's cosmogony. It is possible that they failed to understand his text, or that they did not possess it in its entirety; but, again, I am more inclined to suppose that their perplexity reflects a vague or incoherent account by Anaximander himself.

With Anaximenes a little light shines through. His principle reads:

(5) Everything is from air, and the doxography has preserved an account of his cosmogony:

> Anaximenes, son of Eurystratus, a Milesian who became a companion of Anaximander, himself says that the single underlying nature is indeed unlimited, like Anaximander; but he does not make it indeterminate, like him, but determined, calling it air. And he says that it differs from one thing to another in rareness and density—rarefied, it becomes fire, condensed, wind, then cloud, still more condensed, water, then earth, then stones—and everything else comes from these things (**24**: Simplicius, **13 A 5**).

The parallel accounts in pseudo-Plutarch **(A 6)** and Hippolytus **(A 7)** show that Simplicius is faithful to Theophrastus here.

Anaximenes' principle is air, present in unlimited quantity; and his cosmogony is achieved by the twin operations of rarefaction and condensation, which in effect amount to the single operation of change in density. Rarefied, air becomes fire; condensed, cloud, water, earth, and so on; and thus are engendered all the stuffs of the familiar world. Anaximenes introduced rarefaction *(manôsis)* and condensation *(puknôsis)* into cosmogony, though those particular terms may not have been his own (cf. **B 1**); and the operations became an orthodox feature of Presocratic science.[5] Certainly, the processes have a cosmogonical significance: the earth we stand upon and the clouds we gaze at were originally formed by the condensation of a vast mass of air. But they also serve to provide a quasi-chemical analysis of the constituents of the present world order. For, as I have argued, the inference from '*Y* was produced from *X* by a ϕprocess' to '*Y* is made of *X*' is eminently plausible and natural when the ϕprocess is one of condensation or rarefaction; and there is, I think, no cause to doubt that Anaximenes was a material monist in the standard Aristotelian sense.

The Milesians were cosmogonists, concerned to name the originative stuff and state of the world. Yet Anaximenes at least also gave an analysis, in Aristotelian vein, of the present stuff of the world; and he was thus a material monist. With Thales and Anaximander we must rule *non liquet;* and we may hazard it that nothing was clear either in the writings or in the minds of those men. Aristotle boldly offers them a coherent view; but though the Aristotelian interpretation gives them something which they might have

said had they said anything clearly, we may prefer to leave their accounts in the dimness which they themselves designed.

(b) *Anaximenes and air*

The doxography reports the first principle and the initial processes of Anaximenes' cosmogony: some sort of motion produces variations in the density of the *Ur*-mass of air, and the basic stuffs of the universe are generated. We also have a quantity of information about Anaximenes' astronomy and meteorology, from which it is clear that the cosmogonical operations also account for many of the phenomena of the present world.

Between these two sets of reports there is a gap. Simplicius' summary notice that 'everything else comes from these things' **(24)** is unrevealing. Is he reporting an 'etc.' in Anaximenes' text, or is he rather abbreviating a wealth of Anaximenean detail? If the latter, did Anaximenes suppose that change in density sufficed to produce all the stuffs that there are, or were supplementary operations called upon? No generative operations other than rarefaction and condensation are ascribed to Anaximenes in our sources; and it is most reasonable to believe that all stuffs were somehow to be generated by the agency of those operations alone.

So far, I have spoken only of the generation of stuffs; and it is a notable feature of Ionian speculation as a whole that its primary concern is with the different materials found in the world. The twin operations of condensation and rarefaction may have seemed sufficient to explain the generation, and the composition, of stuffs such as vapour and rock, wood and flesh; but they are plainly impotent to generate substances, or informed parcels of stuff, such as clouds and pebbles, trees and men. The stuff wood may be compressed air; but trees, even on the crudest analysis, are wood shaped in such and such a way. Flesh and bone may be generable by condensation; but if we want to account for the presence of organic bodies on the earth we need more than lumps of suitable stuffs. In Aristotelian jargon, the Ionian theories touch on the material constitution of things but say nothing about their form. Anaximenes may have thought that he could explain the formal aspect of at least some substances (cf. pseudo-Plutarch, **A 6**: sun, moon, stars); but he appears to have given the question little thought. It was not until the middle of the fifth century that form became a philosophical issue, and then it was tangled in the thickets of Pythagoreanism.

The Pythagoreans associate form with number; and here it might seem that Anaximenes in a sense anticipated them. His cosmogony takes relative density as the one essential feature of stuffs, in terms of which their remaining properties are to be explicated: any stuff is simply air at such and such a density. Now to us density is a quantitative notion, amenable to measurement: thus Anaximenes' physics is fundamentally quantitative, and it adumbrates that principle which comprises 'the very essence of science': 'that quality can be reduced to quantity'.[6] Quantitative sciences allow a mathematical development: seventeenth-century physics advanced precisely because it sloughed off qualities and paraded in its quantitative underskin; and the frailty of modern psychology or economics is due to the false or fantastical quantifications they rely upon.

Was Anaximenes really a precocious quantifier, a Presocratic Boyle? Alas, I suspect he was not. Greek scientists were in general averse to, or incapable of, the application of mathematics to physical processes and phenomena; and there is no evidence that Anaximenes' theory encouraged them to attempt any such application. Nor is there any evidence that Anaximenes himself had any such application in mind: he had no scale and no instrument for measuring density, and for him density was a quantitative notion only in the weakest sense. The scientific appearance of his cosmogonical operations is due to chance, not to insight.

How did Anaximenes attempt to justify or commend his grand theory? We might ask him four questions: (a) why suppose that some single stuff originated and underlies the variety of appearances? (b) why suppose that *Urstoff* to be air? (c) why require an unlimited quantity of air? (d) why generate from air by means of condensation and rarefaction?

To question (a) the only plausible answer is, once more, the compelling attraction of simplicity: the fewer the primitives, the better the system. A single stuff and a single operation (or pair of complementary operations) constitute, from a systematic point of view, the best possible hypothesis. Question (c) is answered in **B 3,** which I have already commented upon (above, p. 35). Fragment **B 2,** which I discuss in a later context (below, p. 55), is sometimes seen as an answer to (b). That leaves (d).

Hippolytus reports that 'the most important factors in generation are opposites—hot and cold' **(A 7)**. The two factors recur in a passage of Plutarch:

> As old Anaximenes thought, we should not leave the hot and the cold in the class of substances, but treat them as common properties of matter which supervene on changes. For he says that the compressed and condensed part of matter is cold, and that the thin and loose (that is the very word he uses) is hot; and that hence it is not unreasonably said that a man releases both hot and cold things from his mouth—for his breath is cooled when pressed and condensed by his lips, while if the mouth is relaxed the exhaled breath becomes hot by rareness **(25: B 1)**.

Only the single word 'loose *(chalaron)*' is a direct quotation from Anaximenes;[7] but Plutarch plainly regards the whole argument in which that word is embedded as Anaximenean, and I am prepared to follow him.[8]

It seems, then, that Anaximenes' cosmogonical speculation began from the familiar paradox that we blow on our hands to warm them and on our porridge to cool it. Observation showed that the hand-warmer huffs with open mouth, while the porridge-cooler whistles through pursed lips; and a further simple observation indicates that the hot air is thinner than the cold: it is palpably less firm against the hand. At this point theory takes over from observation: first, Anaximenes supposes that the thinness of the hot air and the thickness of the cold air are causally connected to their temperature; and he advances the general hypothesis that what temperature a mass of stuff has is determined by its density. Thus changes in temperature are explicable in terms of rarefaction and condensation. Second, Anaximenes generalized his hypothesis further, and suggested that all the properties of a mass of stuff are determined by its density: just as rarefaction can account for the heat of fire, so it can account for its colour and its

characteristic motions; just as condensation can account for the coldness of a cloud, so it can account for its opacity and woolly structure. Finally, the theory was applied to a variety of disparate phenomena—astronomical and meteorological—and to that extent confirmed or corroborated.

We need not embrace Anaximenes' conclusions in order to admire his principles and his methodology: observations of a puzzle situation lead him to form explanatory theories of successively greater generality. And the final theory has many of the hallmarks of science: it is highly general; it is devastatingly simple; it explains the original puzzle; and it applies to, and can therefore be tested against, a mass of superficially unconnected phenomena.

(c) *Fairy tales or science?*

Then is Anaximenes a Greek Galileo? And were the early Milesian cosmologists the world's first natural scientists? The question has aroused passion and dispute. At one extreme, there are scholars who think that 'a new thing came into the world with the early Ionian teachers—the thing we call science—and…they first pointed the way which Europe has followed ever since'.[9] At the other extreme, it is maintained that the Milesians are properly regarded not as the precursors of science but as the successors of the ancient poet-seers, lay dogmatists concerned to propound a secular *Weltanschauung* and unconcerned to defend it by the tiresomely rational methods of the scientist.[10] Those who prefer a middle path imagine that the Milesians strove towards scientific status but did not quite attain it: 'the *phusiologoi*, despite their eagerness to use the senses for all they were worth, failed not only to use but even to understand the experimental method of modern science'.[11]

The controversy has been muddled by two facts: first, the identity of the disputed terrain is shifting and uncertain; second, the disputants unconsciously bring quite different philosophical presuppositions to their arguments. It is worth indicating at the start some of the things to which all parties assent.

First, none of the Milesian theories is true: the Milesians do not compose a Greek Royal Society; and their Transactions would not make any contribution to the sum of scientific knowledge. They and their successors made and recorded various true observations; but the assembly of those observations into true or well-confirmed theory was a long process which the Milesians scarcely began.

Second, none of the Milesians aspired to the sort of precision we require in a scientific theory: their views are incurably vague; and underlying this vagueness is a complete innocence of the delights of measurement and quantification.[12] Thus Anaximenes, as I have remarked, made no attempt to state what degree of compression turned air into cloud or water, or to formulate an equation correlating density and temperature. As a result, his theories are peculiarly resistant to testing: it is simply not clear in what way they are to be 'applied' to the phenomena, nor, hence, what observations will confirm and what refute them. It might be added that Anaximenes' descriptions of his original puzzle and of his observations are negligent and unrigorous: his theory cannot explain the puzzle, since the puzzle is misdescribed. (The outstanding exception to this generalization about Milesian theorizing is provided by Anaximander's astronomy: that

was decked out with precise mathematical hypotheses about the arrangements of the heavenly wheels.)

Third, it will be agreed that the Milesians had certain intellectual aims which are, in a broad sense, characteristic of science: they wanted to describe the phenomenal world; they wanted to explain what the phenomena were and how they were produced; and they aimed at giving an explanation which did not appeal to chance or to stray divinities.

Fourth, the Milesians had some grasp—implicit in their approach if not explicit in their writings—of certain methods of explanation which are also, in a broad sense, characteristic of science: they advanced highly general hypotheses which could (they thought) be applied to and explain the phenomena; they gave reasons for their opinions, however bizarre those opinions might seem; they drew inferences and they suggested analogies or 'models'.

If these points are agreed upon, wherein lies the dispute over the scientific standing of the early Greek thinkers? It is sometimes thought to lie in the question of whether the Milesians adhered to 'the experimental method': crudely put, the Milesians did not indulge in experiments and hence were not scientists.

It is true that, as far as our knowledge extends, the Milesians did not experiment; indeed Greek science as a whole can produce only a handful of experiments, and those are all of a fairly unsophisticated sort.[13] The reasons for this are not hard to guess. Yet I am inclined to think that experimentation is not an essential tool of science, and indeed that in some sciences it is of little or no account. An experiment, after all, is merely the artificial generation of observable phenomena. Experimental observation has certain advantages over observation *au naturel:* the experimenter can isolate the phenomena which interest him, and he can exercise some control over their production. Nevertheless, it is the observable products, and not the manner of their production, which are scientifically significant. In many of the biological sciences (in anatomy, say, or taxonomic botany) experiment has little or no place; in the human sciences (sociology or economics) experiment is not often acceptable; in certain of the physical sciences (astronomy is the prime example) experiment is rarely possible; and in some special sciences (for example, palaeontology) there is no room for experiment at all. The Milesians had a copious abundance of data to explain: 'pioneers, with so many fresh phenomena waiting to be observed, they felt no urge to manufacture more. Having abundance, they saw no need for superabundance.'[14] And in any case, the sciences they showed most interest in are not experimental in any serious sense. Certainly, the devising of a few tests would have enlivened and improved Presocratic science; but the lack of an 'experimental method' does not bar the Presocratics from the halls of science.[15]

Perhaps, then, the Milesians failed because they ignored 'the inductive method': they failed, that is, to live up to Baconian canons of scientific procedure. 'The inductive method' may be interpreted in a procedural or in a logical fashion: it may enjoin either that the garnering of data should precede the formation of theory, or that any formed theory should be supported by a mass of data. Both interpretations have this in common, that they require the scientist to be an ardent collector of particular facts.

The inductive method has fallen on hard times; and few, I imagine, would maintain that an inductive procedure is either essential or even particularly useful to science. Indeed, it is a popular view that the blind collation of data is inimical to the scientific spirit, if not a positively incoherent pursuit. Yet it is reasonable to think that data are not

wholly irrelevant to science: a theory which is supported by a vast number of disparate facts is, I suppose, still preferable to a theory which has no support; and whatever our attitude to Bacon, we are unlikely to conclude that the collection of observational data is simply irrelevant to the scientific enterprise.

How do the Milesians fare if they are measured against these standards? We do not know if they attempted to follow an inductive procedure. I have supposed that Anaximenes' theorizing began from his observations of the effects of breath; but that is merely a guess. He might, for all our sources can tell us, have elaborated his theory first and only later come across the porridge puzzle. In any case, Anaximenes' procedure was hardly inductive even if my guess is right: one observation does not make an induction. Then did Anaximenes support his formed theory by amassing a collection of phenomena to which it might be applied? Here the answer is clearly affirmative. The doxography does not allow us to say how large was the *corpus* of Anaximenes' observations, or whether they were the result of personal inspection, or exactly how the observations were supposed to be related to the general theory; and we may well imagine, as I have already said, that neither the observations nor their subsumption under the theory were carried out in a particularly rigorous fashion. Nonetheless, it is beyond reasonable dispute that Anaximenes had a mass of empirical evidence which, he believed, indirectly corroborated his general theory. And that, I submit, is enough to make him as inductively minded as any scientist need be. In general, it seems fair to conclude that 'the alliance between careful observation and bold speculation is not only natural but essential in early Greek thought, the very condition for the creation of science and philosophy in the Greek sense'.[16]

Finally, a third method, the 'critical method', has been judged the especial mark of scientific endeavour. An adherent of the critical method will be most concerned to refute theories, whether his own or others'; he will elicit the particular implications of a general theory and prove them against the facts of observation; he will occupy himself in devising strenuous and varied tests, and he will not rest until he can invent no more hurdles for a theory to stride.

I am not certain that the 'critical method' constitutes a methodology; and I am certain that the 'critical method' is not specifically scientific. Criticism is a feature of rational procedure in every branch of intellectual study; philosophers and historians are not excluded from a form of thought which physicists and geologists may indulge in. Nonetheless, it is obvious enough that a sharp critical acumen and a determination to probe and test hypotheses are intellectual virtues of a high order; and it is apposite to inquire whether the Milesians possessed them.

The common view, I think, is that they did. The history of Presocratic thought is customarily seen in an Hegelian light: thesis and antithesis alternate in dialectical interplay, each new theory springing from the head of its predecessor. Criticism and refutation thus supply the very structure of Presocratic thought, and the 'critical method' is the key to an understanding of the first development of science.

It is, of course, indisputable that the Presocratics knew and were influenced by the views of their predecessors; and the influence was often negative. I have already purveyed the commonplace conjecture that Anaximenes' innovations were devised in response to the inadequacies of Anaximander's theories; and many similar cases will be noted as this book proceeds. Moreover, we have direct evidence of such awareness. Thus

Xenophanes referred to Thales **(21 B 19)** and criticized Pythagoras **(B 7);** Heraclitus abused Pythagoras and Xenophanes **(22 B 40);** Hippo and Zeno may have animadverted on Empedocles (Aristotle, *An* 405b2=**31 A 4;** Suda, **29 A 2**); Diogenes of Apollonia wrote *Against the Natural Scientists* (Simplicius, **64 A 4**); and Democritus attacked Anaxagoras **(68 B 5)** and Protagoras **(68 B 156)**. Such references can easily be multiplied; and the Hippocratic treatises offer examples of the substance behind them.

Yet it is one thing to know and to reject one's predecessor's views, another to adopt the critical approach to science and philosophy; criticism, after all, is more than the mere contradicting of an opponent. And it is a remarkable fact that the art of critical or destructive argument scarcely appears in Greek thought before Socrates. The earliest examples I know come in the *Dissoi Logoi,* a treatise on which I shall say more later (below, pp. 517–22). Section 6 of the work discusses the question of whether virtue and wisdom can be taught; the author advances some arguments for a negative answer, points to their weakness, and concludes thus: 'That is my argument—you have beginning and end and middle; and I do not assert that it can be taught—but those proofs do not satisfy me' (**90 A 1,** §6.13; cf. §2.23; §3.15; §5.9). That passage makes, clearly and for the first time, the crucial distinction between rejecting an argument for a conclusion and rejecting the conclusion itself. The art of criticism cannot thrive unless that distinction is grasped.

The critical innocence of the Presocratics appears in two forms. First, there is no Presocratic instance of a philosopher criticizing an *argument;* we might expect the successors and opponents of Parmenides to have investigated the structure of his reasonings and explained where it was weak or defective. Yet no example of such investigation survives: neither Empedocles nor Anaxagoras tells us where and why he thinks Parmenides errs, even though both thought that Parmenides did err. Nor does any philosopher before Aristotle tell us what is wrong with Zeno's paradoxes.

Second, and more surprisingly, we have hardly any instances of philosophers criticizing a *theory*. We may well assume that the successors of Thales thought his water thesis mistaken; yet no text tells us why they thought so, or what counter-examples they offered or imagined. Still less do we find self-criticism. Anaximenes' theory suggests to us any number of critical tests; yet there is no evidence that Anaximenes applied any of them. He may have thought, vaguely enough, that compressed earth becomes harder until it turns to stone; yet he does not seem to have attempted the easy task of compressing air—in a leather wine-skin, say—to see if it turned to cloud or water; and there is no evidence that he ever investigated the implications of his thesis that density and temperature were directly proportional.

Our evidence for the Milesians is slight and fragmentary. It is possible that their writings contained critical inquiries which later authors did not think fit to preserve; it is possible too, that the Milesians regarded criticism as a necessary propaedeutic to construction, but scorned to sully their finished publications with such preliminary observations. At all events, we can scarcely avoid the assumption that the Milesians and their successors sometimes rejected earlier theories, and did so on rational grounds. Yet the evidence lends great plausibility to the thought that the Milesians were more interested in construction than in destruction, and that their energies were too absorbed in the creative task of system building to dwell long on the less sublime business of criticism and refutation.

What do these reflexions suggest? It is, I believe, perverse to deny that the Milesians were scientists—and great scientists at that. Their scientific shortcomings were not methodological: they approached their problems in an admirable fashion; and their failures were due not to lack of understanding but to lack of developed techniques of observation and theory construction. Their methodological failing was general and not specifically scientific: intoxicated by the delights of construction, they did not care to submit their buildings to the rough winds of criticism.

(d) *The use of analogy*

A striking feature of Presocratic thought is its use of analogy.[17] In Thales' account of the floating of the earth we have come upon the first simple example of this pattern of thought. The most celebrated and elaborate analogies are found in the fragments of Empedocles: one long passage **(31 B 84)** compares the structure of the eye to the structure of a lantern, in order to explain how it is that our eyes 'flash'; a longer and notoriously difficult fragment **(B 100)** accounts for respiration by a detailed comparison with a *clepsydra* or pipette. But examples can be found in every early Greek thinker; and since the scanty doxography on Anaximenes presents us with several interesting analogies, I shall discuss this widespread 'thought pattern' by reference to him.

Historians of ancient thought sometimes treat analogy as an antiquated device; and sometimes they imply that all analogies are logically on a par. Neither of those notions is correct. First, analogy, in one form or another, is a constant—perhaps a psychologically indispensable—accompaniment of scientific thought: the vogue word 'model' is a modern synonym for 'analogy'. Second, an analogy may be invoked for a variety of purposes, only one of which is properly denominated 'argument from analogy'.

Here are seven passages in which Anaximenean analogies appear:

> The soul, being our air, controls us, and breath and air encompass the whole world **(26: B 2)**.
>
> The stars move…around the earth, just as a turban winds round our head (**27:** Hippolytus, **A 7**).
>
> And some say that the universe whirls like a mill-stone (**28:** Aëtius, **A 12**).
>
> Anaximenes says that the stars are fixed in the crystalline in the manner of nails…(**29:** Aëtius, **A 14**).[18]
>
> Anaximenes says that the sun is flat like a leaf (**30:** Aëtius, **A 15;** cf. **B2a**).
>
> Anaximenes says the same [about thunder] as him [sc. Anaximander], adding the phenomenon we observe on the sea, which gleams when cut by oars (**31:** Aëtius, **A 17;** cf. **12 A 23;** Aristophanes, *Clouds* 404–7).
>
> Just as in old buildings certain parts collapse though not struck, when they have more weight than strength; so in the earth as a whole it comes about that certain parts are loosened by age, and, being loosened, fall and cause the parts above them to tremble. They do this first when they break away (for nothing of any size breaks away without moving what it

> adheres to). Then, when they have collapsed, they meet something solid and spring back again, like a ball which, when it falls, bounces back and is as often driven back as it is sent up from the ground on a new flight (**32:** Seneca, *nat quaest* 6.10=Diels-Kranz, 1.488.30–5; cf. **A 21**).

These seven examples fall into two, or perhaps three, groups.

First, analogy is often used merely as a rhetorical trope, to add colour and vivacity to a flat description. This is pretty clearly the case in **28:** the phrase 'like a mill-stone' adds nothing new to the verb 'whirls'. Example **27** is obscure; but I assume that it is a joke, designed more to enliven than to illuminate Anaximenes' account of the stars. It is likely that **30** also belongs to this class.

Second, an analogy may be more than entertaining but less than explanatory: we observe that an *F* is *G*, but find the observation somehow puzzling; analogy with more familiar cases of things which are *G* may serve to remove our puzzlement. Example **29** is of this sort: the small stars are evidently fixed somehow to the vault of the sky, yet we may wonder how they can stay up there. The observation of nail-heads fixed in an overhead beam shows that the fixture of the stars need not be paradoxical. Again, in **32** the superficially surprising phenomenon of the earth's quaking without being struck is made intellectually palatable by the observation that old buildings will sometimes tumble without being struck. It may be that **31** is a further example of this type; and **30** too may belong here: the sun can float on air, just as leaves can (cf. **A 20;** above, p. 28).

Analogies of this second type are susceptible to a strong and a weak interpretation. Taken strongly, **29** is supposed to show *how* the stars remain in the sky: they are the upper surface of a long spike which is sunk into the sky and thus holds them in place. So construed, the analogy does indeed aim to be explanatory. Taken weakly, **29** is intended to show only that the stars *can* remain in the sky, and not to offer a suggestion about *how* they are fixed. So construed the analogy has no explanatory pretensions, and Anaximenes might as well have added 'or like flies, or pieces of paper glued to the ceiling'.

The difference between the strong and the weak interpretations is not clear-cut: removal of puzzlement slides insensibly into explanation; and it is usually hard to tell what interpretation an author intends (unless he explicitly offers two or more analogies). For all that, the distinction is important. Some students of computer science attempt to simulate human behaviour and to show how it can be that certain sensory inputs into human organisms elicit certain cognitive or motor responses. Computer simulation may be an enlightening discipline; but it does not claim to show how human organisms work: that a computer can produce the same results from the same materials as I can, does not show that I and the computer work in the same way. Other students of computer science speak of artificial intelligence; they aim not to simulate but to reproduce—and hence to explain—human performances. There are thus two distinct ways in which computers may serve as an analogy or 'model' of the human mind; the second way, evidently, makes far stronger claims than the first.

Finally, analogies may be called upon in argument. Observing first that *a* is *F* and also *G*, and secondly that *b* is *F*, we infer that *b*, too, is *G*. Example **26** is commonly taken in this sense, and is treated as Anaximenes' reason for thinking that air, rather than any other stuff, is the material principle of everything. It is then to be paraphrased as follows: 'We men contain an airy soul; and that air keeps us together, i.e., keeps us alive; the

universe as a whole contains air: hence it is air that keeps the universe together, i.e., supplies its underlying stuff.' Air sustains men; so air is probably the *Urstoff* of the universe.

That interpretation of **26** is, I suppose, possible; but it is not demanded by the text (which contains no inferential particle),[19] nor is it a happy interpretation (for the argument it ascribes to Anaximenes is scandalously jejune). Argument by analogy is in effect induction from a single case, and as such it is essentially lacking in probative force; moreover, in the case of **26,** the terms of the analogy are not identical, and the interpretation is obliged to introduce the phrase 'keep together' in order to produce a show of identity. It is preferable to think that **26** contains no argument at all, and *a fortiori* no analogical argument; rather, it presents one of the considerations which may have determined Anaximenes to fix on air as his basic material: if Thales preferred water because water is essential to life, Anaximenes preferred air for the self-same reason. Example **26** does indeed give an answer, or part of an answer, to question (b) of p. 46; for it helps to explain why Anaximenes picked on air as his *Urstoff*. But the answer is not based on analogical argument; and neither in **26** nor elsewhere do we find an argument from analogy in Anaximenes.

Indeed, I do not think there is a single argument from analogy in any of the Presocratics. And that is a happy conclusion: analogies may be scientifically important; they may serve, psychologically, to illuminate a dry exposition or to dispel a puzzlement; and they may be useful, methodologically, in suggesting a synthesis or provoking a generalization. But they have no inferential status: argument 'from analogy' is one of the numerous species of bad argument.