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(*b*. Abdera, Thrace, *fl*. late fifth century b.c.)

physics, mathematics.

There were two main chronologies current in antiquity for Democritus. According to the first, which was followed by Epicurus among others, Democritus was the teacher of the Sophist Protagoras of Abdera and was born soon after 500 b.c. and died about 404 b.c. The other chronology puts his birth about 460 b.c., making him a younger contemporary of Socrates and a generation or more younger than Protagoras; in this case, the tradition that he lived to a great age would bring his death well into the fourth century b.c. According to Democritus' own words, he was a young man when Anaxagoras was old, and he may actually have said that he was younger by forty years. Although there was also more than one ancient chronology for Anaxagoras, this statement probably supports the later dates for Democritus, and these have usually been accepted by modern scholars. The question is an important one for our understanding of the history of thought in the fifth century b.c., and it is unfortunate that the occurrence of the name Democritus, presumably as a magistrate, on a fifth-century tetradrachm of Abdera does not help to settle the question, because we cannot be certain that it is the name of the Democritus here discussed nor can the tetradrachm be dated with certainty earlier than 430 b.c. (this would fit with either chronological scheme).

Most of the stories about Democritus are worthless later inventions, but it is probable that he was well-to-do, and stories of extensive travels may have a foundation in fact. He is reported to have said that he visited Athens, but no one knew him there, and from Cicero and Horace we learn that—at least in their time—he was known as the "laughing philosopher" because of his amusement at the follies of mankind. His only certainly attested teacher was Leucippus. The titles of more than sixty writings are preserved from a catalog that probably represented the holdings of the library at Alexandria. Of these we have only some 300 alleged quotations, many of which may not be genuine. More valuable for the understanding of Democritus' theories are the accounts given by Aristotle, Theophrastus, and the later doxographic tradition. Democritus left pupils who continued the tradition of his teachings and one of them, Nausiphanes, was the teacher of Epicurus. Epicureanism represents a further elaboration of the physical theories of Democritus, and surviving writings of Epicurus and others provide further interpretations and sometimes specific information about earlier atomist doctrines.

According to Posidonius in the first century b.c., the theory of atoms was a very old one and went back to a Phoenician named Mōchus, who lived before the Trojan War, in the second millennium b.c. According to others, Democritus was a pupil of Persian magi and Chaldean astrologers, either as a boy in his native Abdera or later in Egypt. Both stories seem to have originated only in the third century b.c. and to be part of the wholesale attempts to derive Greek thought from Oriental sources that followed the "discovery"of the East resulting from the establishment of Alexander's empire. More intriguing is the fact that certain Indian thinkers arrived at an atomic explanation of the universe, which is expounded in the Vaiśeṣika Sūtra and is interpreted by the aphorisms of Kanada. However, the Vaiśeṣika atoms are not quality-free but correspond to the four elements; nor is soul made from these atoms. Moreover, the date of the first appearance of the doctrine in India is probably subsequent to the founding of the Greek kingdom of Bactria, so that coincidences could be due to Greek influences on Indian thought. There is no early evidence of external sources for Democritus' thought; these are not needed, because the doctrines can be shown to have arisen naturally and almost inevitably as a result of the way in which the problems of explaining the physical universe had been formulated by Democritus' immediate predecessors among the pre-Socratics, who were of course Greeks. Consequently, Aristotle is probably right (*De generatione et corruptine*, 325a23 ff.) in explaining his views as developed in reply to the doctrines of the Eleatics. This need not exclude the possibility that the atomists were also influenced by what is sometimes called Pythagorean number-atomism, although whether this preceded or arose only after the time of Leucippus remains uncertain, and it is clear that Democritus did not invent atomism but received the essentials of the doctrine from Leucippus.

By the middle of the fifth century b.c., it seemed to many thinkers that Parmenides, the founder of the Eleatic school, had proved that nothing can come into being out of that which is not, and that anything which is cannot alter, because that would involve its becoming that which is not. Previous attempts to explain the physical universe as derived from one or more primary substances were thus doomed to failure, as they all involved change in the primary substances and so violated Parmenides' conclusions. Anaxagoras, at least in one view of his doctrine, made a heroic attempt to escape from the difficulty by supposing that all substances were always present in all other substances and that apparent change was simply the emergence of the required substance—which had been present unnoticed all the time. The atomism of Democritus was similar in its approach but went further in depriving the primary constituents of most, but not all, of the qualities apparent in objects derived from them. Moreover, Leucippus had boldly accepted empty space or void—the existence of which the Eleatics regarded as impossible because it would be that which is not—as necessary to make movement possible.

Atoms and void are the bases of Democritus' system for explaining the universe: solid corporeal atoms, infinite in number and shape, differing in size, but otherwise lacking in sensible qualities, were originally scattered throughout infinite void. In general, the atoms were so small as to be invisible. (They were all invisible for Epicurus, but later sources raise the possibility that for Democritus some exceptional atoms may have been large enough to be seen or even that an individual atom might be as big as the cosmos.) The atoms are physically indivisible—this is the meaning of the name *atomos*, which, while not surviving in the fragments of Democritus, must certainly have been used by him. Whether the atoms were conceptually or mathematically indivisible as well as physically is a matter of dispute. But they were certainly extended and indestructible, so that if he thought about it Democritus ought not to have denied mathematical divisibility, especially as the atoms' variety of shape implied the concept of parts within each physically indivisible atom. They are homogeneous in substance, contain no void and no interstices, and are in perpetual motion in the infinitely extended void, probably moving equally in all directions.

When a group of atoms becomes isolated, a whirl is produced which causes like atoms to tend toward like. Within a kind of membrane or garment, as it were, woven out of hook-shaped atoms, there develops a spherical structure which eventually contains earth, sky, and heavenly bodies—in other words a spherical cosmos. The only detailed description of the process ascribes it to Leucippus (Diogenes Laertius, IX, 30 ff.), but there is no reason to doubt that it was repeated by Democritus. There is no limit to the number of atoms nor to the amount of void, and so not one cosmos but many are formed. Some dissolved again before the formation of our cosmos; others coexist with ours, some larger and some smaller, some without sun or moon, and some without living creatures, plants, or moisture. From time to time a cosmos is destroyed by collision with another.

Our earth and everything in it, like everything, elsewhere, is compounded of atoms and void, and there are no other constituents of the universe of any kind. Apart from differences in shape, atoms differ in arrangement and position. As Aristotle says, the letter *A* differs from *N* in shape; *AN* from *NA* in arrangement; and *Z* from *N* in position, although both have the same shape. We must add, although Aristotle does not say so here, that the spacings between atoms may vary from the zero space of actual contact through increasing distances apart. Soft and yielding bodies and bodies light in weight contain more void than heavier or harder objects of equal extent. Iron is lighter than lead because it has more void, but it is harder because it is denser than lead at particular points, the void not being distributed evenly throughout, as is the case with lead. It is probable that for Democritus the atoms when entangled do not cease to be in motion (their individual movement is naturally less extensive), but they participate in movements of the object of which they are a part. It appears that atoms were not regarded as possessing weight in their own right; this was Epicurus' innovation. But physical objects possess weight, and according to Aristotle, atoms are heavier in proportion to their excess of bulk. Objects as a whole are heavier the greater the proportion of atoms to void. It may be that weight operates only in a developed world and is the result of a tendency of compound objects to move toward the center of a whirl. For Democritus all movement and all change are due to "necessity", but this is an internal cause and not an agency operating from without: it is the necessary result of the natural movement of the atoms. All events are determined, and if Cicero is right at all in saying Democritus attributed events to chance, this can have meant only that they could not be predicted, not that they were not determined.

The perceived qualitative differences between objects depend upon the nature and arrangement of the relevant atoms and void. The importance and novelty of this doctrine were fully appreciated by Theophrastus, who discussed it at some length in his surviving *De sensibus*. It might have seemed sufficient answer to Parmenides' challenging argument to have said that secondary qualities such as colors and tastes were produced by the appropriate arrangement of atoms in the sense that they were present in any object possessing the appropriate atomic configuration and would be altered or disappear when the configuration changed. But Theophrastus complains that Democritus is inconsistent on this point and that, while explaining sensations causally in terms of configurations, he insists that the perceived qualities depend upon the state of the percipient—for example, his health—to such an extent that the qualities exist not in the object but only in the percipient at the time he is perceiving them. According to Sextus Empiricus, Protagoras, in his "Man is the measure" doctrine, had held that there are present in actual objects multiple qualities which are selectively perceived by different percipients. Democritus is said (fr. 156) to have criticized the doctrine of Protagoras at great length, and it could be that he carried the relativism of Protagoras one step further by supposing that secondary qualities did not exist in the configuration of atoms which constitute a thing but only in the consciousness of the percipient. But not all accept Sextus Empiricus' account of Protagoras on this point.

We lack details of many aspects of Democritus' cosmology. The earth is flat and elongated—twice as long as it is broad. Although earlier it strayed about, it is now stationary at the center of the universe. The angle between zenith and celestial pole is explained by the tilting of the earth because the warmer air to the south—under the earth—offered less support than that in the north. Earthquakes are caused by heavy rain or drought changing the amount of water in the cavities of the earth. While some explanations of meteorological phenomena were offered in terms of the theory of atoms (for example, the attraction of like atoms to like as an explanation of magnetism), in general Democritus seems to have followed traditional explanations drawn from earlier pre-Socratics, above all from Anaximander. Unlike Leucippus, who put the sun's orbit outermost in the heavens, Democritus had the normal order of fixed stars, planets, sun, Venus, moon. The moon, like the earth, contained valleys and glens, and its light was derived from the sun.

Two particularly quick-moving constituents of the universe, fire and soul, were for Democritus composed of spherical atoms. Spherical atoms are not themselves either fire or soul but become such by the suitable aggregation of a number of themselves. Such aggregation cannot be by entanglement, which is not possible with spherical atoms, but only by the principle of the attraction of like to like. Whereas air, water, and perhaps earth, and things containing them, were regarded as conglomerations of atoms of all shapes, only the one shape seems to have occurred in fire and soul. Aristotle more than once speaks as if soul

and fire were identical, and he adds that the soul can be fed by breathing in suitable atoms from the air around us. In this way, losses of soul atoms from the body can be replaced. When we can no longer breathe, the pressure from the atmosphere outside continues to squeeze out the soul atoms from the body and death results. A slight excess of loss over replacement produces sleep only and not death. Even when death results, the loss of soul atoms takes time, so that some functions, such as growth of hair and nails, continue for a while in the tomb; a certain degree of sensation may also continue for a time, and in exceptional cases, even resuscitation may be possible. We do not know the contents of the work *On Those in Hades*, attributed to Democritus, except that it included reference to such resuscitations.

Within the living body, soul atoms are distributed throughout the whole in such a way that single atoms of the soul and body alternate, and it has sometimes been said that this involves treating isolated atoms as soul atoms and so reintroducing qualities into individual atoms. But such an alternation could be achieved within a lattice pattern of one kind or another for the soul atoms, so that there is no actual inconsistency. These soul atoms are the immediate source of life, warmth, and motion in a living body. In addition to the soul atoms dispersed throughout the body, there is another part of the soul, the mind, located in one part of the body, namely the head.

Sensation for Democritus was based upon touch and was due to images entering the sense organs from outside and producing alterations in the percipient. Sensation is thus the result of the interaction of image and organ. In the case of flavors, there is always a multitude of configurations of atoms present in what is tasted, but the preponderant configuration exerts the greatest influence and determines the flavor tasted, the result being influenced also by the state of the sense organs. In the case of sight, images continually stream off the objects, which are somehow imprinted—by stamping, as it were—on the intervening air. This imprinted air is then carried to the eyes, where its configuration produces the sensation of color. A similar analysis seems to have been offered for hearing and perhaps for smell. Taste, however, entails direct contact between organ and object: large, rough, polygonal shapes produce astringent flavors, and son.

Thought, like sensation, is the result of a disturbance of the soul atoms by configurations of atoms from outside; it is what occurs when the soul achieves a fresh balance after the movement which is sensation. The details of the process are obscure, and the text of Theophrastus' description is uncertain. But there is no sure evidence to suggest that Democritus held the later theory of Epicurus that it is possible for certain externally originating images to bypass the senses and secure direct access to the mind in thought. For Democritus, thought follows after sensation, and we may believe that Democritus expressed his real view when he said (fr. 125) that the mind takes its evidence from the senses and then seeks to overthrow them, but that the overthrow is a fall for the mind also. Nonetheless, in an important fragment (fr. 11) Democritus did claim that there were two kinds of knowledge, one genuine or legitimate, and the other bastard. To the bastard belong the senses; genuine knowledge operates on objects too fine for any sense to grasp. This must surely refer to our knowledge of the atomic theory, including the imperceptible atoms and void of which things are composed, but we do not know what mechanical procedure, if any, Democritus envisaged for the acquisition of such knowledge.

It follows from the above view of the soul and the way it leaves the body at death that there is no survival of the individual soul, although the soul atoms themselves survive because, like all atoms, they are indestructible. It might have been expected that this approach would shed doubt on the existence of gods and spirits, especially since we are told that Democritus attributed early man's fear of the gods to his misunderstanding of natural phenomena such as lightning and eclipses. But he accepted that images of beings both beneficent and maleficent, destructible and yet able to foretell the future while being seen and heard, come to men apparently out of the air itself, without any more ultimate source. We do not know what doctrine lies behind this, but it is likely that there was no external source posited for these images other than the soul atoms at large in the air.

The list of Democritu's writings contains the titles of a number of works on mathematics, and it is clear from the few surviving scattered references that his mathematical interests were not inconsiderable. Protagoras had argued that the tangent touches the circle not at one point but over a distance. Democritus treated the sphere as "all angle," and Simplicius explained this as meaning that what is bent is an angle and the sphere is bent all over. It is inferred that he supposed that the sphere is really a polyhedron with imperceptibly small faces, presumably because a physical sphere involves atoms which cannot be further broken down. In such a case he would be in agreement with Protagoras as to the actual relation between tangent and circle while in disagreement as to the apparent relation. But with atoms in an infinite variety of shapes. there is no reason why Democritus could not have posited a perfect physical sphere made up of atoms of indivisible magnitude but with curved faces. In any case Democritus could probably distinguish a physical from a mathematical sphere well enough.

Of very great interest is Democritus' discussion of the question whether the two contiguous surfaces produced by slicing a cone horizontally are equal or unequal. If equal, it might seem that the cone is a cylinder, while if unequal, the cone becomes steplike and uneven (fr. 155). Chrysippus the Stoic, when discussing Democritus' doctrine, declared that Democritus was unaware of the true answer—namely, so he claimed, that the surfaces are neither equal nor unequal. Unfortunately what Democritus' view was remains in doubt. Some suppose that he argued for a stepped physical cone; others that he regarded the dilemma as genuine; and still others that he considered them equal, at least as far as mathematics was concerned. Archimedes records that Democritus was concerned with the ratios of size between cylinders, pyramids, and prisms of the same base and height. While this is evidence of further interest in problems associated with cones of the kind that were so important for the subsequent history of mathematics, we do not actually know the nature of Democritus' discussions concerning them.

Tantalizing references to individual doctrines and the titles of a number of his writings have suggested to some that Democritus' biological work rivaled Aristotle's in both comprehensiveness and attention to detail. The indications that survive do not for the most part suggest that he made any very particular application of atomic theories to biology, and it is probable that his clearly extensive writings were essentially within the general framework of Ionian speculation. More we cannot say through lack of positive information.

Later writers—as well as some from the fifth and fourth centuries b.c.—preserve details which all seem to come from a single account of the origins and development of human civilization. They have in common not only various particular points but also a basic conception—namely, that civilization developed from lower levels to higher, which contrasted strongly with the dominant view that human history represented a continuous decline from an original golden age. The clearest version of this history of culture survives in the *Bibliotheca historica* of Diodorus (bk. I, ch. 8), written in the age of Cicero. It is clear that Democritus held a similar view, and it is possible, although by no means certain, that he originated the whole tradition. Certain features of it, however, are already in Aeschylus' picture of Prometheus and probably in the writings of Protagoras summarized in Plato's dialogue named after the Sophist. Part of Democritus' treatment of the evolution of culture concerned the origin and development of language, taking the view that names were not natural but conventional.

Special problems affect the reconstruction of Democritus' ethical doctrines, to which a very large part of the surviving fragments relate. Many of these are attributed in the manuscript tradition not to Democritus but to an otherwise unknown Democrates, so that their authority for the reconstruction of the views of Democritus is uncertain. Most of the fragments are extremely commonplace, and hardly any are related to atomic theory. The doxographic tradition does, however, suggest that he had a general theory of *euthymia* ("cheerfulness" or "contentment") as the end of ethics. It was based on a physical state, the actual constitution of the body at any one time, of which the external expression is pleasure or enjoyment when the state itself is satisfactory. Even this much is a matter of conjecture, and we do not know how it was all worked out by Democritus.

Most of the fragments dealing with what we would call political questions are as traditional in content as those dealing with ethics. He seems to have had no doubts about the importance of law, although its function was limited to preventing one man from injuring another. It is inferior to encouragement and persuasion, but "it is right to obey the law, the ruler and the man who is wiser" (fr. 47). Democritus had declared that secondary qualities of perception, such as sweetness, existed only by *nomas*, not in reality, and *nomas*, which means "custom" or "convention," is also the word used for "law." It is perhaps not going too far to say that in ethics and politics, just as in physics, Democritus was searching for a truth and a reality behind or beyond the world of appearances; but at the same time, he wished to reaffirm the importance of changing phenomena as the product of an unchanging reality. It is probable that political obedience to the law was regarded as rooted in the well-being of the soul, just as wrongdoing is not to be justified by the thought that one will escape discovery.

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G. B. Kerferd