NATURE AND THE GREEKS

and

SCIENCE AND HUMANISM

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With a foreword by
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or to grasp costs us nowadays some effort and labour of abstraction. One may think this infancy of human thought is, figuratively, 'still nearer to Nature'. The rational picture of the world was not yet attained, the construction of 'the real world around us' not yet achieved. At any rate we do have many instances of such early deep thought in the old religious writings of many peoples, the Indians, the Jews, the Persians.

In comparing these early periods of deep philosophical awareness, I cannot help remembering a word of P. Deussen, the great Sanskritist and interesting philosopher, who said: 'It is a great pity that children in the first two years of their life cannot talk, for if they could, they probably would talk Kantian philosophy.'

CHAPTER VI

THE ATOMISTS

Is the ancient atomic theory, which is attached to the names of Leucippus and Democritus (born around 460 B.C.), the true forerunner of the modern one? This question has often been asked and very different opinions about it are on record. Gomperz, Cournot, Bertrand Russell, J. Burnet say: Yes. Benjamin Farrington says that it is, 'in a way', and that the two have a lot in common. Charles Sherrington says: No, pointing to the purely qualitative character of ancient atomism and to the fact that its basic idea, embodied in the word 'atom' (uncuttable or indivisible), has made this very name a misnomer. I am not aware that the negative verdict has ever passed the lips of a classical scholar. And when it comes from a scientist, he always shows by some remark that he regards chemistry —not physics—as the proper domain of the notions of atoms and molecules. He will mention the name of Dalton (born 1766) and omit, in this context, the name of Gassendi (born 1592). It was the latter who definitively reintroduced atomism into modern science, and he came to it after studying the fairly substantial extant writings of Epicurus (born around 341 B.C.), who had taken up the theory of Democritus, of which only scarce original fragments have come down to us. It is noteworthy that in chemistry, after the momentous development that had followed the discoveries of

Lavoisier and Dalton, a strong movement ('energeticists'), headed by Wilhelm Ostwald, supported by the views of Ernst Mach, arose towards the end of the nineteenth century in favour of abandoning atomism. It was said that it was not needed in chemistry and ought to be dropped as an unproved and unprovable hypothesis. The question as to the origin of ancient atomism and as to its connexion with modern theory is of much more than purely historical interest. We shall return to it. First, I shall briefly indicate the main features of Democritus' views. They are these:

(i) The atoms are invisibly small. They are all of the same stuff or nature (φύσις), but there is an enormous multitude of different shapes and sizes, and that is their only characteristic property. For they are impermeable and act on each other by direct contact, pushing and turning each other; and thus the most various forms of aggregation and interlacing of atoms of the same and of different kinds produce the infinite variety of material bodies, as we observe them, in their manifold interaction with each other. The space outside them is empty—a view that seems natural to us, but was subject to infinite controversy in antiquity, because many philosophers concluded that the μὴ ὄν, the thing that *is not*, could not possibly *be*, that is to say there cannot be empty space!

(ii) The atoms are in *perpetual motion*, and we may take it that this motion was regarded as irregularly or disorderly distributed in all directions, since nothing else is thinkable if the atoms are to be in perpetual motion even in bodies that are at rest or move with

slow speed. Democritus states explicitly that in empty space there is no above and below, in front or behind, no direction privileged—empty space is isotropic, we should say.

(iii) Their continual motion persists by itself, it does not come to rest; this was taken for granted. This discovery, by guess, of the *law of inertia* must be regarded as a great feat, since it is patently contradicted by experience. It was reinstated 2000 years later by Galileo, who arrived at it by ingenious generalization on carefully conducted experiments about pendulums and balls rolling down an inclined groove. At the time of Democritus it did not seem at all acceptable; it gave great difficulty to Aristotle, who regarded only the circular motion of the celestial bodies as a natural one that could persist without change indefinitely. In modern terms we should say that the atoms were endowed with *inertial mass*, which made them continue their motion in empty space and impart it to other atoms which they hit.

(iv) Weight or gravity was *not* regarded as a primitive property of the atoms. It was explained in a manner that in itself is quite ingenious, namely by a general whirl-motion which makes the bigger, more massive atoms tend towards the centre where the rotational speed is smaller, the lighter ones being thereby pushed or thrown away from the centre, into the heavens. Reading the description one is reminded of what happens in a centrifuge, though this, of course, is quite the opposite, the specifically heavier bodies being thrust outward, the lighter ones tending towards the centre. On the other hand if Democritus had ever made himself a cup of tea and stirred it round with a spoon, he would have found the tea leaves gathering in the centre of the cup, an excellent example to illustrate his whirl-theory. (The true ground of this is again just the opposite, the whirl being stronger in the middle than in the outer parts where it is retarded by the walls.) What amazes me most is this: one would think that this idea of gravity being due to a continual whirl would automatically suggest a world-model of spherical symmetry, and thus a spherical earth. But that was not the case, Democritus rather inconsistently kept to the form of a tambourine; he continued to regard the daily revolutions of the celestial bodies as real—and let the tambourine-earth reside on an air-cushion. Perhaps he was so disgusted by silly talk of the Pythagoreans and Eleatics that he did not wish to accept anything from them.

(v) But, to my view, the gravest defeat the theory suffered, which condemned it to become a 'sleeping beauty' for so many centuries, was due to its extension to the *soul*; the soul was considered as composed of material atoms, particularly fine ones with particularly high mobility, probably spread all over the body and attending its functions. This was sad, because it was bound to repel the finest and deepest thinkers in the following centuries. We must be careful not to take Democritus to task too severely. It was thoughtlessness in a man whose deep understanding of the theory of knowledge I shall prove presently. He took over, and implemented along the lines of the atomic theory,

the old misconception, firmly anchored in the language up to the present day, that the soul is breath. All the old words for soul originally meant air or breath: *ψυχή*, *πνεῦμα*, *spiritus*, *anima*, (Sanskr.) *athman* (modern: expire, animate, inanimate, psychology, etc.). Well, this breath was air, and air was composed of atoms—and so the soul was composed of atoms. It is a condonable short-cut to the central metaphysical problem, which really is unsolved up to the present day—see the masterful discussion in Charles Sherrington's *Man on his Nature*.

It has a terrible consequence, which has haunted the thinkers of many centuries and in slightly changed form still puzzles us today. The world-model consisting of atoms and empty space implements the basic postulate of *Nature being understandable*, provided that at any moment the subsequent motion of the atoms is uniquely determined by their present configuration and state of motion. Then the situation reached at any moment engenders of necessity the following one, and this the next following one, and so on for ever. The whole going-on is strictly determined at the outset, and so we cannot see how it should embrace also the behaviour of living beings including ourselves, who are aware of being able to choose to a large extent the motions of our body by free decision of our mind. If then this mind or soul is itself composed of atoms moving in the same necessitous way, there seems to be no room for ethics or moral behaviour. We are compelled by the laws of physics to do at every moment just exactly the thing we do; what is the good of deliberating whether it is right or wrong? Where is room for the moral law if the natural law overpowers and entirely frustrates it?

The antinomy is as unsolved today as it was twenty-three centuries ago. Still we are able to analyse Democritus' assumption into one very creditable and one very absurd constituent. He admitted

(*a*) that the behaviour of *all* the atoms inside a living body was determined by the physical laws of Nature, and

(*b*) that some of them went to compose what we call mind or soul.

I consider it very much to his credit that he held unswervingly on to (*a*), even though it implies an antinomy, with or without (*b*). Indeed, if you admit (*a*), the motion of your body is predetermined and you fail to account for your sensation that you move it at will, whatever you may think about the mind.

The truly absurd feature is (*b*).

Unfortunately Democritus' successors, Epicurus and his disciples, finding their minds not strong enough to face the antinomy, abandoned the creditable assumption (*a*) and clung to the absurd blunder (*b*).

The difference between the two men, Democritus and Epicurus, was that Democritus was still modestly aware that he knew nothing, while Epicurus was very sure that he knew very little short of everything.

Epicurus added to the system another piece of nonsense conscientiously echoed by all his followers, including, of course, Lucretius Carus. Epicurus was a sensualist of the purest breeding. Where the senses give

us conclusive evidence, we must follow it. Where they do not we are allowed to make any reasonable hypothesis to explain what we see. Unfortunately he included in the things about which the senses give us conclusive, indubitable evidence, the size of the sun, the moon and the stars. Speaking in particular about the sun, he argued (*a*) that its circumference is sharp, not blurred, and (*b*) that we feel its heat. He argued further that, if a big terrestrial fire is still near enough for us to discern its contours clearly and to feel anything of its heat, then we also discern its actual size, 'we see it just as big as it is'! Conclusion: the sun (and the moon and the stars) are just as big as we see them, neither bigger nor smaller.

The main nonsense is, of course, the expression 'as big as we see them'. It is astonishing that even modern philologists, when they report on this, are not shaken by this meaningless expression, but only by Epicurus' saying yes to it. He does not distinguish between angular size and linear size—living in Athens nearly three centuries after Thales, who measured the distance of ships by triangulation, as we do.

But let us take his words at the face value. What can he have meant? How big, then, do we see the sun? And how far is it thus away if it is as big as we see it?

The angular size is 1/2 of a degree. From this you easily make out, that if it were 10 miles away, it would have to have a diameter of roughly 1/10 of a mile or 500 feet. I do not think anybody could hold that the sun gives the immediate impression of being even as big as a cathedral. But let us grant him ten or fifteen times the size, which would give a diameter of a mile and a half and a distance of 150 miles. That would mean that when you saw the sun in the morning in Athens on the eastern horizon, it was actually rising from the coast of Asia Minor. Think of it:

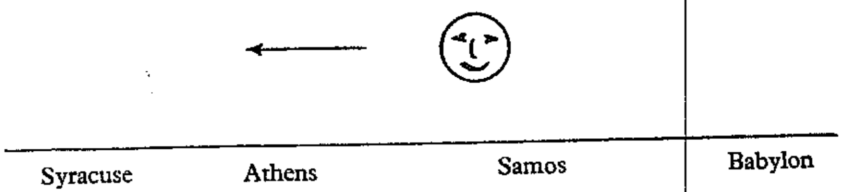

Fig. 4.

Did he think it passed horizontally over the Mediterranean? With his ignorance of angular size that is quite possible.

At any rate I think this shows that after Democritus the colours of physics were flown by philosophers who had no real interest in science and who, by the great influence they had as philosophers, wrecked it, in spite of the brilliant specialized work that was going on in Alexandria and elsewhere. It had little influence on the attitude of the population at large, including even such men as Cicero, Seneca or Plutarch.

Let us now return to the historical questions raised at the beginning of this chapter of which I said that they have much more than only historical interest. We are facing here one of the most fascinating cases in the history of ideas. The astonishing point is this. From the lives and writings of Gassendi and Descartes, who introduced atomism into modern science, we know as

an actual historical fact that, in doing so, they were fully aware of taking up the theory of the ancient philosophers whose scripts they had diligently studied. Furthermore, and more importantly, all the basic features of the ancient theory have survived in the modern one up to this day, greatly enhanced and widely elaborated but unchanged, if we apply the standard of the natural philosopher, not the myopic perspective of the specialist. On the other hand we know that not a scrap of the wide experimental evidence that a modern physicist adduces in support of those basic features was known either to Democritus or to Gassendi.

Whenever this kind of thing happens one has to envisage two possibilities. The first is that the early thinkers made a lucky guess which later proved to be correct. The second is that the thought pattern in question is not so exclusively based on the recently discovered evidence as the modern thinkers believe, but on the co-operation of much simpler facts, known before, and on the *a priori* structure, or at least the natural inclination, of the human intellect. If the likelihood of the second alternative can be proved, it is of paramount importance. It need not, of course, even if it were certain, induce us to abandon the idea—in our case atomism—as a mere fiction of our mind. But it will give us deeper insight into the origin and nature of our thought picture. These considerations urge us to find out, if possible, how were the ancient philosophers led to their conception of immutable atoms and the void?

For all I know there is no extant evidence to guide us. Today, if we state our own or another person's scientific beliefs, we feel bound to add why we or they hold them or held them. The mere fact that N.N. believed this or that, without motivation, seems uninteresting to us. This was not a very common practice in antiquity. Particularly the so-called doxographoi are usually quite content to tell us e.g. 'Democritus held...'. But it is noteworthy in our present context that Democritus himself regarded his insight as a creation of the intellect. This can be seen from fr. 125, quoted below *in extenso*, and also (fr. 11) from his distinction between two kinds of vehicle for obtaining knowledge, the genuine and the dark. The latter are the senses. They let us down when we try to penetrate into small regions of space. Then the genuine method of obtaining knowledge based on a refined organ of thought comes to our aid. That this refers *inter alia* to the atomic theory is obvious, though in the extant fragment it is not mentioned explicitly.

What then guided his refined organ of thought so as to produce the concept of atoms?

Democritus was intensely interested in geometry, not as a mere enthusiast like Plato; he was a geometer of distinction. The theorem that the volume of a pyramid or a cone is *one-third* of the product of its base and height is to his credit. To him who knows the calculus this is a commonplace, but I have met good mathematicians who had some trouble in remembering the elementary proof they had learnt as schoolboys. Democritus can hardly have arrived at the theorem

without using, at one step at least, a substitute for the calculus (so does the schoolboy, viz. the principle of Cavalieri—at least in Austria). Democritus had deep insight into the meaning and into the difficulties of *infinitesimals*. This is proved by an interesting paradox which he obviously met on thinking up that proof. Let a cone be cut in two by a plane parallel to its base; are the two circles, produced by the cut on the two parts (the smaller cone above and the cone-stump below), equal or unequal? If unequal, then, since this would hold for any such cut, the ascending part of the cone's surface would not be smooth but covered with indentations; if you say equal, then for the same reason, would it not mean that all these parallel sections are equal and thus that the cone is a cylinder?

From this and from the extant *titles* of two other scripts ('On a difference of opinion or on the contact of a circle and a sphere'; 'On irrational lines and solids') one gains the impression that he eventually arrived at a clear distinction between, on the one hand, the geometrical concepts of a body, a surface or a line of well-defined properties (as e.g. a pyramid, a square surface or a circular line), and, on the other hand, the more or less imperfect realizations of these concepts by or on a physical body. (Plato, a century later, reckoned the first category among his 'ideas'; nay they were, so I believe, his prototypes thereof; thus the thing got muddled up with metaphysics.)

Now grasp this together with the fact that Democritus not only knew the opinions of the Ionian philosophers, but may be said to have continued their tradition; moreover that the last of them, Anaximenes, as we said in Chapter IV, successfully and in full agreement with our modern views, maintained that all the momentous changes observed in matter were only apparent, actually due to rarefaction and condensation. But is it meaningful to say that the material itself remains unchanged, if actually every bit of it, however small, becomes thinned out or compressed? The *geometer* Democritus was well able to conceive of this 'however small'. The obvious way out is to think of any physical body as actually composed of innumerable small bodies, which remain always unchanged, while rarefaction is produced when they recede from each other, condensation, when they crowd more closely together into a small volume. To allow them to do this, within limits, it is a necessary requirement that the space between them be void, i.e. contain nothing at all. At the same time the integrity of pure geometrical statements could be saved by diverting the paradoxes and challenges from the geometrical concepts to their imperfect physical realizations. The surface of a real cone or, for that matter, of any real body, was actually not smooth, since it was formed by the top layer of atoms and thus was riddled with small holes with prominences between them. It could also be granted to Protagoras (who had put forward challenges of this kind) that a real sphere resting on a real plane had not just one point of contact with it, but a whole small region of 'near' contact. All this would not hamper the exactness of pure geometry. That this was Democritus' view may be inferred from

a remark of Simplicius, who tells us that, according to Democritus, his physically indivisible atoms were in a mathematical sense divisible *ad infinitum*.

During the last fifty years we have obtained experimental evidence of the 'real existence of discrete corpuscles'. There is a wide range of most interesting observations that we cannot summarize here and that the atomists at the end of the nineteenth century did not anticipate in their most intemperate dreams. We can see with our own eyes the recorded linear traces of the paths of single elementary particles in the Wilson cloud-chamber and in photographic emulsions. We have instruments (Geiger counters) which respond with an audible click to a single cosmic ray particle that enters the instrument; moreover the latter may be so devised that at every click an ordinary commercial electricity meter is advanced by one, so that it counts the number of particles that have arrived within a given time. Such counts performed by different methods and under varied conditions are in full agreement with each other as well as with the atomic theories developed long before this direct evidence was available. The great atomists from Democritus down to Dalton, Maxwell and Boltzmann would have gone into raptures at these palpable proofs of their belief.

But at the same time modern atomic theory has been plunged into a crisis. There is no doubt that the simple particle theory is too naïve. This is not altogether too astonishing, from the above speculations about its origin. If these are correct, then atomism was forged as a weapon to overcome the difficulties of the mathematical continuum, of which, as we have seen, Democritus was fully aware. To him atomism was a means for bridging the gulf between the real bodies of physics and the idealized geometrical shapes of pure mathematics. But not only to Democritus. In a way atomism has performed this task all through its long history, the task of facilitating our thinking about palpable bodies. A piece of matter is resolved in our thought into an innumerably great, yet finite number of constituents. We can imagine our *counting* them, while we are unable to tell the number of points on a straight line of 1 cm. length. We can *count*, in our thought, the number of mutual impacts within a given time. When hydrogen and chlorine unite to form hydrochloric acid, we can, in our mind, pair off the atoms of the two kinds and think that every pair unites to form a new little body, a molecule of the compound. This counting, this pairing off, this whole manner of thinking has played a prominent role in discovering the most important physical theorems. It would seem impossible under the aspect that matter is a continuous structureless jelly. Thus atomism has proved infinitely fruitful. Yet the more one thinks of it, the less can one help wondering to what extent it is a *true* theory. Is it really founded exclusively on the actual objective structure of 'the real world around us'? Is it not in an important way conditioned by the nature of human understanding—what Kant would have called '*a priori*'? It behoves us, so I believe, to preserve an extremely open mind towards the palpable proofs of the existence of individual single particles,

without detriment to our deep admiration for the genius of those experimenters who have furnished us with this wealth of knowledge. They are increasing it from day to day and are thereby helping to turn the scales with respect to the sad fact, that our theoretical understanding thereof is, I venture to say, diminishing at almost the same rate.

Let me conclude this chapter by quoting some agnostic and sceptic fragments of Democritus, which have impressed me most. The translations follow Cyril Bailey.

(D. fr. 6) A man must learn on this principle that he is far removed from the truth.

(D. fr. 7) We know nothing truly about anything, but for each of us his opinion is an influx (i.e. is conveyed to him by an influx of 'idols'[1] from without).

(D. fr. 8) To learn truly what each thing is, is a matter of uncertainty.

(D. fr. 9) In truth we know nothing unerringly, but only as it changes according to the disposition of our body, and of the things that enter into it and impinge on it.

(D. fr. 117) We know nothing truly, for the truth lies hidden in the depth.

And now the famous dialogue between the intellect and the senses:

(D. fr. 125) (*Intellect:*) Sweet is by convention and bitter by convention, hot by convention, cold by convention, colour by convention; in truth there are but atoms and the void.

(*The Senses:*) Wretched mind, from us you are taking the evidence by which you would overthrow us? Your victory is your own fall.

[1] Gk. εἴδωλον, picture.