

earth; for it is the most immobile of the four bodies and the most retentive of shape, and these are characteristics that must belong to the figure with the most stable faces. And of the basic triangles we have assumed, the isosceles has a naturally more stable base than the scalene, and of the equilateral figures composed of them the square is, in whole and in part, a firmer base than the equilateral triangle. So we maintain our principle of likelihood by assigning it to earth, while similarly we assign the least mobile of the other figures to water, the most mobile to fire, and the intermediate to air. And again we assign the smallest figure to fire, the largest to water, the intermediate to air; the sharpest to fire, the next sharpest to air, and the least sharp to water. So to sum up, the figure which has the fewest faces must in the nature of things be the most mobile, as well as the sharpest and most penetrating, and finally, being composed of the smallest number of similar parts, the lightest. Our second figure will be second in all these respects, our third will be third. Logic and likelihood thus both require us to regard the pyramid as the solid figure that is the basic unit or seed of fire; and we may regard the second of the figures we constructed as the basic unit of air, the third of water. We must, of course, think of the individual units of all four bodies as being far too small to be visible, and only becoming visible when massed together in large numbers; and we must assume that the god duly adjusted the proportions between their numbers, their movements, and their other qualities and brought them in every way to the exactest perfection....

1.2 Aristotle, (a) *Physics*, (b) *On the Heavens*, from Aristotle, *Complete Works*, vol. 1, ed. Jonathan Barnes (Princeton, NJ: Princeton University Press, 1984), (a) pp. 342–3, 354–5, (b) pp. 448–51, 458–61, 487–8

(a) *Physics*

BOOK III

Nature is a principle of motion and change, and it is the subject of our inquiry. We must therefore see that we understand what motion is; for if it were unknown, nature too would be unknown.

When we have determined the nature of motion, our task will be to attack in the same way the terms which come next in order. Now motion is supposed to belong to the class of things which are continuous; and... place, void, and time are thought to be necessary conditions of motion....

To begin then, as we said, with motion.

Some things are in fulfilment only, others in potentiality and in fulfilment....

We have distinguished... between what is in fulfilment and what is potentially; thus the fulfilment of what is potentially, as such, is motion – e.g. the fulfilment of what is alterable, as alterable, is alteration; of what is increasable

and its opposite, decreaseable..., increase and decrease; of what can come to be and pass away, coming to be and passing away; of what can be carried along, locomotion.

That this is what motion is, is clear from what follows: when what is buildable, in so far as we call it such, is in fulfilment, it is being built, and that is building. Similarly with learning, doctoring, rolling, jumping, ripening, aging.

The same thing can be both potential and fulfilled, not indeed at the same time or not in the same respect, but e.g. potentially hot and actually cold. Hence such things will act and be acted on by one another in many ways: each of them will be capable at the same time of acting and of being acted upon. Hence, too, what effects motion as a natural agent can be moved: when a thing of this kind causes motion, it is itself also moved. This, indeed, has led some people to suppose that every mover is moved.... It is possible for a thing to cause motion, though it is itself incapable of being moved.

It is the fulfilment of what is potential when it is already fulfilled and operates not as itself but as movable, that is motion. What I mean by 'as' is this: bronze is potentially a statue. But it is not the fulfilment of bronze as bronze which is motion....

It is evident that this is motion, and that motion occurs just when the fulfilment itself occurs, and neither before nor after. For each thing is capable of being at one time actual, at another not. Take for instance the buildable: the actuality of the buildable as buildable is the process of building. For the actuality must be either this or the house. But when there is a house, the buildable is no longer there. On the other hand, it is the buildable which is *being* built. Necessarily, then, the actuality is the process of building. But building is a kind of motion, and the same account will apply to the other kinds also. [...]

BOOK IV

The physicist must have a knowledge of place, too, as well as of the infinite – namely, whether there is such a thing or not, and the manner of its existence and what it is – both because all suppose that things which exist are *somewhere* (the non-existent is nowhere – where is the goat-stag or the sphinx?), and because motion in its most general and proper sense is change of place, which we call 'locomotion'.

The question, what is place? presents many difficulties. An examination of all the relevant facts seems to lead to different conclusions....

The existence of place is held to be obvious from the fact of mutual replacement. Where water now is, there in turn, when the water has gone out as from a vessel, air is present; and at another time another body occupies this same place. The place is thought to be different from all the bodies which come to be in it and replace one another. What now contains air formerly contained water, so that clearly the place or space into which and out of which they passed was something different from both.

Further, the locomotions of the elementary natural bodies – namely, fire, earth, and the like – show not only that place is something, but also that it exerts a certain influence. Each is carried to its own place, if it is not hindered, the one up, the other down. Now these are regions or kinds of place – up and down and the rest of the six directions. Nor do such distinctions (up and down and right and left) hold only in relation to us. To *us* they are not always the same but change with the direction in which we are turned: that is why the same thing is often both right *and* left, up *and* down, before *and* behind. But in *nature* each is distinct, taken apart by itself. It is not every chance direction which is up, but where fire and what is light are carried; similarly, too, down is not any chance direction but where what has weight and what is made of earth are carried – the implication being that these places do not differ merely in position, but also as possessing distinct powers. . . .

These considerations then would lead us to suppose that place is something distinct from bodies, and that every sensible body is in place. . . . If this is its nature, the power of place must be a marvellous thing, and be prior to all other things. For that without which nothing else can exist, while it can exist without the others, must needs be first; for place does not pass out of existence when the things in it are annihilated. [. . .]

(b) On the Heavens

[. . .] All natural bodies and magnitudes we hold to be, as such, capable of locomotion; for nature, we say, is their principle of movement. But all movement that is in place, all locomotion, as we term it, is either straight or circular or a combination of these two which are the only simple movements. And the reason is that these two, the straight and the circular line, are the only simple magnitudes. Now revolution about the centre is circular motion, while the upward and downward movements are in a straight line, 'upward' meaning motion away from the centre, and 'downward' motion towards it. All simple motion, then, must be motion either away from or towards or about the centre. . . .

Bodies are either simple or compounded of such; and by simple bodies I mean those which possess a principle of movement in their own nature, such as fire and earth with their kinds, and whatever is akin to them. Necessarily, then, movements also will be either simple or in some sort compound – simple in the case of the simple bodies, compound in that of the composite – and the motion is according to the prevailing element. Supposing, then, that there is such a thing as simple movement, and that circular movement is simple . . . then there must necessarily be some simple body which moves naturally and in virtue of its own nature with a circular movement. . . . Further, this circular motion is necessarily primary. For the complete is naturally prior to the incomplete, and the circle is a complete thing. This cannot be said of any straight line: – not of an infinite line; for then it would have a limit and an end: nor of any finite line; for in every case there is

something beyond it, since any finite line can be extended. And so, since the prior movement belongs to the body which is naturally prior, and circular movement is prior to straight, and movement in a straight line belongs to simple bodies – fire moving straight upward and earthy bodies straight downward towards the centre – since this is so, it follows that circular movement also must be the movement of some simple body. For the movement of composite bodies is, as we said, determined by that simple body which prevails in the composition. From this it is clear that there is in nature some bodily substance other than the formations we know, prior to them all and more divine than they. . . . Further, if, on the one hand, circular movement is *natural* to something, it must surely be some simple and primary body which naturally moves with a natural circular motion, as fire moves up and earth down. If, on the other hand, the movement of the rotating bodies about the centre is *unnatural*, it would be remarkable and indeed quite inconceivable that this movement alone should be continuous and eternal, given that it is unnatural. At any rate the evidence of all other cases goes to show that it is the unnatural which quickest passes away. . . . On all these grounds, therefore, we may infer with confidence that there is something beyond the bodies that are about us on this earth, different and separate from them; and that the superior glory of its nature is proportionate to its distance from this world of ours.

In consequence of what has been said, . . . it is clear that not every body possesses either lightness or heaviness. We must explain in what sense we are using the words 'heavy' and 'light' Let us then apply the term 'heavy' to that which naturally moves towards the centre, and 'light' to that which moves naturally away from the centre. The heaviest thing will be that which sinks to the bottom of all things that move downward, and the lightest that which rises to the surface of everything that moves upward. Now, necessarily, everything which moves either up or down possesses lightness or heaviness or both – but not both relatively to the same thing; for things are heavy and light relatively to one another; air, for instance, is light relatively to water, and water light relatively to earth. But the body which moves in a circle cannot possibly possess heaviness or lightness. For neither naturally nor unnaturally can it move either towards or away from the centre. Movement in a straight line certainly does not belong to it *naturally*, since one sort of movement is, as we saw, appropriate to each simple body, and so we should be compelled to identify it with one of the bodies which move in this way. . . .

It is equally reasonable to assume that this body will be ungenerated and indestructible and exempt from increase and alteration. . . . Now the motions of contraries are contrary. If then this body can have no contrary, because there can be no contrary motion to the circular, nature seems justly to have exempted from contraries the body which was to be ungenerated and indestructible. For it is on contraries that generation and destruction

depend. Again, that which is subject to increase increases upon contact with a kindred body, which is resolved into its matter. But there is nothing out of which this body can have been generated. And if it is exempt from increase and destruction, the same reasoning leads us to suppose that it is also unalterable. For alteration is movement in respect of quality; and qualitative states and dispositions, such as health and disease, do not come into being without changes of properties. But all natural bodies which change their properties we see to be subject to increase and diminution. This is the case, for instance, with the bodies of animals and their parts and with vegetable bodies, and similarly also with those of the elements. And so, if the body which moves with a circular motion cannot admit of increase or diminution, it is reasonable to suppose that it is also unalterable.

The reasons why the primary body is eternal and not subject to increase or diminution, but unaging and unalterable and unmodified, will be clear from what has been said to any one who believes in our assumptions. Our theory seems to confirm the phenomena and to be confirmed by them. For all men have some conception of the nature of the gods, and all who believe in the existence of gods at all, whether barbarian or Greek, agree in allotting the highest place to the deity, surely because they suppose that immortal is linked with immortal and regard any other supposition as impossible. If then there is, as there certainly is, anything divine, what we have just said about the primary bodily substance was well said. The mere evidence of the senses is enough to convince us of this, at least with human certainty. For in the whole range of time past, so far as our inherited records reach, no change appears to have taken place either in the whole scheme of the outermost heaven or in any of its proper parts. The name, too, of that body seems to have been handed down right to our own day from our distant ancestors who conceived of it in the fashion which we have been expressing. The same ideas, one must believe, recur in men's minds not once or twice but again and again. And so, implying that the primary body is something else beyond earth, fire, air, and water, they gave the highest place the name of *aether*, derived from the fact that it 'runs always' for an eternity of time....

It is also clear from what has been said why the number of what we call simple bodies cannot be greater than it is. The motion of a simple body must itself be simple, and we assert that there are only these two simple motions, the circular and the straight, the latter being subdivided into motion away from and motion towards the centre.

[...] [W]hatever possesses weight or lightness will have its place either at one of the extremes or in the middle region. But this is impossible while the world is conceived as infinite. And, generally, that which has no centre or extreme limit, no up or down, gives the bodies no place for their motion; and without that movement is impossible. A thing must move either naturally or unnaturally, and the two movements are determined by the proper and alien places. Again, a place in which a thing rests or to

which it moves unnaturally, must be the natural place for some other body.... From these arguments then it is clear that the body of the universe is not infinite.

We must now proceed to explain why there cannot be more than one heaven....

... [T]he elements must also be the same everywhere. The particles of earth, then, in another world move naturally also to our centre and its fire to our circumference. This, however, is impossible, since, if it were true, earth must, in its own world, move upwards, and fire to the centre; in the same way the earth of our world must move naturally away from the centre when it moves towards the centre of another universe. This follows from the supposed juxtaposition of the worlds. For either we must refuse to admit the identical nature of the simple bodies in the various universes, or, admitting this, we must make the centre and the extremity one as suggested. This being so, it follows that there cannot be more worlds than one. [...]

A consideration of the other kinds of movement also makes it plain that there is some point to which earth and fire move naturally. For in general that which is moved changes from something into something, the starting-point and the goal being different in form, and always it is a finite change. For instance, to recover health is to change from disease to health, to increase is to change from smallness to greatness. Locomotion must be similar; for it also has its goal and starting-point – and therefore the starting-point and the goal of the natural movement must differ in form – just as the movement of coming to health does not take any direction which chance or the wishes of the mover may select. Thus, too, fire and earth move not to infinity but to opposite points; and since the opposition in place is between above and below, these will be the limits of their movement.... There must therefore be some end to locomotion: it cannot continue to infinity.

This conclusion that local movement is not continued to infinity is corroborated by the fact that earth moves more quickly the nearer it is to the centre, and fire the nearer it is to the upper place. But if movement were infinite, speed would be infinite also; and if speed then weight and lightness. [...]

We must show not only that the heaven is one, but also that more than one heaven is impossible, and, further, that, as exempt from decay and generation, the heaven is eternal. [...]

Let us first decide the question whether the earth moves or is at rest. For, as we said, there are some who make it one of the stars, and others who, setting it at the centre, suppose it to be rolled and in motion about the pole as axis. That both views are untenable will be clear if we take as our starting-point the fact that the earth's motion, whether the earth be at the centre or away

from it, must needs be a constrained motion. It cannot be the movement of the earth itself. If it were, any portion of it would have this movement; but in fact every part moves in a straight line to the centre. Being, then, constrained and unnatural, the movement could not be eternal. But the order of the universe is eternal. Again, everything that moves with the circular movement, except the first sphere, is observed to be passed, and to move with more than one motion. The earth, then, also, whether it moves about the centre or is stationary at it, must necessarily move with two motions. But if this were so, there would have to be passings and turnings of the fixed stars. Yet no such thing is observed. The same stars always rise and set in the same parts of the earth.

Further, the natural movement of the earth, part and whole alike, is to the centre of the whole – whence the fact that it is now actually situated at the centre – but it might be questioned, since both centres are the same, which centre it is that portions of earth and other heavy things move to. Is this their goal because it is the centre of the earth or because it is the centre of the whole? The goal, surely, must be the centre of the whole. For fire and other light things move to the extremity of the area which contains the centre. It happens, however, that the centre of the earth and of the whole is the same. Thus they do move to the centre of the earth, but accidentally, in virtue of the fact that the earth's centre lies at the centre of the whole. ... It is clear, then, that the earth must be at the centre and immovable, not only for the reasons already given, but also because heavy bodies forcibly thrown quite straight upward return to the point from which they started, even if they are thrown to an unlimited distance. From these considerations then it is clear that the earth does not move and does not lie elsewhere than at the centre.

From what we have said the explanation of the earth's immobility is also apparent. If it is the nature of earth, as observation shows, to move from any point to the centre, as of fire contrariwise to move from the centre to the extremity, it is impossible that any portion of earth should move away from the centre except by constraint. For a single thing has a single movement, and a simple thing a simple: contrary movements cannot belong to the same thing, and movement away from the centre is the contrary of movement to it. If then no portion of earth can move away from the centre, obviously still less can the earth as a whole so move. For it is the nature of the whole to move to the point to which the part naturally moves. Since, then, it would require a force greater than itself to move it, it must needs stay at the centre. This view is further supported by the contributions of mathematicians to astronomy, since the phenomena – the changes of the shapes by which the order of the stars is determined – are fully accounted for on the hypothesis that the earth lies at the centre. Of the position of the earth and of the manner of its rest or movement, our discussion may here end.

Its shape must necessarily be spherical. For every portion of earth has weight until it reaches the centre, and the jostling of parts greater and smaller

would bring about not a waved surface, but rather compression and convergence of part and part until the centre is reached. The process should be conceived by supposing the earth to come into being in the way that some of the natural philosophers describe. ... If, on the one hand, there were a similar movement from each quarter of the extremity to the single centre, it is obvious that the resulting mass would be similar on every side. For if an equal amount is added on every side the extremity of the mass will be everywhere equidistant from its centre, i.e. the figure will be spherical. But neither will it in any way affect the argument if there is not a similar accession of concurrent fragments from every side. For the greater quantity, finding a lesser in front of it, must necessarily drive it on, both having an impulse whose goal is the centre, and the greater weight driving the lesser forward till this goal is reached. ...

If the earth was generated, then, it must have been formed in this way, and so clearly its generation was spherical. ...

1.3 Lucretius, *On the Nature of the Universe*, trans. R. E. Latham (Harmondsworth: Penguin, 1951), pp. 31, 33–7, 39, 44–5, 54–7, 63–4, 66, 70, 72–3, 80, 91–2, 177, 195–7

[...] [O]ur starting-point will be this principle: *Nothing can ever be created by divine power out of nothing.* [...]

The second great principle is this: *nature resolves everything into its component atoms and never reduces anything to nothing.* If anything were perishable in all its parts, anything might perish all of a sudden and vanish from sight. There would be no need of any force to separate its parts and loosen their links. In actual fact, since everything is composed of indestructible seeds, nature obviously does not allow anything to perish till it has encountered a force that shatters it with a blow or creeps into chinks and unknits it. [...]

Again, all objects would regularly be destroyed by the same force and the same cause, were it not that they are sustained by imperishable matter more or less tightly fastened together. Why, a mere touch would be enough to bring about destruction supposing there were no imperishable bodies whose union could be dissolved only by the appropriate force. Actually, because the fastenings of the atoms are of various kinds while their matter is imperishable, compound objects remain intact until one of them encounters a force that proves strong enough to break up its particular constitution. Therefore nothing returns to nothing, but everything is resolved into its constituent bodies. [...]

Well, Memmius, I have taught you that things cannot be created out of nothing nor, once born, be summoned back to nothing. Perhaps, however, you are becoming mistrustful of my words, because these atoms of mine are not visible to the eye. Consider, therefore, this further evidence of *bodies whose existence you must acknowledge though they cannot be seen.* ...